Final report for Ofcom

Delivering high-quality video services online

10 November 2008

Ref: 12122-462

analysys mason

Contents

Analysys Mason Limited
St Giles Court
24 Castle Street
Cambridge CB3 0AJ
UK
Tel: +44 (0)1223 460600
Fax: +44 (0)1223 460866
enquiries@analysysmason.com
www.analysysmason.com

1 Executive summary

1.1 Introduction

Video content, such as TV programmes, films and short video clips, is readily available over the Internet and is increasingly popular. Such material is very bandwidth-hungry: one minute of medium-quality video equates to around 7–10 MB of data, which must be transmitted over a telecoms network to the consumer. If that network does not have sufficient capacity, the quality of the video being carried may be impaired. In fact, the delivery of video content often involves data traversing *multiple* networks, sometimes across different countries. If any of the individual network links are congested, this will impact the delivery of content to the end user. Although current networks are generally able to cope with the demand from today's video services, it is questionable as to whether problems may arise in the future as more and more video content is carried.

In this context, Ofcom wishes to understand the impact that congestion could have on the ability to provide high-quality video services over the Internet in the UK, and what regulatory measures, if any, may be required to alleviate such problems.

Video content is available over the Internet via a variety of services that use different kinds of delivery mechanisms. We can classify these delivery mechanisms into three broad types: download-and-store, streamed to a PC or TV using an 'open' platform, and streamed to a TV using a 'closed' (proprietary) IPTV platform. These three categories are shown in Figure 1.1.

	Download-and-store video	Streamed video (open)	Streamed video (closed IPTV)
Mode	Non-linear	Non-linear VoD	Linear and non-linear VoD
User interface	PC (TV*)	PC (TV*)	TV
Relative video quality	Medium	Low	High
Relative bandwidth requirement	Low	Medium	High
Examples	4oD, iPlayer, Sky Anytime	YouTube, iPlayer	Tiscali, BT Vision, Virgin Media

Figure 1.1: Simple classification of the different types of mechanisms used for delivering video content over the Internet. The (*) indicates a transition to TV from PC, already starting, enabled by in-home technologies [Source: Analysys Mason]

The first mechanism, **download-and-store**, involves users downloading video files for storing and viewing later.[1] The files are typically 500–1000 MB[2] in size and are typically stored and viewed on a PC. This mechanism is used by services such as Channel 4's 4oD, the BBC's iPlayer or Sky's Anytime. This video content is non-linear which means that there is no pre-determined schedule for when the content is viewed, unlike traditionally broadcast TV. However, as these downloads usually take a number of hours, download-and-store does not give the user instant access to the content. This has limited the growth of this type of video content, even though it often offers higher-quality video.

Much of the recent growth in video services has come from the second category, **open (or 'over-the-top') streamed video**. Streamed video is a form of video on demand (VoD), in which the consumer is able to view content when they want to, with no need to wait until the whole video file has been received. The success of streamed video has shown that there is an underlying demand for online video services, which provide instant gratification. However, there is concern over the ability of current broadband networks to support the widespread adoption of such services at a high level of quality.

There has also been growth in the third category of **closed IPTV** systems.[3] These also use streaming to deliver content, but have the benefit of being higher quality, and are often easier to use. One notable example is Virgin Media's implementation of the BBC's iPlayer, this offer has been particularly successful. A large part of this success is likely to come from the fact that consumers can access the content on a TV, as opposed to the smaller-screened PC which is used by the standard Web-based iPlayer. Once it becomes easier to access on-demand services on TVs, there may be significant additional growth in the consumption of online video services in open network environments.

1.2 Approach of the study

Ofcom commissioned Analysys Mason Limited to undertake this study of video delivered via broadband, in order to understand the issues that may arise relating to quality, thereby informing Ofcom's future activities in this area.

We began by discussing the key issues with a number of stakeholders, who represent different parts of the telecoms and media sectors, in order to ensure that our assumptions were reasonable and that all the major issues were considered. We then constructed four different demand scenarios and carried out a technical and economic analysis to identify any potential bottlenecks and the

[1] Note: such services can be broader than just video services – audio, games and other content types are relevant. However, for this study, we focus just on video.

[2] On a 4Mbit/s broadband connection, this would take 17–33 minutes to download.

[3] Closed IPTV systems involve purchasing both broadband and television services from the same provider. The subscriber is then supplied with a specific set-top box for that television platform. This approach allows the service provider to have more control over the service, which should lead to a higher quality of video service for the end user.

implications for the quality of video services. Our analysis quantified the impact of the growth in traffic on broadband networks using a model that considers the main drivers of network costs for a range of service provider types. Finally, the findings from the technical and economic analysis were used to draw conclusions and make recommendations for Ofcom. This approach is illustrated in Figure 1.2 below.

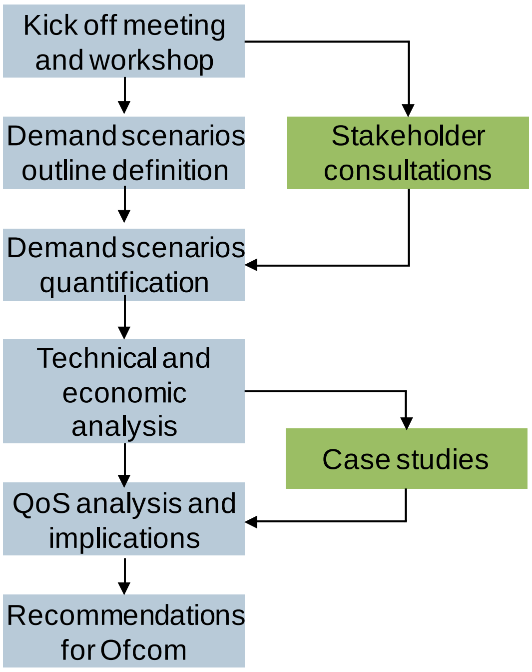

Figure 1.2: Overview of approach to the study [Source: Analysys Mason]

In the sections below we cover the following topics:

- **Key findings from the stakeholder interviews:** the key themes that emerged from our discussions with the nine different organisations that we interviewed.
- **End-to-end delivery of high-quality video:** the issues with delivering high-quality video to consumers is introduced in this section. The section also highlights where the major bottlenecks are, which would limit the delivery of high-quality video.
- **Future demand scenarios:** the different demand scenarios are defined and the demand parameters are quantified.
- **Technical and economic analysis:** an analysis of how each demand scenario would impact broadband networks, and how networks would evolve to cope with additional traffic.
- **Evolving business models:** it is possible that business models for the delivery of online video may have to evolve to support a viable business case. Some of the potential changes to business models are discussed here.

- **Implications for Ofcom:** the implications of the analysis are outlined and include a number of areas that Ofcom may wish to monitor in the future.

1.3 Key findings from the stakeholder interviews

During June and July 2008, Analysys Mason interviewed nine stakeholders who represent different parts of the telecoms and media sectors. The organisations we spoke to were: BBC, BT Wholesale, Carphone Warehouse, Channel 4, Cisco, Sky, Velocix, Virgin Media, and a multinational content owner who wishes to remain anonymous. The principal points that came from these discussions are summarised below.

- Demand for online video is currently growing; this growth is expected to continue, with streaming being the predominant method of video delivery in the future.
- Backhaul[4] in broadband networks is currently a bottleneck, although alternative operators that take advantage of local loop unbundling[5] (LLU) can exploit economies of scale to offer additional capacity at a lower cost than those operators that rely on wholesale bitstream services.[6]
- The limited capacity of much of the current access network may be a bottleneck, which limits the offering of higher quality video services. However, investments in next-generation access (NGA) infrastructure expected from Virgin Media[7] show that the market is beginning to address this bottleneck, and in the long term, access speeds are unlikely to be a limitation for a significant proportion of the country.
- Technological solutions such as multicasting and caching can limit the impact of increased traffic, although caching solutions that require more intelligent servers closer to the end user face technical challenges.[8]
- Business models are likely to evolve so that service providers will be able to include additional revenue from video services; at present, there is no clear, favoured model.

4 Telecoms networks can be divided into three parts: (a) the high-capacity core (also called the backbone); (b) the backhaul network which links the core network to the ‘local point of presence’ (e.g. the local telephone exchange); and (c) the access network that connects the customer’s premises to the local point of presence.

5 Local loop unbundling (LLU) is a suite of products supplied by incumbent operators (e.g. BT) to allow other operators to place their equipment in the telephone exchange and rent the copper access line to the customer’s premises.

6 B**itstream is** a wholesale product, typically from an incumbent such as BT, that allows other operators to provide broadband connections on a wholesale basis. Bitstream does not require significant investment in infrastructure from alternative operators.

7 The planned NGA investment by BT will also address the access network bottleneck, although this investment had not yet been announced when we conducted our stakeholder interviews.

8 Multicasting is a way of reducing the traffic load on a network by sending the same data to many users at the same time instead of sending a dedicated stream to each user. Caching involves storing data closer to the end user so that it does not have to be sent over the whole network each time it is requested.

1.4 End-to-end delivery of high-quality video

The end-to-end delivery of video content often involves data traversing multiple networks, sometimes across different countries, or even continents. For example if a consumer from a smaller service provider in the UK requests content from a Web site hosted in the USA, the data may traverse a number of networks in the USA, across the Atlantic and within the UK.

If any of the individual links are congested, this will impact the quality of the video service delivered to the end user. **Quality of service** (QoS) is a technical term that generally refers to a measure of reliability in the delivery of content over IP[9] networks. Metrics to measure QoS can include guaranteed bandwidth, the fraction of packets lost, and latency (delays in the transmission of the data). A high QoS is often required to ensure that video services are delivered so that they can be watched without loss of picture quality.

Some content owners wish to improve the QoS for the delivery of their content, and to achieve this they typically use a **content distribution network** (CDN). One of the key features roles of a CDN is that it is able to deliver content close to the end user using a combination of caching and dedicated capacity that provides a higher QoS than the public Internet. The role of a CDN is illustrated in Figure 1.3 below.

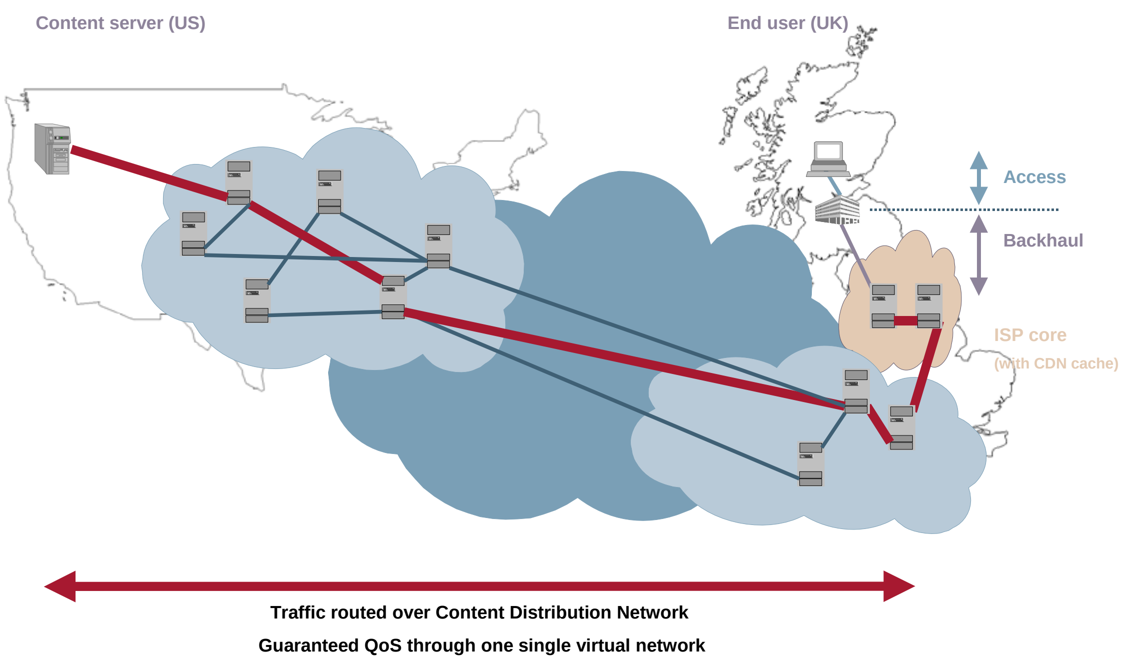

Figure 1.3: End-to-end traffic routeing using a content distribution network [Source: Analysys Mason]

9 Internet Protocol (IP) is the protocol used for transferring packet-based data that underpins the Internet.

Many large content owners, both national and international, purchase services from CDNs so that they can deliver their content. The detailed business model for CDNs varies between operators but generally involves charging content owners either per gigabyte (the volume of data carried) or per Mbit/s (the rate at which data is transmitted) for the content that is delivered. There is usually no charge to the service provider that supports the end user, although the service provider does sometimes have to provide space in which to house the necessary equipment (caches and routers), and also provide some bandwidth to the CDN. The costs to service providers of supplying these facilities are usually minimal when compared with the benefits they receive in reduced IP transit costs.[10] Our discussions with stakeholders indicated that this business model should be able to handle an expansion in online video distribution.

It is not normally possible to provide guaranteed end-to-end QoS over multiple networks as the commercial arrangements to provide the additional features required have not been agreed. Our consultations with stakeholders suggest that there is no underlying *technical* reason for this, as QoS features are standardised across modern networking equipment. We therefore believe that if there was a real demand – and need – for end-to-end QoS to be available over the public Internet, then these services would emerge. Indeed, the first signs of the these services emerging can already be observed. Level 3, which is a global Tier 1 carrier, purchased the CDN business of SAVVIS in 2007. This now allows Level 3 to provide end-to-end QoS over its global backbone network. Although Level 3 does not yet provide QoS over multiple networks, the convergence of CDN providers and traditional Tier 1 carriers indicates that QoS may become more of a standard feature over time.

We believe that the business models, technology and competitive pressures exist to ensure that content owners can deliver their content to the final service provider that serves the end user. For these reasons, we do not think that Ofcom has any major reason for concern.

As mentioned above, the connection from the core network to the end user has two components: the backhaul network from the service provider's core network to the local point of presence (e.g. telephone exchange), and the access network to the customer's premises. These parts of the end-to-end network are of more interest to Ofcom as they relate to parts of the network that have persistently functioned as economic bottlenecks.

10 IP Transit costs are incurred when service providers have to purchase connectivity to external networks run by large carriers. These costs are reduced if a CDN is present as CDNs cache content in the service providers' own network, reducing the total amount of traffic that needs to be delivered from external networks.

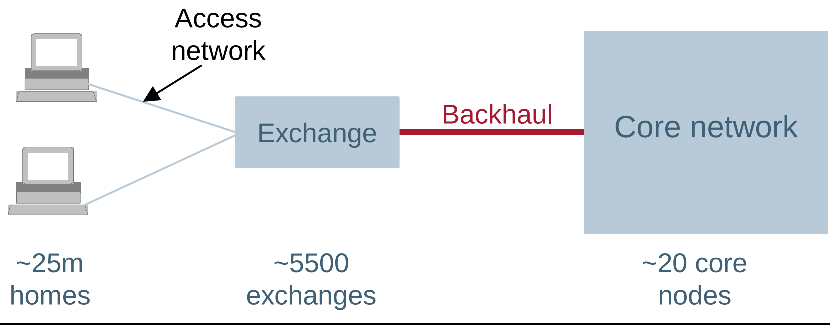

Figure 1.4: Illustration of access, backhaul and core networks [Source: Analysys Mason]

The **backhaul** network typically has capacity shared between many end users, with each service provider using its own engineering rules to dimension the total capacity. Due to the recent growth in the broadband market and the drive towards lower prices due to competition, we believe that in many cases these backhaul networks are running at close to their maximum capacity. As a consequence, we believe that this part of the network may currently be a bottleneck for some end users of video services. The provision of capacity in the backhaul network has therefore been a major focus of our technical and economic analysis.

The **access** network may also become a bottleneck for video services, particularly for the delivery of high-definition (HD) content (which requires greater bandwidth). An analysis of access networks has not been included in our work as NGA networks involve many other issues that go beyond the scope of this study. The geographical extent of any bottleneck in the access network will depend on the deployments of NGA networks by BT and other operators.

1.5 Future demand scenarios

In order to obtain a picture of how the broadband market may evolve over the next ten years, we have used a scenario planning approach, constructing four possible scenarios for how broadband networks may be affected by the demands placed upon then by video services. The essence of scenario analysis is to focus on the issues that have the **most uncertainty** and the **greatest impact** upon the area being studied. (Outcomes that are *highly likely* to occur generally require little analysis – it is relatively easy to plan for these. And outcomes that will have *little impact* do not demand as much attention as those that will have a significant effect.)

In line with this approach, we have identified a number of issues that may impact the traffic arising from video on broadband networks. The six factors that are most uncertain and have the greatest impact are as follows.

- **Shift to on-demand TV**: TV viewing behaviour is likely to shift away from scheduled programming to more on-demand viewing, with programmes delivered via IP networks.
- **High-definition content**: the industry is slowly moving towards HD. Better picture quality will lead to larger files and therefore more demand for network capacity.
- **Fragmentation of content providers**: the evolution of niche content providers might challenge the current dominance of a limited number of content providers (e.g. iPlayer and YouTube) and make caching more complicated.
- **Structure of broadband industry**: the UK broadband market is in a period of consolidation, which is occurring because LLU is more scalable than bitstream products and operators are exploiting these scale economies. At present, most service providers purchasing a wholesale bitstream product in order to provide broadband use the IP Stream product from BT Wholesale. However, BT Wholesale is now moving to its new fibre-based **WBC** (Wholesale Broadband Connect) product based on its 21CN next-generation network. This shift from IP Stream to WBC may lead to a more fragmented market. This could be caused, for example, by the deployment of an NGA network by BT, which might mean that service providers become more reliant on bitstream services.
- **Linear content broadcast over IP networks**: IPTV is slowly gaining a foothold in the UK market. As a result, there may be a significant increase in the amount of linear broadcast content that is delivered via IP networks.
- **Shift away from physical DVDs to a download-based model**: the increase in online video may lead to content that has traditionally been viewed on DVDs being downloaded instead. Services from iTunes, LOVEFiLM and Netflix indicate that this new download-based business model is beginning to gain momentum.

Based upon these key issues, we have defined the following four scenarios.

Scenario 1: Gradual increase in online video content
• Most TV viewing is via traditional linear broadcasts (or via Sky+-type devices) • On-demand content is generally consumed on the PC at a lower quality, with some people accessing the same lower-quality content on their TV • Most content is from traditional broadcasters, plus a few online specialists • Very limited shift to broadcasting linear content over IP networks • Modest move to DVDs being downloaded • Relatively concentrated set of service providers

Scenario 2: Large increase in online and on-demand TV, concentrated service providers
• Major shift in TV viewing preferences to on-demand content, often delivered over IP networks • A larger proportion of the content is from specialist independent channels rather than existing broadcasters • Limited shift to broadcasting linear content over IP networks • Content is easily accessible on the TV, with the majority in HD • Significant move to DVDs being downloaded • Relatively concentrated set of service providers

Scenario 3: Large increase in online and on-demand TV, fragmented service providers
• As Scenario 2, but with a fragmented set of service providers

Scenario 4: Almost all TV is online and on demand
• Almost all TV is on-demand and consumed over IP networks • All content is in HD • More pronounced shift to broadcasting linear content over IP networks • Wide range of specialist independent channels, at the expense of existing broadcasters • Larger move to DVDs being downloaded • The service provider market is fragmented

Scenario 1 is a natural evolution of the market today; Scenarios 2 and 3 are quite likely to emerge if NGA is widely deployed; and Scenario 4 is an extreme scenario that is less likely to emerge but it illustrates the impact of a major shift in content distribution.

Figure 1.5 below shows our forecasts for demand per line during the busy-hour under the four scenarios.[11]

[11] Scenarios 2 and 3 have the same traffic forecasts, but use different assumptions for the market shares held by operators.

It can be seen that in 2008 the busy-hour bandwidth requirement per household in the UK is around 24kbit/s (of which about 20% originates from video services). Under Scenario 1 this is forecast to grow at a compound annual growth rate (CAGR) of 29% to reach around 300kbit/s per household by 2018. Under Scenarios 2 and 3 the bandwidth requirement grows to around 950kbit/s per household in 2018, and in Scenario 4 to about 2000kbit/s per household.

For comparison with historical trends, we understand (based on our discussions with industry contacts) that in 2001, ISPs typically provisioned 5–6kbit/s per user for busy-hour bandwidth. The growth rate between 2001 and 2008 was therefore 23% per annum. It seems reasonable to expect a higher rate of growth in the future given the increasing availability and user awareness of video services.

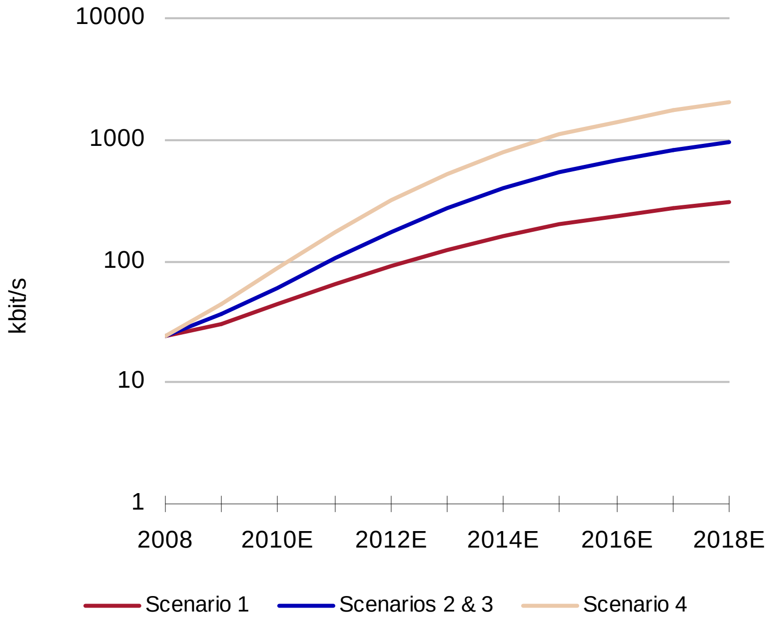

Figure 1.5: Busy-hour average bandwidth required per household [Source: Analysys Mason]

1.6 Technical and economic analysis

In order to quantify the impact of this traffic growth on broadband networks, we have developed a model of the network costs for three main types of service providers, as follows.

- **LLU operators** are alternative operators that purchase access to unbundled local loops, over which they provide their own retail services using their own network equipment (typically co-located with the incumbent operator’s equipment in the local exchange).
- **Bitstream operators** are smaller service providers that do not have the scale required for LLU to be attractive from a cost perspective. Such operators purchase wholesale bitstream products from BT Wholesale, thus avoiding the need to deploy any equipment in the access network. The operator simply purchases the required high-speed connections, over which it provides its own retail services; it does not own the physical line or the equipment at the local exchange. It

may be noted that the incumbent retail operator (BT Retail) also provides broadband offerings to consumers by purchasing wholesale backhaul and access services from BT Wholesale.

- The larger alternative operators in the UK take a hybrid LLU/bitstream approach, using bitstream to serve those areas not covered by their LLU networks.

There is also the **cable operator** Virgin Media, which provides retail broadband services over an access network based on coaxial cable rather than copper. We have not considered Virgin Media because of its vertically integrated status. Virgin Media should also have similar economies of scale to LLU operators.

It should be noted that the technical and economic analysis does not consider either new revenue streams or the potential for a reduction in the price of products supplied by Openreach.

As discussed above, we believe that the bottleneck in supplying video services with a high level of QoS is primarily in the backhaul and access networks of retail service providers. Our technical and economic analysis focuses on the additional network costs that arise from increases in video traffic: it therefore only includes **costs that are traffic-related**. In the access network, however, the costs are primarily driven by the number of lines provided, and not the amount of traffic carried. (An operator must provide a functioning line for each customer, irrespective of how much traffic that customer generates.) For that reason, our cost analysis **excludes the access network**.

Generally speaking there are two methods that service providers can use to ensure that services such as video or voice are delivered with a high level of QoS: either (a) deploy additional bandwidth, or (b) reserve bandwidth specifically for those applications. The choice between these two is essentially driven by the relative costs of bandwidth and servers respectively. Most core and backhaul networks are based upon optical fibre, so deploying incremental bandwidth is a relatively low-cost option as it is possible to exploit economies of scale.[12] In addition, purchasing additional bandwidth is a simpler option for network operators than prioritising specific traffic types. It also avoids having to provide a lower-quality service for other applications during busy periods. In our analysis the majority of bandwidth is required by real-time video services. There is therefore limited scope for prioritising this traffic over other types of traffic. Our discussions with stakeholders did not raise any major concerns about the ability to deploy QoS within broadband networks if it was to be required (as illustrated by the deployment of traffic shaping, which is a form of QoS, by many service providers). Our analysis therefore focuses on deploying additional bandwidth to ensure a high level of QoS.

At present, most service providers purchasing wholesale broadband use the IP Stream product from BT Wholesale. However, service providers will be migrated to the fibre-based WBC bitstream product as BT rolls out its 21CN next-generation network. Our detailed analysis has

[12] For a typical alternative operator using LLU, the costs of the three different bandwidths of backhaul link available are roughly in the ratio of 2:4:7, whereas the bandwidths available are in the ratio of 1:10:100. The costs of providing backhaul capacity are therefore subject to large economies of scale. In contrast, bitstream pricing does not offer any economies of scale with increasing bandwidth for the major cost components.

therefore been based upon WBC. Until 21CN is completed, we have assumed that operators using bitstream services will not be able to take advantage of the economies of scale that are expected to emerge with the 21CN-based WBC product.[13]

1.6.1 Results of the analysis

The main cost that is traffic-driven is the backhaul link between the local exchange and the core network. A large proportion of the total network costs are primarily driven by the number of lines. These include the costs of copper access lines and active equipment in the exchange such as DSLAMs.[14] However, these cost factors are independent of the amount of traffic and therefore excluded from the analysis.

LLU-based operators which typically use fibre-based backhaul products from Openreach are able to exploit significant economies of scale that help to limit the cost increases under most scenarios (although there are still significant increases in costs under the most aggressive scenario). We have assumed that the prices of backhaul products from Openreach (e.g. BES) remain unchanged over time.

Operators using bitstream-based services from BT Wholesale would face extremely large increases in costs if the demand forecasts were to materialise *without* a significant reduction in the price of those wholesale products. The forecast cost increases – under current bitstream wholesale pricing – are so large that they may limit the growth of online video services.[15]

We understand that BT Wholesale will begin to use fibre-based backhaul products from Openreach in its 21CN network. This offers the prospect of lower bitstream prices, as BT Wholesale will be able to exploit similar economies of scale to unbundlers in its own backhaul once migration to 21CN is complete and all service providers have been migrated to WBC.

We have illustrated the impact of potential future prices of bitstream products based upon an estimate of the costs incurred by BT Wholesale, by taking as inputs Openreach fibre products for backhaul (including an allowance for additional costs and profits). These illustrations are based on the assumption that WBC prices per Mbit/s fall drastically over time if traffic volumes increase, i.e. following similar economies of scale to today's Ethernet-based backhaul products.

Our WBC analysis is based upon a national average, though the differences in costs by exchange may lead to an element of geographic pricing in the future that we have not attempted to include.

---

13 IP Stream has a broadly similar pricing structure, with backhaul being the most significant cost that is dependent upon bandwidth. IP Stream prices are generally higher than those for WBC.

14 A DSLAM is a digital subscriber line access multiplexer that receives signals from digital subscriber line (DSL) connections and transfers the signal to the network.

15 The current pricing means that backhaul costs are essentially linear with traffic. A significant growth in traffic would therefore lead to significant increases in costs to over GBP100 per month per line in our highest traffic scenario. Clearly, this would not be commercially sustainable.

As the WBC roll-out is still underway, it may not be possible for service providers to benefit from these economies of scale in the near term. If this is the case, the current prices of bitstream services may mean that the rise in costs associated with growth in online video consumption are prohibitive in which case service providers may contend their network capacity more, which could impact the user experience for video services.

Once bitstream services are able to exploit economies of scale in the backhaul network, it should be possible for wholesale prices of bitstream services to decline. However, for this to occur the reduction in costs per Mbit/s for BT Wholesale would need to be passed on to service providers. As BT Wholesale's biggest customer is BT Retail, we believe that there should be incentives for BT Wholesale to pass on these cost savings, although there may be timing issues associated with how rapidly this occurs; this could limit the ability of retail service providers to offer a service that allows customers to consume as much online video content at the same quality as customers on LLU networks.

The introduction of technical solutions such as traffic shaping, multicasting and content caching at the exchange should allow service providers to further minimise the cost impacts of increased video traffic on their networks. The benefits that each technical solution brings are dependent upon the volume of different traffic types on the network. In our analysis the deployment of traffic shaping yields cost savings throughout the timeframe considered. However, under our base case the business case for investing in multicasting only becomes positive in the middle years of our analysis; and the case for content caching at the exchange becomes positive in the final years. However, if the costs of deploying these technical solutions were to fall significantly it may become economical to deploy them significantly earlier.

1.6.2 A comparison of future and current network costs

To assess the impact of increased network costs it is useful to compare the costs to those currently experienced by service providers. In assessing the costs in 2008 it is important to recognise the differences between service providers. Some will have lower pricing, and typically attract lower-usage subscribers, while other service providers may have higher pricing and attract subscribers who generate more traffic. There is therefore a range in the costs experienced by service providers at present.

We believe that our analysis of the costs per subscriber per month, with and without traffic shaping deployed in 2008, provides a reasonable upper and lower bound for the costs per subscriber per month in 2008. We have therefore used these two estimates of costs in 2008 as the baseline costs for our analysis of the commercial impact of increased traffic upon service providers. The results for the cost per line per month[16] when deploying all technical solutions that are commercially attractive are shown below in Figure 1.6 for LLU, and Figure 1.7 for bitstream.

---

[16] The total monthly traffic costs include backhaul, core network and IP transit costs but exclude costs of the access network that are independent of bandwidth usage.

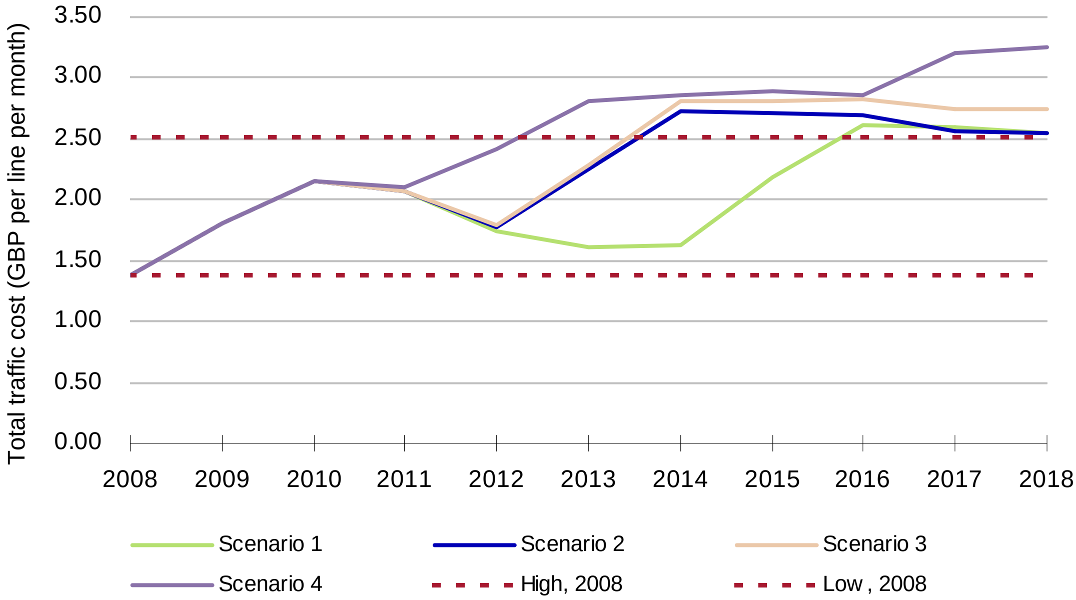

Figure 1.6: *Overview of the total monthly cost per line when deploying all technical solutions for Scenarios 1 to 4 for an LLU-based operator [Source: Analysys Mason]*

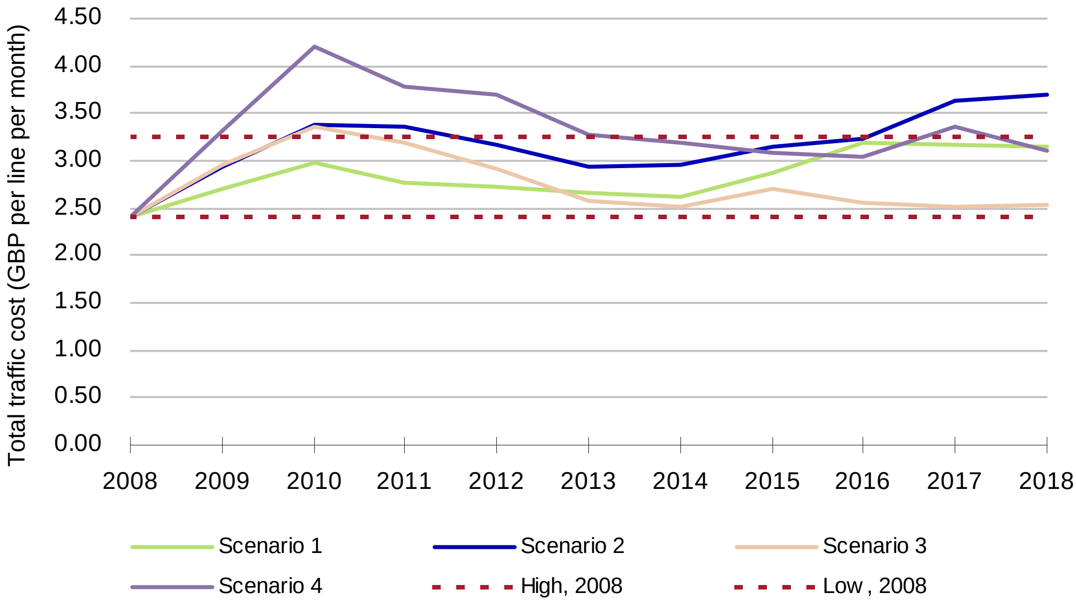

Figure 1.7: *Overview of the total monthly cost per line when deploying all technical solutions for Scenarios 1 to 4 for a bitstream-based operator [Source: Analysys Mason]*

For an LLU operator, if the technical solutions are deployed, the increase in network costs by 2018 is not significantly above the high baseline for 2008 in Scenarios 1, 2 and 3. Under Scenario 4 there is a reasonable increase above the upper baseline by 2018.

For a WBC (bitstream) operator, the costs increase above the baseline in two periods: 2010–2012 under Scenario 4, and in the final years under Scenario 2. The increase during 2010–12 is due to the incomplete migration to 21CN, which means it is not possible to exploit the economies of scale associated with the fibre-based backhaul products used in WBC. The higher costs for Scenario 2 in the final years are due to the high traffic levels per line and the lower total traffic levels due to a lower market share for WBC operators when compared to Scenarios 3 and 4.

Our demand modelling has assumed that no demand constraints will arise in access networks. However, the limited availability of NGA may mean that take-up of HD services is slower than forecast, and this would limit the impact of the increased costs for bitstream operators in 2010–12. During this period the proportion of HD under Scenario 4 is assumed to be 10–20% of all video traffic.

Technological advances in content caching[17] may make it cheaper to deploy this kind of technical solution – our modelling indicates that caching could limit the cost increase to levels similar to our base-line 2008 costs per line per month.

As mentioned previously, we have not considered either new revenue streams or the potential for a reduction in the price of products supplied by Openreach. It appears reasonable to assume that a combination of these two factors would minimise the impact of increased network costs to a level that could be supported by operators.

1.7 Evolving business models

It may be that service providers will need to realise additional revenue streams from online video services in order to support the costs of providing such services. We have identified two broad types of business model they might adopt:

- **Retail business models** involve the service provider charging additional fees to its customers for high-quality access to video content. Current examples of this business model include BT Vision and Tiscali TV. Of particular interest is the catch-up TV service from BT Vision. This gives users access to video content that can already be obtained free of charge on a PC directly from the BBC and Channel 4 – the BT service provides this content to the TV set, with a guaranteed level of quality.
- **Wholesale business models** involve payments to the service provider (possibly via a CDN from content owners down the value chain, for services that help to ensure their content is

17 Examples include the small footprint caching solutions from companies such as Edgeware.

delivered with a high quality of service. Such wholesale business models are currently less mature, and may take a number of years to develop. These business models can also be described as ‘two-sided’, as revenue is obtained from both end users and other businesses.

It is possible that the retail and wholesale business models outlined above could also receive contributions from advertising revenue. In the case of the retail business model, the service provider would deal directly with advertising agencies, but in the wholesale model advertisers would have a relationship with the content owners.

1.8 Implications for Ofcom

Analysys Mason believes there are five areas which could have regulatory implications for Ofcom. We do not believe that any of these areas require immediate action.

- **A delay in the migration to 21CN-based bitstream products** may have a negative impact on service providers that use current bitstream products, as growth in consumption of video services could be held back due to the prohibitive costs of backhaul capacity to support them on the legacy core network. We believe that the timely migration to 21CN will be important in enabling significant take-up of online video services at prices that are reasonable for consumers.

- **Video traffic could be accommodated by increasing the total bandwidth available**, and it is not essential to deploy advanced technologies to prioritise video traffic over other types of traffic in order to ensure a high QoS for video services.

- If video services are to continue to grow without leading to significant increases in costs to service providers, **there will have to be a significant reduction in the cost per Mbit/s of bitstream products**. This should be achievable once BT Wholesale has fully migrated to 21CN by exploiting the economies of scale associated with fibre-based Ethernet services, and the associated cost savings are passed on to service providers.

- Even in the most aggressive demand scenario (Scenario 4), the cost implications may not be excessive if **future bitstream pricing benefits from the economies of scale** that fibre-based backhaul products offer unbundlers today (as outlined in the point above), and if there are **technological advances in Ethernet services** that further reduce the cost per Mbit/s (e.g. through the availability of 100Gbit/s equipment).

- Finally, **innovative business models might be limited by regulation**: if the ability to develop and deploy novel approaches was limited by new regulation, this might limit the potential for growth in online video services.

2 Introduction

This section provides some background to the study, then moves on to outline the objectives of the study, and the approach taken.

2.1 Background

Ofcom wishes to understand the impact that congestion would have on the ability to provide video services over the Internet and what regulatory measures might be taken to overcome it.

Video content is already available over the Internet and is increasingly popular, offered over a variety of services. We can classify different kinds of delivery mechanisms for video content over the Internet into three broad types, as shown in Figure 2.1.

	Download-and-store video	Streamed video (open)	Streamed video (closed IPTV)
Mode	Non-linear	Non-linear VoD	Linear and non-linear VoD
User interface	PC (TV*)	PC (TV*)	TV
Relative video quality	Medium	Low	High
Relative bandwidth requirement	Low	Medium	High
Examples	4oD, iPlayer, Sky Anytime	YouTube, iPlayer	Tiscali, BT Vision, Virgin Media

Figure 2.1: Simple classification of the different types of mechanisms used for delivering video content over the Internet. The (*) indicates a transition, already starting, enabled by in-home technologies (see main text) [Source: Analysys Mason]

Firstly, there are download and store services, such as Channel 4’s 4oD, the BBC’s iPlayer and Sky’s Anytime service. This is non-linear in the sense that there is no set schedule for viewing, unlike traditional broadcast television. Users download video files, typically 500–1000MB[18] in size, to a PC for storing and viewing.[19] Some content of this kind may only be viewable in a limited time window (e.g. seven days), with content being protected by digital rights management (DRM) technologies. Peer-to-peer (P2P) delivery technologies may also be used in order to increase delivery efficiency. Downloads by their very nature are not time-critical and thus can provide relatively high video quality without requiring large amounts of bandwidth by spreading out the delivery. It is not uncommon for download and store services to offer higher quality video content than streamed video for this reason – the BBC’s iPlayer is a good example of differential

18 On a 4Mbit/s broadband connection, this would take 17–33 minutes to download.

19 Note: such services are broader than just video services – audio, games and other content types are relevant. However, for this study, we focus on video.

quality for the same content dependent on the delivery mechanism. Others, such as Vuze, already offer some high-definition (HD) content for download. By their very nature, download and store video services do not require any specific quality of service (QoS) for their delivery; however, the volume of such content being delivered across the Internet is such that it may affect overall congestion, and hence may need to be considered in the broader scope of this work.

Secondly, streamed video services comprise a vast range of content classes, ranging from short clips, to full-length feature films. Broadly, these may be termed video-on-demand (VoD). YouTube is perhaps the most well-known example, which aggregates content provided by users and select channels – in July 2006, YouTube delivered 100 million video streams per day. Other social networking sites, such as MySpace and Facebook, also offer video streaming functionality, as does the BBC's iPlayer with a Flash-based streaming service. Finally, there is a range of new players such as Joost and Babelgum which offer TV-like channel experiences. Currently, streaming is done to a PC, although there are signs of movement to the TV.

Thirdly, it is also possible to access both linear and non-linear content via closed IPTV networks. These services typically have a proprietary set-top box that ensures a high quality user experience that is closely managed. As the set-top box is closely tied to the underlying broadband network it is also possible to ensure a higher quality video service. One notable example here is Virgin Media's implementation of the iPlayer which has been particularly successful. A large part of this success is likely to come from being able to access the content on a large TV, as opposed to the PC when using the standard Web-based iPlayer. Once it becomes easier to access on demand services such as iPlayer on traditional TVs there may be significant additional growth in the usage of online video services.

There is already some evidence emerging that suggests streaming video is having quite an impact on ISPs' networks – see Figure 2.2 below. VUDU in the USA appears to have an interesting solution whereby real-time streaming of enhanced or even high-definition video over a DSL connection works with as little as 2Mbit/s of throughput. However, this may not scale well to all sources of traffic or a dramatic increase of up-take. Information from Virgin Media (September 2007) indicates that 45% of their customer base use VoD at least once a month; it was also stated that there were over 270 million VoD viewings during 2007.[20]

20 Source: Malcolm Wall, Virgin Media, speaking at the Westminster Media Forum, 31 January 2008.

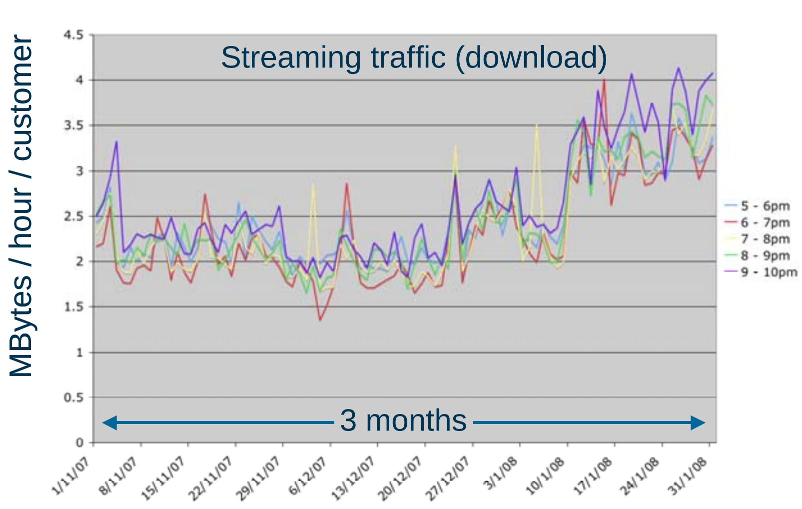

Figure 2.2: Recent data on the increase in streaming video [Source: Plusnet, 2008; annotation by Analysys Mason]

The quality of streamed video is currently relatively low – content providers recognise that broadband networks have certain limitations in terms of bandwidth available. Streamed video content also tends to be free to the end user, being generally supported by paid advertising, and thus consumers may be willing to tolerate quality levels that would not be tolerable in a paid service. Other factors, such as PC processing power, can also be important in determining the overall quality level, and cannot be controlled by the video provider.

Recent data from the BBC regarding the use of iPlayer indicates that, when there is a choice of download and store or streaming, users show a very strong preference for streaming: eight times more people are now using the Flash-based streaming iPlayer than the desktop P2P download and store version.[21] This may have important implications for this study (and in a broader context, for the BBC and the industry at large).

For both download and store video and streamed video it is common today for the content to be viewed on a PC screen. However, in-home technologies that connect PC to TV, e.g. Apple TV, will start to change users' viewing habits. Since TV screens are larger than PC screens, and with increasing numbers of consumers purchasing larger LCD and plasma screens, which will be further stimulated by the digital switch-over, it seems likely there will be increasing demand for higher quality streamed video. This clearly has implications for networks and hence this study.

The final classification is streamed TV, or IPTV, services, where content similar to that provided by cable or satellite transmission services is delivered. Internet Protocol (IP) is used for transmission, and the service is linear (broadcast according to a schedule). IPTV is generally a paid service, and thus quality expectations are high, particularly when there is competition with other more established models such as satellite broadcasting. Linear broadband TV is also real-time and this has implications for networks. In the UK, Tiscali offers such a service.[22] In Europe, there is a

21 Data from HitWise, an Internet traffic research firm, supports this. HitWise reported a 14-fold increase in visits to iPlayer following the release of the Mac-compatible streaming version, and the marketing campaign around the launch. See http://www.hitwise.co.uk/press-center/hitwiseHS2004/iplayer.php.

22 BT Vision uses DTT for broadcast TV, and streamed video for VoD services (film, 'catch up' TV, sport, music and kids content)

wide range of similar offers from incumbents (e.g. MaLigne TV from France Telecom, Home TV from Telecom Italia and Belgacom TV) and alternative operators (e.g. Free and Neuf Cegetel in France, and Fastweb in Italy).

Whereas streamed video is often buffered,[23] this is much more difficult to do in IPTV – a change of channel means that the buffer will not hold the right content and there would be a noticeable delay, a feature that users do not like. IPTV providers can ensure high-quality transmissions because they offer the service as part of a managed service,[24] meaning that they provision the service in a manner similar to the way in which a cable company does – delivering content to points in their network where it can be delivered over reserved bandwidth to users. Local caches and other technologies can play an important role here.

QoS becomes increasingly important in contended networks where congestion may occur. QoS enables network operators to differentiate and prioritise between different traffic streams in contended networks. In this context, real-time services can be prioritised over less time-critical services to ensure IP packets arrive at the customer's premises in a timely manner to meet the quality of experience expected by the customer. When considering QoS, it is important to look at the end-to-end delivery, which may entail content traversing multiple different networks, and how the content is delivered, e.g. via unicast, multicast or P2P.

It is interesting to consider QoS in the context of some of the players already mentioned. Figure 2.3 shows the distribution mechanism used and whether or not QoS is currently being implemented.

Content provider	*Distribution mechanism*	*QoS implemented?*
BBC – iPlayer	Download and Flash streaming over the Internet	No
Channel 4 – 4OD	Download over the Internet	No
Sky – Sky Anytime	Download and progressive download over the Internet	No
YouTube	Flash streaming over the Internet	No
Tiscali	Streaming over an LLU network	No
BT Vision VoD	Streaming over a managed closed network	Yes

Figure 2.3: Distribution and QoS summary for a range of content providers [Source: Analysys Mason]

At present, QoS implementations are limited. Providers such as Tiscali, which both broadcast TV content and provide VoD services like BT Vision, provision sufficient capacity in their backhaul networks (for unbundling, using 1Gbit/s BES circuits) rather than use any specific QoS

23 The buffer stores a certain number of seconds of a stream in the end device – thus even if there is a delay in input or a need to request retransmission of packets, it can continue to output from the buffer without any noticeable pause in the service.

24 Inuk Networks offers its Freewire IPTV service to university halls of residences in the UK (as part of a triple play offer with broadband and telephony). Although the screen is a PC rather than a TV, they claim "broadcast quality TV". This is possible as it is delivered over a managed network.

implementation. BT Vision uses a BT Wholesale product that does include QoS functionality. In the near future, other QoS products will become available, e.g. the 21CN product Wholesale Broadband Connect (WBC).

2.2 Objectives of the study and approach taken

Ofcom's ITT asks for a solution that combines elements of everything described above:

> *"…to determine what technical and economic conditions regarding distribution (e.g. end to end quality of service across multiple networks, bandwidths in the core and access networks, use of multi-casting etc.) would need to be met for most households to be able to access video content anywhere on the internet and watch it on their living room TVs, at the same level of service quality as programming distributed by terrestrial cable or satellite transmission." [ITT Appendix 3]*

The approach we have taken is to address this objective is illustrated in Figure 2.4 below:

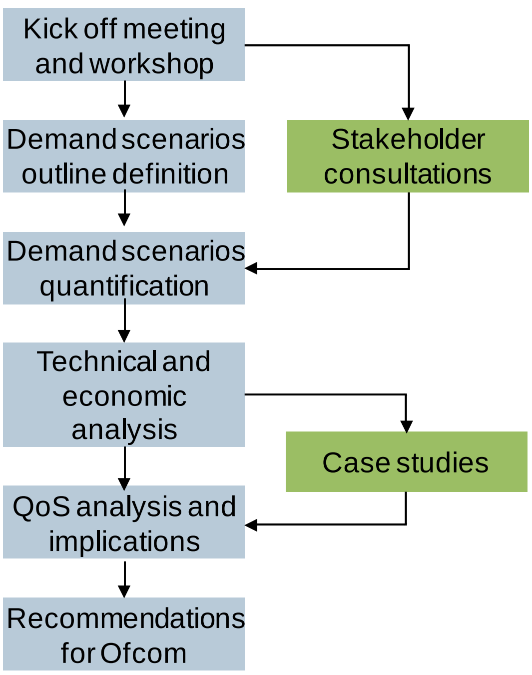

Figure 2.4: Overview of proposed approach [Source: Analysys Mason]

Section 3 includes a summary of findings from our interviews with various stakeholders in the telecoms and media sectors. These discussions were carried out at the start of the study to identify key trends and issues, and to confirm our initial assumptions. The detailed interview notes are confidential, so a summary of the key findings is presented in this report.

Section 4 discusses how online video is delivered from one end of the network to the other. At the extreme, data may cross the globe using many different networks that do not guarantee QoS. Content distribution networks (CDNs) are therefore often used to provide an end-to-end delivery solution that can guarantee a higher quality of service for video distribution. However, these CDNs do not include the final networks operated by the consumers' service providers. It is in these final networks that we believe there are currently bottlenecks to the deliver of high-quality video services.

Section 5 describes the scenario-planning approach we have used to identify the key issues for further analysis. We have defined the four future scenarios for broadband demand, depending on different possible developments in the video market. These issues were chosen based upon desk research and our interviews with key stakeholders. The traffic delivered over broadband networks for each of the four scenarios is quantified in terms of overall consumption (e.g. minutes and gigabytes of data), and more importantly for its bandwidth impact upon broadband networks (i.e. kbit/s in the busy hour).

Section 6 presents our technical and economic analysis of the impact of increased traffic under the four demand scenarios. The analysis focuses on the impact of increased traffic upon network costs that are bandwidth dependent. These costs, which relate predominantly to the backhaul networks between the local exchange and the core network, are compared with a 'base case' in which only currently used technologies are present. We then discuss a number of technical solutions that reduce the impact of increased traffic (e.g. multicasting, or caching of content at the local exchange). The impact of these technical solutions is quantified. Finally, we assess the commercial impact of the increases in traffic under each of the four scenarios.

Section 7 considers how new business models for the delivery of online video may help to generate additional revenue for service providers. This additional revenue could then be used to help fund any additional investments in network capacity to support high-quality video services. These business models have been identified through our desk research, a number of case studies (which are detailed in Annex C), and the stakeholder consultations.

Finally, **Section 8** sets out our conclusions from the technical and economic analysis, and the implications for regulatory policy.

The report includes a number of annexes containing supplementary material:

- Annex A sets out key issues in the definition of our demand scenarios
- Annex B describes the demand scenarios
- Annex C presents case studies of companies and services relevant to online video
- Annex D explains the technical challenges involved in implementing caching at the exchange
- Annex E provides results from our technical and economic analysis
- Annex F provides a glossary of terms.

3 Key findings from stakeholder interviews

During June and July 2008, Analysys Mason interviewed nine stakeholders, covering a number of sectors:

- BBC
- BT Wholesale
- Carphone Warehouse
- Channel 4
- Cisco
- Sky
- Velocix (a CDN provider)
- Virgin Media
- a multinational content owner which did not want its identity to be disclosed.

The main messages that came out of these discussions are summarised in the following sections.

3.1 Demand for online video will continue to grow

There was a consensus that demand for online video services will continue to increase, and that services such as the current version of the BBC iPlayer are only the start. However, some organisations noted that 'pre-meditated' recording or the use of storage services such as Sky+ will limit the impact of true on-demand services on broadband networks.

Advertising revenue is likely to be an important aspect of some online video businesses.

3.2 Backhaul is currently a bottleneck

At present, the biggest bottleneck in the UK – for both LLU and bitstream operators[25] – is the backhaul between exchanges and the core network. It was generally recognised that there are better economies of scale for LLU operators[26] than for bitstream operators. The new bitstream product from BT Retail, Wholesale Broadband Connect (WBC), will help to reduce costs for those ISPs not using LLU. However, there was a view that the costs of LLU will always be lower than those of other wholesale products.

---

25 These terms are explained in Section 6, which also contains a discussion of the relative economies of scale that can be realised by LLU and bitstream operators.

26 Also see investor presentation from Carphone Warehouse in April 2008 on the economies of scale in LLU backhaul, http://library.corporate-ir.net/library/12/123/123964/items/287985/Analyst_Day_150408_Pres.pdf

3.3 The access network may become a bottleneck

A significant proportion of homes in the UK are currently served by low-speed ADSL connections, and it is only just possible to provide video services to these customers. Moreover, these ADSL connections will not realistically support high-definition (HD) content.

The soon-to-be-launched network upgrade from Virgin Media and the announcement of BT's next-generation access (NGA) strategy[27] on 15 July 2008 are likely to mean that, for the foreseeable future, access speeds will not be a long-term bottleneck for a reasonable proportion of the country, although we note that BT is requesting that a number of conditions be met before it commences any roll-out.

It should be noted that consideration of NGA networks is outside the scope of this study.

3.4 Technological solutions can limit the effect of traffic, whilst providing the same service

Most of the technical solutions would involve caching at various levels in the network – potentially including at the customer premises equipment (CPE). However, the current location of the broadband remote access server (BRAS) may make caching at the exchange difficult: the BRAS is generally located more centrally, and placing a cache deeper in the network creates technical challenges. This is discussed in more detail in Annex D.

Other solutions may also require the development of new types of CPE. It may be desirable for more sophisticated CPE to be based upon open standards. The development of such CPE would need to be agreed through industry co-operation.

3.5 The business models for QoS and caching are not yet mature

The value chain may evolve, with CDN providers offering more advanced services to content owners, including deep network caching. Under such a scenario, CDN providers may pay network operators for capacity or caching services. Another model would be for service providers to charge consumers directly for QoS as a separate element of the transaction, distinct from delivery of the content.

The preferred business model is not yet clear. This is discussed further in Section 7.

---

27 BT's publicly announced strategy includes deploying VDSL to around 10 million homes by 2012. There will also be small amounts of FTTH for newly built properties. See http://www.btplc.com/news/articles/showarticle.cfm?articleid=efd7b1fa-52ed-45bb-b530-734fac577e94.

4 End-to-end delivery of high-quality video services

The end-to-end delivery of content often involves data traversing multiple networks, sometimes across different countries, or even continents. For example if a consumer from a smaller service provider in the UK was requesting traffic from a Web site hosted in the USA the data may take the following path:

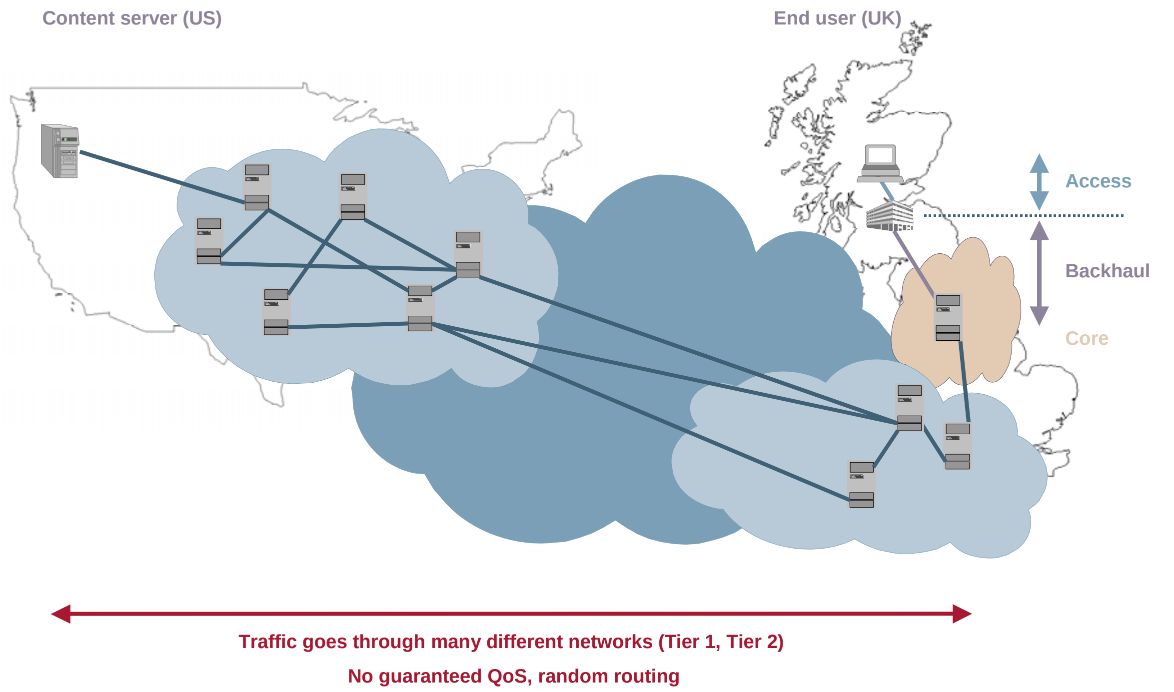

Figure 4.1: End-to-end traffic routeing via the public Internet [Source: Analysys Mason]

If any of the individual links in the above network are congested, this will impact the delivery of content to the end user. No-one organisation in the above diagram is able to control all of the parts of the network to ensure that there is a guaranteed QoS. Because of this, all peering agreements between networks on the public Internet are on a best-effort basis.

As shown in Figure 4.1 above, the series of connections between the content provider's server and the consumer can be divided into two parts: (a) the **public Internet**, which is made up of many intermeshing networks, and (b) the final connections to the consumer that are the responsibility of the particular chosen service provider. This final part is made up of the **backhaul network** which connects the local point of presence (e.g. the local exchange) to the **core network**, and the **access network** which connects the local point of presence to the end-user's premises. In the following, we first consider QoS issues in the Internet backbone, and then in the backhaul and access connections provided by the service provider.

4.1 QoS in the public Internet and the role of content distribution networks

To overcome the limitations of the public Internet in delivering content with a guaranteed high quality, a number of organisations have developed content distribution networks.[28] The role of a CDN in the previous example is illustrated below:

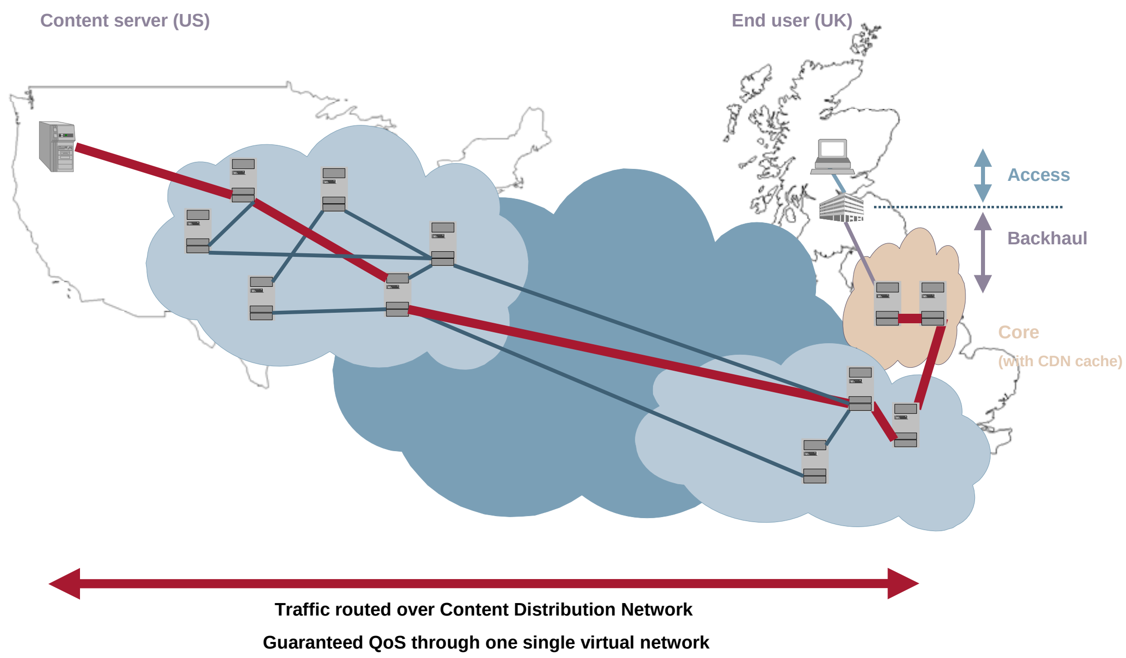

Figure 4.2: End-to-end traffic routeing using a CDN [Source: Analysys Mason]

CDNs are able to guarantee a high-quality service for the delivery of valuable content, as they use a mixture of caching close to the user, which negates the need for the data to be transferred over the whole network for each request. CDN providers also control dedicated links between the content server and the end user's service provider: this allows them to ensure that any congestion elsewhere in the network does not impact the delivery of content.

Many large content owners, both national and international, purchase services from CDN providers so that they can deliver their content. The detailed business model for CDN providers varies, but they generally charge content owners either per gigabyte (volume) or per Mbit/s (data rate) for the content that they deliver. There is usually no charge to the service provider that supports the end user, although the service provider does sometimes have to provide co-location space for the caches and routers, and also some bandwidth to the CDN provider at no charge. The costs to service providers of supplying these facilities are generally minimal when compared to the

28 Historically, another reason why CDNs evolved was that they made it possible to aggregate traffic and provide operators with lower prices per Mbit/s for capacity due to increased economies of scale.

benefits they receive in reduced IP transit costs.[29] Our discussions with stakeholders during this study generally indicated that this business model should be able to handle an expansion in online video distribution.

It is also possible for content owners to play the role of a CDN provider themselves. For example, Google has a large portfolio of data centres across the globe, which allows it to place its servers closer to the end users that are requesting content. Google also rents dedicated high-speed connections between some of its data centres, allowing it to operate its own high-speed backbone that does not use the public Internet.[30] This combination of distributed servers and dedicated connectivity plays a role similar to a CDN. Although smaller organisations will not have the same economies of scale making it more likely that they will purchase services from CDNs.

Within the UK, the most widely discussed online video service is the iPlayer from the BBC, which has seen significant growth during 2008. For this purpose, the BBC has high-capacity connections linking it directly to many service providers, ensuring that it is able to deliver video content in a controlled manner to the edge of the service providers' networks. However, such a model of direct peering links between content owners and service providers is only likely to be efficient for large, national content owners. Content owners with a more globalised audience, or those that are smaller in scale, are more likely to need to reply upon other approaches such as using CDNs

At present, it is not generally possible to provide guaranteed end-to-end QoS over multiple networks as the commercial arrangements to provide these additional features have not been agreed. Our consultations with stakeholders suggest that there is no underlying *technical* reason for this, as QoS features are standardised across modern networking equipment. We therefore believe that if there was a real demand, and need, for end-to-end QoS to become available over the public Internet, these services would emerge. Indeed, there are signs that these services are now beginning to develop. For example, the global Tier 1 carrier Level 3 purchased the CDN business of SAVVIS in 2007, allowing Level 3 to provide end-to-end QoS over its global backbone network. Although Level 3 does not yet provide QoS over *multiple* networks, the convergence of CDNs and traditional Tier 1 carriers indicates that QoS may become more of a standard feature over time.

In conclusion, we believe that the business models, technology and competitive pressures exist to ensure that content owners will continue to be able to deliver high-quality online video content to the final service providers that serve consumers. For these reasons, we do not envisage any major reason for concern from Ofcom's perspective.

---

29 IP transit costs are incurred when service providers have to purchase connectivity to external networks run by large carriers. These costs are reduced if a CDN is present as content is then cached in the service provider's network, reducing the total amount of traffic that needs to be delivered over external networks.

30 Such networks do not connect to end users, but provide connectivity over a similar portion of the Internet to traditional CDNs.

4.2 QoS in the backhaul and access networks

The connection between the core network and the end user is made up of the backhaul and access networks operated by the consumer's service provider. These networks are of more interest to Ofcom as they have persistently functioned as economic bottlenecks in the past, and we believe they are likely to be bottlenecks to the delivery of high-quality video services.

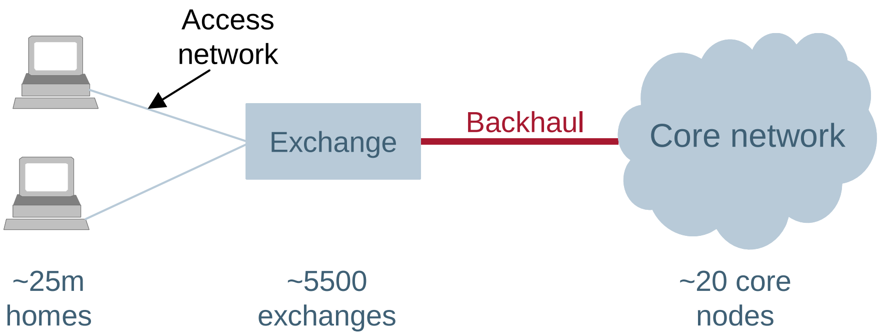

Figure 4.3: Illustration of access, backhaul and core networks [Source: Analysys Mason]

The **backhaul** network typically has capacity that is shared between many end users, with each service provider using its own engineering rules to dimension the total capacity. Due to the recent growth in the broadband market and the drive towards lower prices due to competition, we believe that in many cases these backhaul networks are running at close to their maximum capacity. As a consequence, for some end users this part of the network may be a bottleneck for video services at present. Our technical and economic analysis, described in Section 6, has therefore focused on the provision of capacity in the backhaul network.

The **access** network may also become a bottleneck for video services. This network typically has a headline bandwidth which is dedicated to each customer. In most cases this is high enough to support current video services, though it may not be high enough to support HD video, which can require over 10Mbit/s per video stream.

An analysis of access networks is not within the scope of this study as the development of next generation access networks is a fast moving area, with many complicated issues associated with it. In addition, the whole area is being covered by a number of other studies in much more detail. However, we may note that the ongoing network upgrades by Virgin Media, and the planned roll-out of a high-capacity VDSL next-generation access network by BT, will eliminate access bottlenecks in the areas served by these networks. Problems will remain in other areas using older access technologies, and the geographical extent of this will depend on the deployments of NGAs by BT and other operators.

5 Future demand scenarios

In order to obtain a picture of how the broadband market may evolve over the next ten years, we have used a scenario-planning approach, constructing four possible scenarios for how broadband networks may be affected by the demands placed upon then by video services. Section 5.1 sets out our definition of the demand scenarios, and Section 5.2 provides quantitative results from each of the scenarios we have modelled.

5.1 Definition of demand scenarios

In developing suitable traffic demand scenarios, we first identified a range of issues which may determine how end users consume content in the future. Figure 5.1 provides an overview of these key issues (a more detailed description is provided in Annex A).

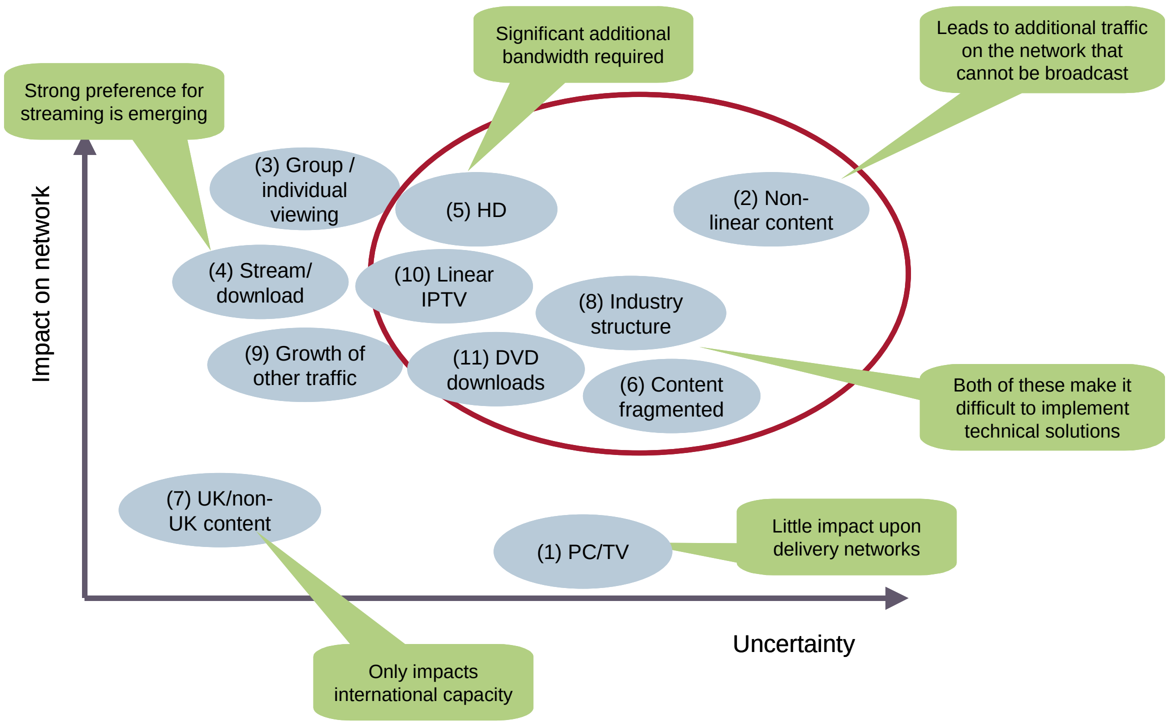

Figure 5.1: Categorisation of issues to be included in traffic demand scenarios [Source: Analysys Mason]

The essence of scenario analysis is to focus on the issues that have the **most uncertainty**, and the **greatest impact** upon the area being studied. (Outcomes that are *highly likely* to occur generally require little analysis – it is relatively easy to plan for these. And outcomes that will have *little impact* do not demand so much attention as those that will have a significant effect.) In line with this, we ranked each of the issues in Figure 5.1 against the two criteria of uncertainty and impact on the network: if we regarded a factor as highly uncertain but likely to have a significant impact on the network, we included it in the definition of our scenarios. Our evaluation resulted in the following six issues which we believe will play a key role in determining future traffic demand per household.

- **Shift to on-demand TV**: TV viewing behaviour is likely to shift away from scheduled programming to more on-demand viewing, with programmes delivered via IP networks.
- **High-definition content**: the industry is slowly moving towards HD. Better picture quality will lead to larger files and therefore more demand for network capacity.
- **Fragmentation of content providers**: the evolution of niche content providers might challenge the current dominance of a limited number of content providers (e.g. iPlayer and YouTube) and make caching more complicated.
- **Structure of broadband industry**: the UK broadband market is in a period of consolidation, which is occurring because LLU is more scalable than bitstream products, and operators are exploiting these scale economies. At present, most service providers purchasing a wholesale bitstream product in order to provide broadband use the IP Stream product from BT Wholesale. However, BT Wholesale is now moving to its new fibre-based WBC product, based on its 21CN next-generation network. This shift from IP Stream to WBC may lead to a more fragmented market. This could be caused, for example, by the deployment of NGA by BT which might mean that service providers become more reliant on bitstream services.
- **Linear content broadcast over IP networks**: IPTV is slowly gaining a foothold in the UK market. As a result, there may be a significant increase in the amount of linear broadcast content that is delivered via IP networks.
- **Shift away from physical DVDs to a download-based model**: the increase in online video may lead to content that has traditionally been viewed on DVDs being downloaded instead. Services from iTunes, LOVEFiLM and Netflix indicate that this new download-based business model is beginning to gain momentum.

Based upon these key issues, we have defined the following four scenarios:

Scenario 1: Gradual increase in online video content
• Most TV viewing is via traditional linear broadcasts (or via Sky+-type devices) • On-demand content is generally consumed on the PC at a lower quality, with some people accessing the same lower-quality content on their TV • Most content is from traditional broadcasters, plus a few online specialists • Very limited shift to broadcasting linear content over IP networks • Modest move to DVDs being downloaded • Relatively concentrated set of service providers

Scenario 2: Large increase in online and on-demand TV, concentrated service providers
• Major shift in TV viewing preferences to on-demand content, often delivered over IP networks • A larger proportion of the content is from specialist independent channels rather than existing broadcasters • Limited shift to broadcasting linear content over IP networks • Content is easily accessible on the TV, with the majority in HD • Significant move to DVDs being downloaded • Relatively concentrated set of service providers

Scenario 3: Large increase in online and on-demand TV, fragmented service providers
• As Scenario 2, but with a fragmented set of service providers

Scenario 4: Almost all TV is online and on-demand
• Almost all TV is on-demand and consumed over IP networks • All content is in HD • More pronounced shift to broadcasting linear content over IP networks • Wide range of specialist independent channels, at the expense of existing broadcasters • Larger move to DVDs being downloaded • The service provider market is fragmented

Scenario 1 is a natural evolution of the market today; Scenarios 2 and 3 are quite likely to emerge if NGA is widely deployed; and Scenario 4 is an extreme scenario which is less likely to emerge but illustrates the impact of a major shift in content distribution.

5.2 Quantification of demand scenarios

This section provides a summary of the methodology we have employed to derive forecasts for traffic demand under the four scenarios, and presents a selection of key results. It should be noted that our analysis here is in effect limited to three scenarios, as the differences between Scenarios 2 and 3 are related to the industry structure, and do not affect the consumption per household. The differences between Scenarios 2 and 3 are included in the technical and economic analysis, which is discussed in detail in Section 6.1.

The key issues identified above form the basis of the different assumptions behind each scenario, with other assumptions remaining constant across all scenarios. The assumptions that change from one scenario to another include, for example, the take-up of HD services and the growth in non-linear viewing. Further details of the parameters and their values are provided in Annex B.1.

An important input to our technical and economic analysis is the composition of traffic in the busy hour. This is significant because the congestion issues arising from different traffic types can be mitigated to varying degrees by technical solutions. As the market for video content evolves, the differentiation between types of application will become less distinct. However, we have attempted to classify video content into four categories, with an additional category for other types of traffic on broadband networks. The five categories (which are analysed in more detail in Section 6) are as follows.

- **Broadcast video traffic**: defined as video content for linear viewing which is broadcast via IP networks.
- **Pre-meditated video traffic**: content for on-demand viewing which the user has decided to download or record in advance of viewing. This traffic can be pushed to the user, or recorded on a personal video recorder (PVR) from a broadcast source significantly before the time of consumption.
- **Spontaneous video traffic**: content for on-demand viewing which is not pre-mediated. This must therefore be streamed to the consumer as it is watched. Examples of this include iPlayer and YouTube.
- **DVD downloads**: video downloads or streams that replace the act of buying or renting a DVD.
- **Other Web traffic**: includes all non-video traffic categories, such as P2P, Web, email or VoIP traffic.

In order to quantify the bandwidth requirement on the network, we first calculate the total consumption first in terms of both minutes of viewing per day and then as gigabytes of traffic per month. Following on from this, we estimate the proportion of this traffic that is consumed in the busy hour, which allows us to quantify the peak load on the network in terms of **busy hour bandwidth (kilobits per second) per household**.

We have assumed that the total broadband traffic per household in the UK at the end of 2008 will be **5.2GB per month**. This estimate is based upon publicly available data: for example, Plusnet[31] indicates that average Internet usage was about 6.75GB per month per household in January 2008, while Carphone Warehouse[32] reported usage of around 2.5 to 3GB per month per household for the period from December 2007 to March 2008. Our estimate is close to the average of these numbers, taking into account further growth that can be expected in the period up to the end of 2008.

From this starting point, we project that over the next ten years the total traffic per household will increase significantly under all demand scenarios. As shown in Figure 5.2 below, for Scenario 1 traffic per household will reach **63GB per month** by 2018 (equivalent to a CAGR of 28%), while for Scenarios 2 and 3 it will increase to approximately **140GB per month** (CAGR of about 39%).

31 See http://community.plus.net/blog/2008/02/08/iplayer-usage-effect-a-bandwidth-explosion

32 See http://library.corporate-ir.net/library/12/123/123964/items/287985/Analyst_Day_150408_Pres.pdf

Under Scenario 4, the most aggressive demand scenario, traffic per household will rise to **260GB per month** (CAGR of 48%).

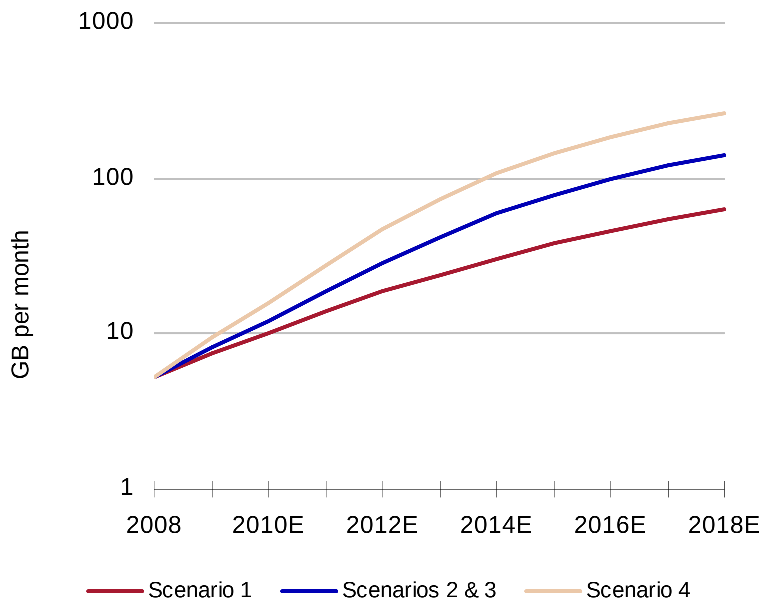

Figure 5.2: Total monthly broadband traffic per household in the UK [Source: Analysys Mason]

Based on these figures for total traffic per household, we then calculated the busy-hour bandwidth requirement per household. In 2008, we expect this to be about **24kbit/s per household**, of which about **20% originates from video services**. This is in line with reported industry benchmarks (though it should be noted that figures vary between service providers): for example, Carphone Warehouse has reported a busy-hour requirement of about 22kbit/s for March 2008.

Over the next ten years, the bandwidth required will increase significantly. As shown in Figure 5.3 below, in Scenario 1 the average bandwidth requirement per household rises to over **300kbit/s** by 2018, while in Scenarios 2 and 3 it grows to about **950kbit/s**, and about **2000kbit/s** for Scenario 4. Our results clearly indicate that even in the most cautious scenario, bandwidth requirements will increase dramatically, with average annual growth rates ranging from **29%** in Scenario 1 to **56%** in Scenario 4.

For comparison, we understand from our own discussions with industry contacts that in 2001 ISPs typically provisioned 5–6kbit/s per user for busy-hour bandwidth. By 2008 this rose to 24kbit/s, representing an average CAGR of 23%. It seems reasonable to expect a higher rate of growth in the future, given the increasing availability and user awareness of video services.

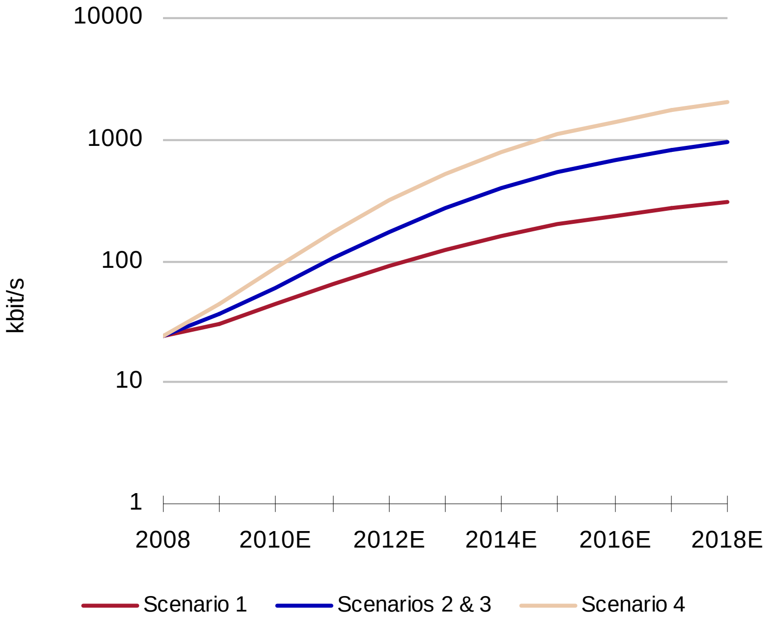

Figure 5.3: Average busy-hour bandwidth required per household in the UK [Source: Analysys Mason model]

In 2008, video traffic only accounts for about 20% of the total bandwidth required, but as shown in Figure 5.4 below, video services will become the main source of broadband traffic in the future, with 55–90% of traffic arising from video services. Even in Scenario 1, which has the most cautious traffic assumptions, over 50% of bandwidth is required for video services by 2018. The role of other Web traffic is less significant, especially in the more aggressive scenarios, being below 20% in Scenarios 2 and 3 and even less in Scenario 4.

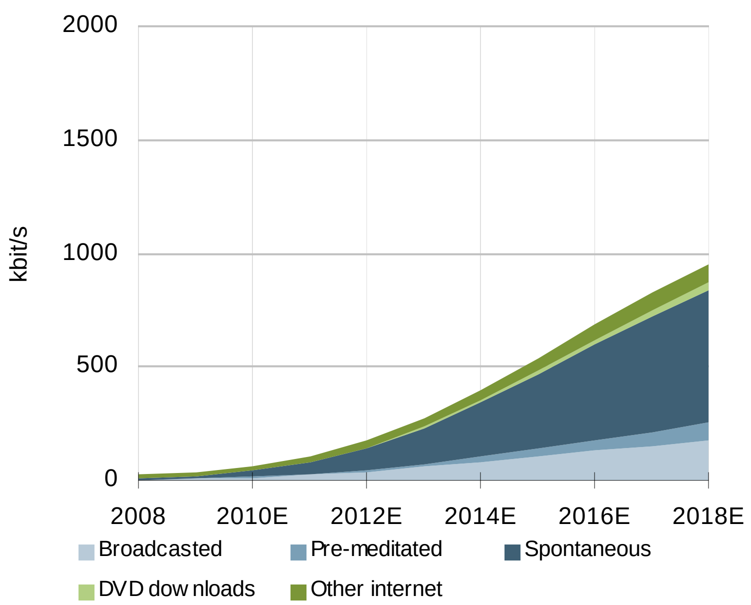

Figure 5.4: Composition of busy-hour bandwidth for Scenarios 2 and 3 [Source: Analysys Mason]

Figure 5.4 shows how busy-hour bandwidth is split out between the different types of traffic. Within the overall category of video services, spontaneous video will be the main growth driver, due to a shift towards non-linear TV and the rapid take-up of online video services. However, we also expect broadcast video to play an important role in the future, being the second-largest category overall. Growth of broadcast video will primarily be driven by higher penetration and an increased take-up of HD services.

Full details of our traffic forecasts can be found in Annex B.2.

6 Technical and economic analysis

We have conducted a technical and economic analysis based on the four demand scenarios described in the previous section. We have also examined the impact of a number of different technical solutions that may be deployed to minimise the impact of traffic growth. Our analysis has been conducted in five stages:

- **Market definition**: specification of the economic environment in which our analysis takes place, including the size of the different operators in the market and the spread of various technologies.
- **Network costs under the base case**: quantification of the costs to service providers of supporting each demand scenario without the deployment of additional technical solutions.
- **Potential technical solutions**: a description of the different technical solutions available, the costs of deploying them, and our assumptions regarding their effectiveness in reducing the costs for service providers due to increased network traffic network.
- **Impact of technical solutions**: analysis of the impact on traffic and network costs of deploying different technical solutions.
- **Commercial impact of increased network traffic**: consideration of whether existing business models can support the predicted increase in costs for service providers.

6.1 Market definition

As part of the technical and economic analysis it is necessary to define the market shares of different operators, and the mixture of networks that they use. There are two main types of networks that are used by ADSL operators: bitstream and LLU.

At present, bitstream services are predominantly based on BT Wholesale's *IP Stream* product. This is used by BT Retail, LLU operators outside their LLU coverage, and smaller service providers. However, over the next few years BT plans to migrate bitstream services to its new fibre-based WBC product. As *IP Stream* will be discontinued in the medium term, we have focused our analysis on WBC.

In considering the different ways in which the UK broadband market may develop, we have previously defined **market fragmentation** as an important differentiator between the demand scenarios. Essentially, there are two possible routes of development. In Scenarios 1 and 2, the market becomes more **concentrated**, with fewer, larger service providers competing for customers. This trend has already been observed with the consolidation in the market that followed the move by many service providers to use LLU in urban areas. In Scenarios 3 and 4, the market becomes more **fragmented** over time, with the entry of a growing number of alternative operators. We assume that these smaller operators will rely on bitstream services such as WBC, as they do not have the scale required for LLU to be an attractive option from a cost perspective. This leads to a reduced market share for larger alternative operators and an increase in the number of small operators in the market. We have not included wireless and satellite technologies in our analysis.

To determine the relevant market shares of the various players, we have assigned the existing operators to four types:

- the retail incumbent (BT Retail)
- large alternative operators (relying on a mix of LLU and bitstream services)
- small alternative operators (relying only on bitstream services)
- cable operators.

Figure 6.1 shows the total market shares for each of the types of operator in 2018 for the two different market developments (concentrated versus fragmented market). We have assumed that operators within a particular segment are of similar size.

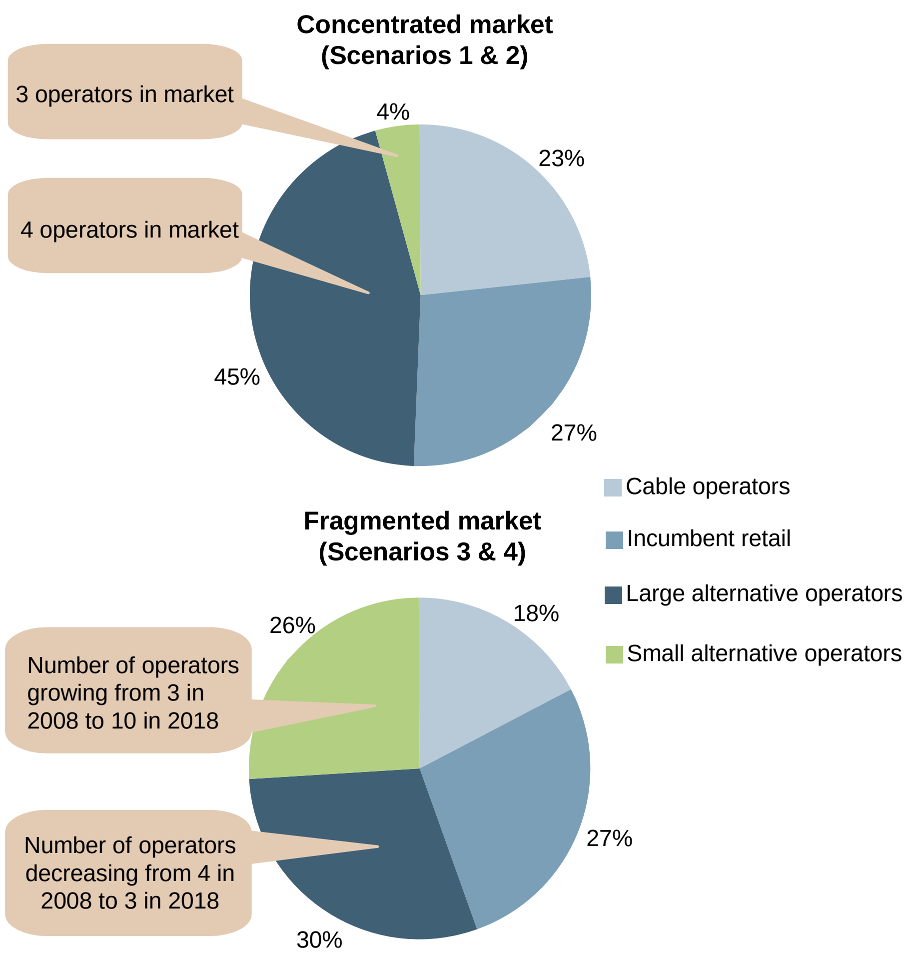

Figure 6.1: Market shares in 2018 by operator segment [Source: Analysys Mason, operator data]

The geographic coverage of each type of network varies, which leads to different regional market shares. We have estimated the market shares of different types of operators in areas covered by LLU, and areas not covered by LLU. Figure 6.2 shows the retail market shares for BT Retail, a operator using LLU and bitstream, a purely LLU operator, and a purely bitstream operator in the LLU and non-LLU areas in 2018 for the concentrated and fragmented scenarios.

It can be seen that in the fragmented scenarios the market shares of LLU operators decline as more customers are provisioned over bitstream.

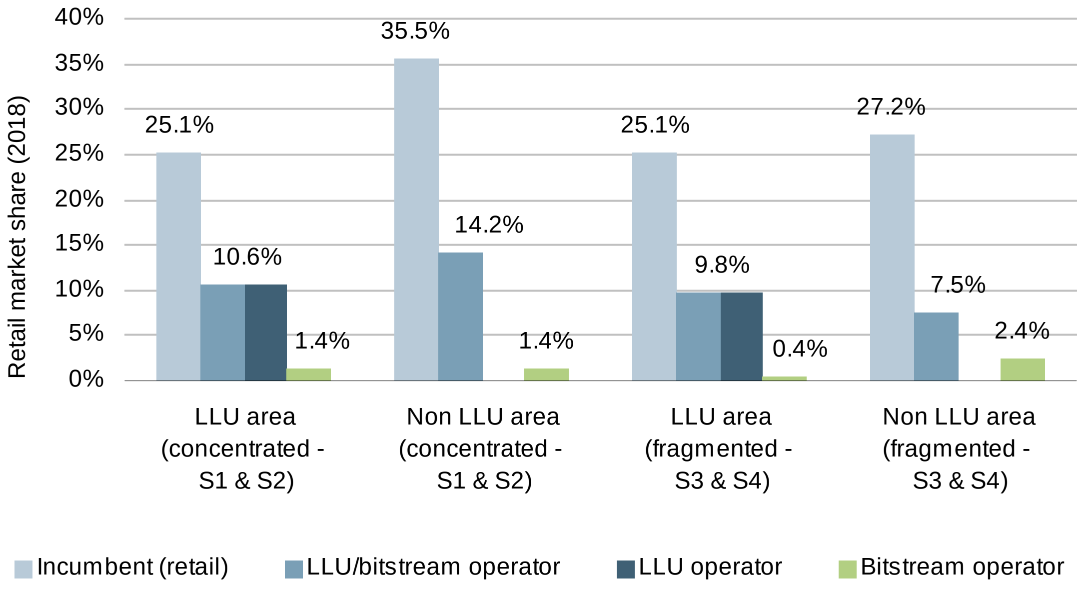

Figure 6.2: Market shares in 2018 by operator type [Source: Analysys Mason][33]

6.2 Network costs under the base case

As discussed previously in Section 4, we believe that the bottleneck in supplying video services with a high level of QoS is primarily in the networks of end users' service providers. Generally speaking there are two methods that service providers can use to ensure that services such as video or voice are delivered with a high level of QoS: either (a) deploy additional bandwidth, or (b) reserve bandwidth specifically for those applications. The choice between these two is essentially driven by the relative costs of bandwidth and servers respectively. Most core and backhaul networks are based upon optical fibre, so deploying incremental bandwidth is a relatively low-cost option as it is possible to exploit economies of scale. In addition, purchasing additional bandwidth is a simpler option for network operators than prioritising specific types of traffic, and it also

33 The market shares do not add up to 100%, since we assume that there are a number of equally-sized alternative operators in the market.

avoids having to provide a lower-quality service for other applications during busy periods. In our analysis the majority of bandwidth is required by real-time video services. There is therefore limited scope for prioritising this traffic over other types of traffic. Our discussions with stakeholders did not raise any major concerns about the ability to deploy QoS within broadband networks if it was to be required (as illustrated by the deployment of traffic shaping, which is a form of QoS, by many service providers). Our analysis therefore focuses on deploying additional bandwidth in the core and backhaul networks to ensure a high level of QoS.

We do not focus on the international networks in detail as we believe that CDNs will be able to scale to cope with additional traffic demands at a reasonable price for content owners.

We have quantified the costs of supporting each of the four demand scenarios for the different types of service provider that use networks based on a combination of LLU and bitstream services from BT Wholesale. Our approach to quantifying these network costs is outlined below.

In our analysis we have not considered Virgin Media because of its vertically integrated status. Virgin Media should have similar economies of scale to those described for LLU operators.

6.2.1 LLU-based service providers

Figure 6.3 illustrates the reference network design of an alternative operator offering broadband services using LLU. Our analysis focuses on backhaul and core costs which arise from an increase in network traffic. In the following, we will use the term **total cost** to refer to these specific costs. As explained earlier, we have not included an evaluation of the access loop. This is a major cost component for an LLU operator, but because its pricing is bandwidth-independent it is not relevant to our analysis.

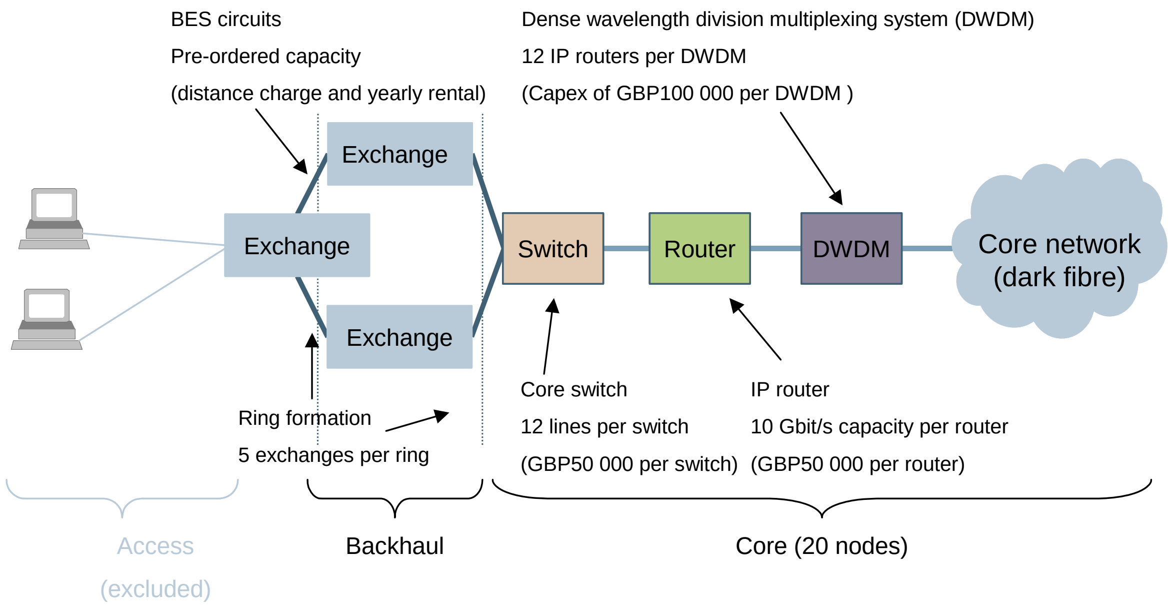

Figure 6.3: LLU architecture for an alternative operator [Source: Analysys Mason]

As NGA technologies such as VDSL and fibre-to-the-home (FTTH) get deployed, the future of LLU is subject to some uncertainty, as some implementations of these technologies may not enable alternative operators to obtain access to a 'local loop' at the exchange. However, we believe that (in the UK at least) it is likely that alternative operators will be able to gain access at the exchange, as shown by the recent work carried out by Ofcom on defining an Ethernet Active Line Access (ALA) product. This wholesale product would allow alternative operators to access new NGA technologies at the local exchange, and then use their existing backhaul networks. The nature of these products is still uncertain, though we believe that they are unlikely to have a significant negative impact on the economics of delivering video over broadband networks.

We have assumed that core networks are pieced together using dark fibre which can be upgraded to provide almost limitless capacity using Dense Wavelength Division Multiplexing (DWDM). This means that the core network costs are relatively fixed. Examples of operators that use dark fibre include Carphone Warehouse and Tiscali, which have both purchased long-term leases from Geo. We have assumed that each LLU operator deploys 20 core nodes.

Figure 6.4 below shows the relative proportion of traffic-related costs represented by backhaul and core capex and opex for an LLU operator.

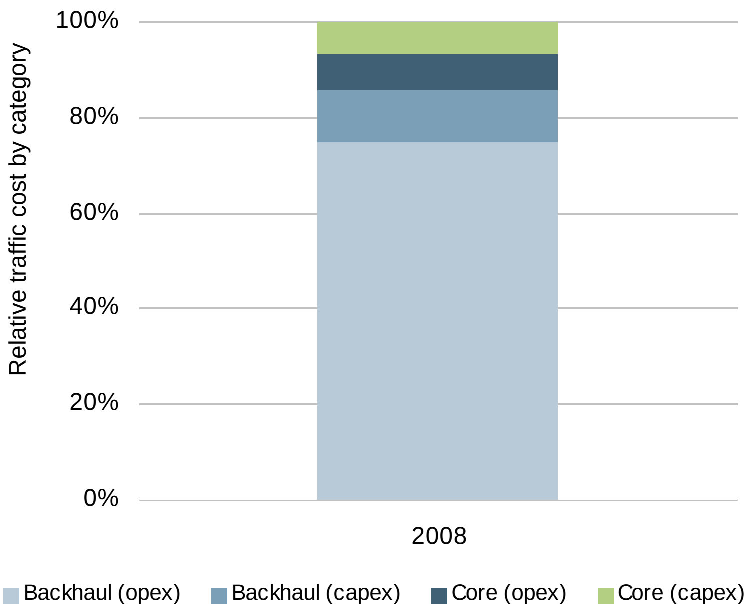

Figure 6.4: Relative traffic cost by category for an LLU operator [Source: Analysys Mason, based partially on Openreach data]

The key cost driver for an LLU-based service provider are the backhaul opex (i.e. the cost to connect from the local exchange to the core network). We have assumed that these backhaul connections are provided using the Backhaul Extension Service (BES) from Openreach[34]. The

34 Some service providers also use alternative suppliers of backhaul, but we have assumed that all operators only use Openreach, as this is likely to represent an upper limit for backhaul costs. Pricing of BES services is available at: http://www.openreach.co.uk/orpg/pricing/wes/downloads/ORPL_WBB_BES.htm

BES product is available in a number of different bandwidths[35], but we have restricted our analysis to the typical Ethernet products (100Mbit/s, 1Gbit/s and 10Gbit/s). Based on our experience, we understand that at the moment operators typically use circuits with a capacity of either 100Mbit/s or 1Gbit/s.

The pricing structure of recurring costs for BES includes two components: a charge per metre that does not vary with bandwidth, and a charge per link that does vary with bandwidth. The recurring costs of BES circuits at the three bandwidths considered are shown in Figure 6.5 below for a range of circuit lengths.

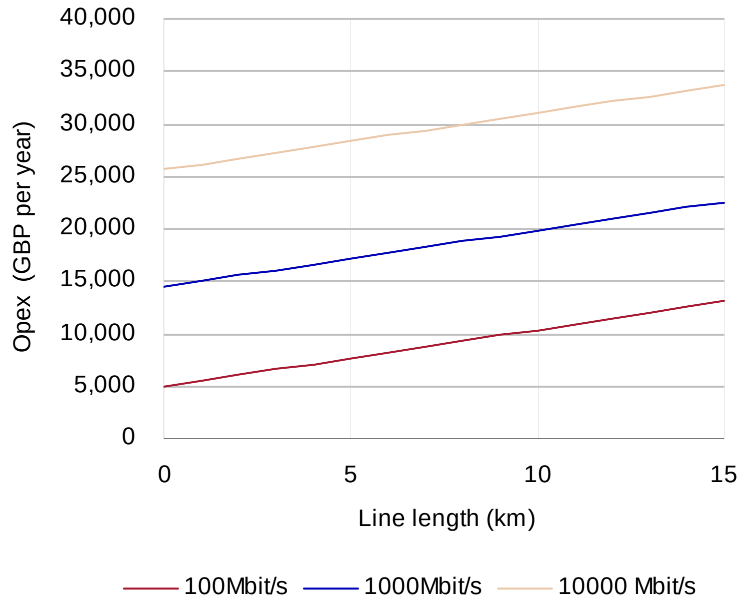

Figure 6.5: Yearly cost per BES line with different bandwidths [Source: Openreach, Analysys Mason]

In our analysis we have **assumed that BES prices do not change over time**.

We estimate that within the areas covered by an LLU operator that is serving 80% of all UK households, the average length of a BES circuit is approximately 5.60km.[36] At this distance, the costs of the three different bandwidths available are roughly in the ratio of 2:4:7 , whereas the bandwidths available are in the ratio of 1:10:100. The costs of providing backhaul capacity are therefore subject to large economies of scale that help to limit the increase in costs as the amount of bandwidth required increases in our four scenarios.

Figures 6.6 and 6.7 below show, for each of the four scenarios, the recurring costs of a backhaul network covering 80% of all households via LLU, with a market share of 11% per exchange.

[35] Openreach offers six different leased-line bandwidths: 100Mbit/s, 155Mbit/s, 622Mbit/s, 1Gbit/s, 2.5Gbit/s and 10Gbit/s.

[36] We have assumed that coverage is prioritised by the largest exchanges, though in reality proximity to other (large) exchanges also affects which exchanges would be covered by a LLU network

Figure 6.6 displays the total backhaul opex for an LLU-only operator, while Figure 6.7 displays the total backhaul opex per line per month.

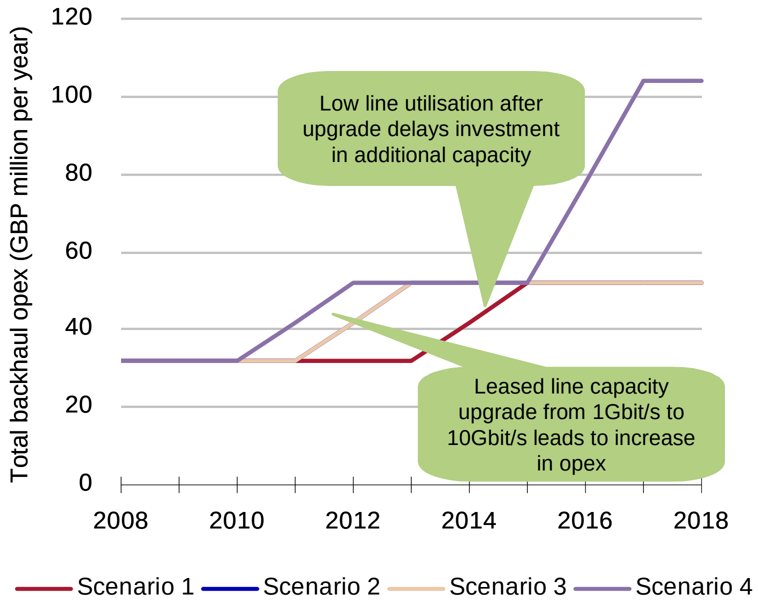

Figure 6.6: Total backhaul opex for an LLU operator [Source: Analysys Mason]

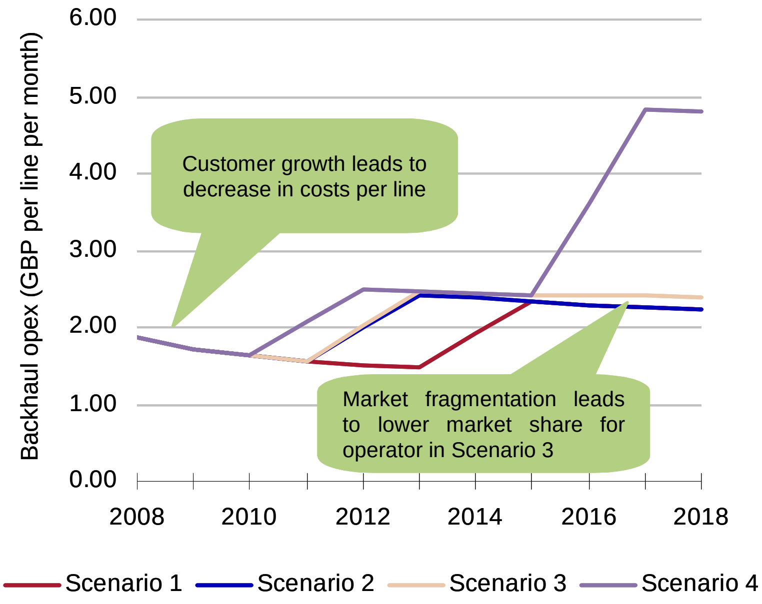

Figure 6.7: LLU backhaul opex per line per month for an LLU operator [Source: Analysys Mason]

This analysis shows that the cost development is fairly stable for the first three scenarios and that total backhaul opex for an LLU operator rises from about GBP30 million in 2018 to about GBP50 million in 2018. In the last two years of Scenario 4, the costs increase significantly to over GBP100 million a year as the operator then requires multiple 10Gbit/s backhaul circuits for each exchange. Such a large increase in costs may lead to financial pressure for operators. The potential solutions for limiting this impact on costs are discussed in Section 6.3 below.

Figure 6.6 also shows that the main difference between the scenarios is that the costs for capacity upgrades occur at different points in time. This indicates that Scenarios 1 to 3 may require upgrades similar to Scenario 4 shortly after 2018, and so the technical solutions may play an important role in future, regardless of the scenario that unfolds.

Figure 6.7 illustrates the monthly cost per line, to show the distribution of opex over the customer base in the different scenarios. From a starting point of about GBP1.90 per line per month, costs initially fall due to a growing customer base (higher line utilisation) but then increase to reach about GBP2.20 to GBP2.40 per line per month in 2018 for Scenarios 1 to 3. In the final two years, the costs per subscriber increase to about GBP4.80 per line per month for Scenario 4. An increase in costs of this magnitude is not likely to be sustainable at the current level of retail prices. This again highlights the need to look at technical solutions to reduce network traffic.

The two figures discussed above only included backhaul opex, while Figure 6.8 below also includes core network costs. The trends are fairly similar, with the cost increasing on average by about GBP0.50 per line per month, except for the final two years of Scenario 4. This leaves our conclusions from the previous section unchanged; price increases in the first three scenarios appear potentially manageable without the use of additional technical solutions, while the implications of Scenario 4 may be more challenging.

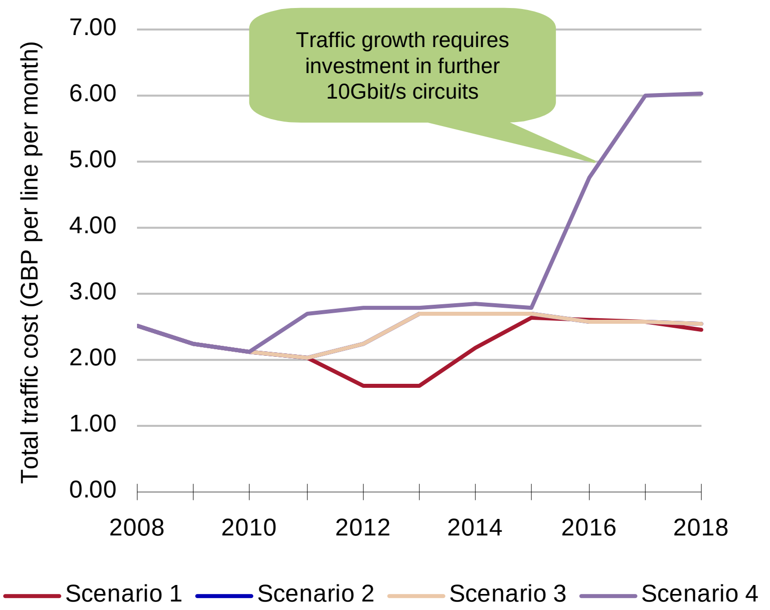

Figure 6.8: Total traffic cost per line per month for an LLU operator [Source: Analysys Mason]

Figure 6.9 shows that the cost of bandwidth falls significantly over the period modelled. The main reason for this trend is the economies of scale from higher-capacity circuits, combined with improved line utilisation. The analysis assumes constant absolute pricing for BES.

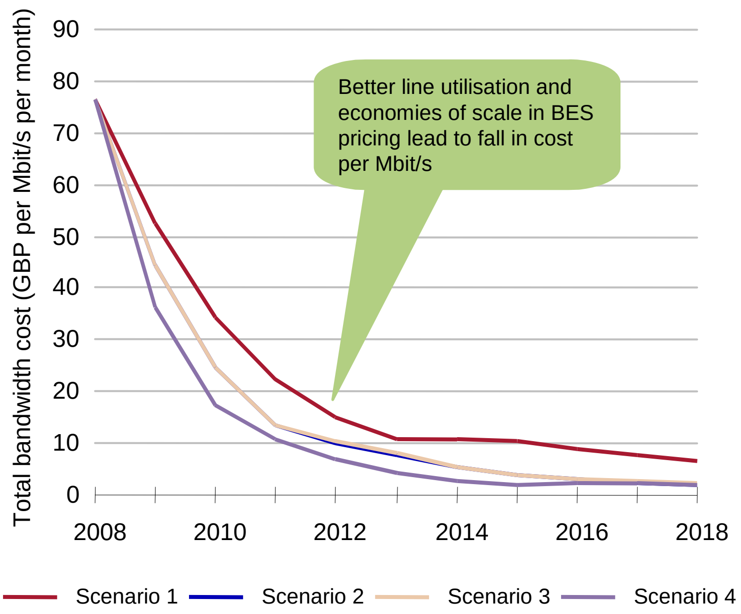

Figure 6.9: Total monthly bandwidth cost per Mbit/s for an LLU operator [Source: Analysys Mason]

Summary: LLU-based operators can exploit economies of scale in the backhaul network that will allow traffic to grow significantly, with a minimal impact upon costs. Only under the most aggressive scenario do costs per line per month increase significantly above current levels.

6.2.2 Bitstream-based service providers

Some operators have chosen to rely on wholesale bitstream offers. BT Wholesale is currently in a transition period, moving from its legacy bitstream product IP Stream to its new 21CN-based WBC product, with a nationwide transition planned to be completed by the end of 2012. Estimates of the progress of this transition are shown in the table below. This means that operators will be moving from IP Stream to WBC over the next few years, and so we have focused our analysis on the cost of WBC.

2008	*2009*	*2010*	*2011*	*2012*	*2013*
5%	55%	85%	92%	98%	100%

Figure 6.10: Expected progress of BT Wholesale's roll-out of WBC (percentage of lines covered) [Source: www.samknows.com, Analysys Mason estimate]

Figure 6.11 illustrates schematically the WBC product structure and indicates the different cost components. We have based this scheme on the current WBC reference offer.[37]

[37] Available at http://www.btwholesale.com/pages/static/Products/Internet/Wholesale_Broadband_Connect_wBBC/Prices_1.html

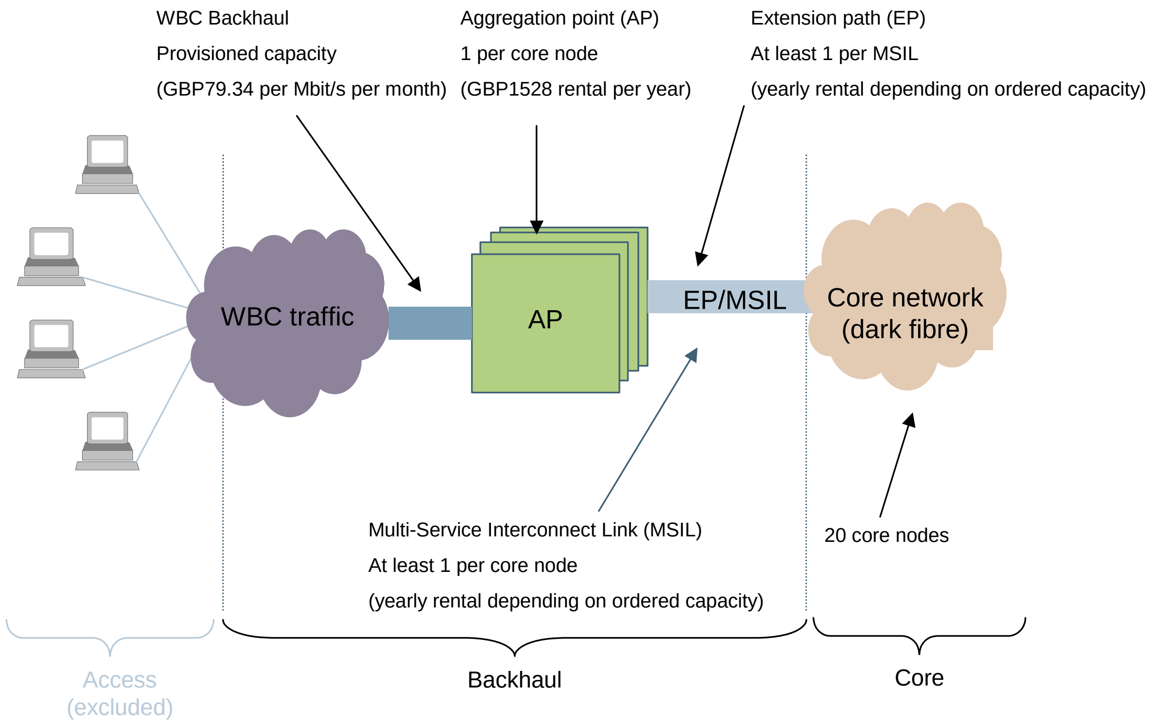

Figure 6.11: Schematic illustration of WBC setup and cost components [Source: BT Wholesale]

Similarly to LLU, the charge per end-user for access accounts for significantly more than 50% of the total monthly cost per line. This is bandwidth-independent and therefore excluded from our analysis. The most relevant costing element for the purposes of our analysis is the 'contracted bandwidth charge', which accounts for more than 90% of the remaining costs for bitstream services.

When using WBC, the bandwidth component is currently priced at GBP79.34 per Mbit/s per month, which is very similar to the cost encountered by an LLU operator in its first year, as shown in Figure 6.9 above. However, it is markedly lower than the cost of IP Stream, which has a resulting price of more than GBP100 per Mbit/s per month[38]. It is important to note that bitstream pricing does not offer any economies of scale with increasing bandwidth for these major cost components. Figure 6.12 indicates the development of the monthly cost per line per month for bitstream-based service providers under an assumption that prices for WBC do not change in the future. It is evident that bitstream services would not be economically viable under such conditions.

38 The annual rental of a 155Mbit/s BT central circuit is GBP196 200, which equates to a monthly cost per Mbit/s of GBP105.50. Higher-bandwidth options do not offer the same level of economies of scale as available with Openreach's BES pricing.

Summary: If bitstream products retain a pricing model where costs grow linearly with traffic, and there is no significant decline in price per Mbit/s, the costs of providing enough bandwidth to support the forecast growth in online video services will be prohibitive and will limit the growth of these new services on bitstream networks.

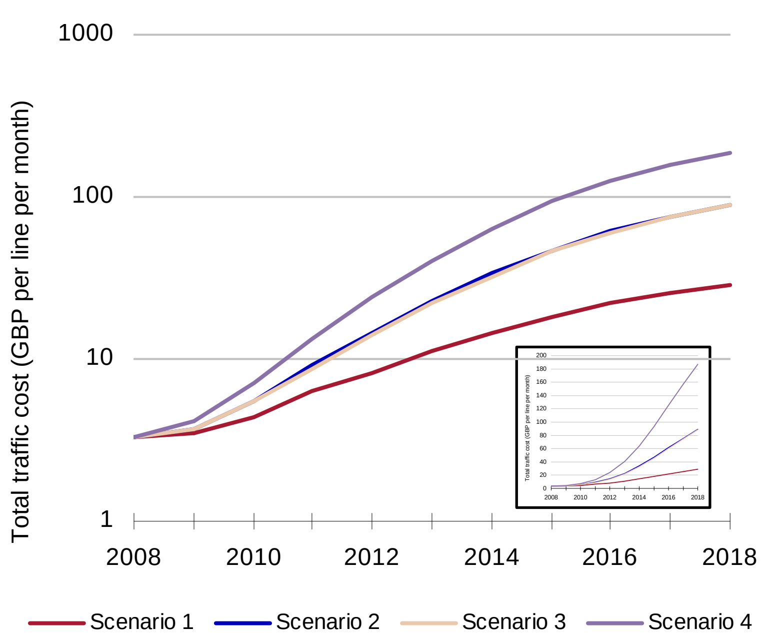

Figure 6.12: Total monthly traffic cost per line for a bitstream operator at current WBC bandwidth pricing (logarithmic scale, with linear scale on the inset) [Source Analysys Mason]

We next look at traffic costs under the assumption that bitstream bandwidth pricing will decline with time. As WBC is based on the same fibre-based inputs as LLU, we believe that over time there will be economies of scale for BT Wholesale that will allow it to reduce its prices. We have modelled the costs of BT Wholesale as if it were an LLU operator using Openreach's BES product (as discussed for LLU operators in Section 6.2.1 above). This results in a decline of bandwidth costs for BT Wholesale similar to those shown for LLU operators in Figure 6.9 on page 44. We then assume that WBC prices will follow a broadly similar trend. Figure 6.13 illustrates our methodology for projecting the prices of WBC. It should be noted that this exercise is carried out primarily to illustrate the effect of a different pricing regime rather than to 'second guess' BT's future pricing strategy.

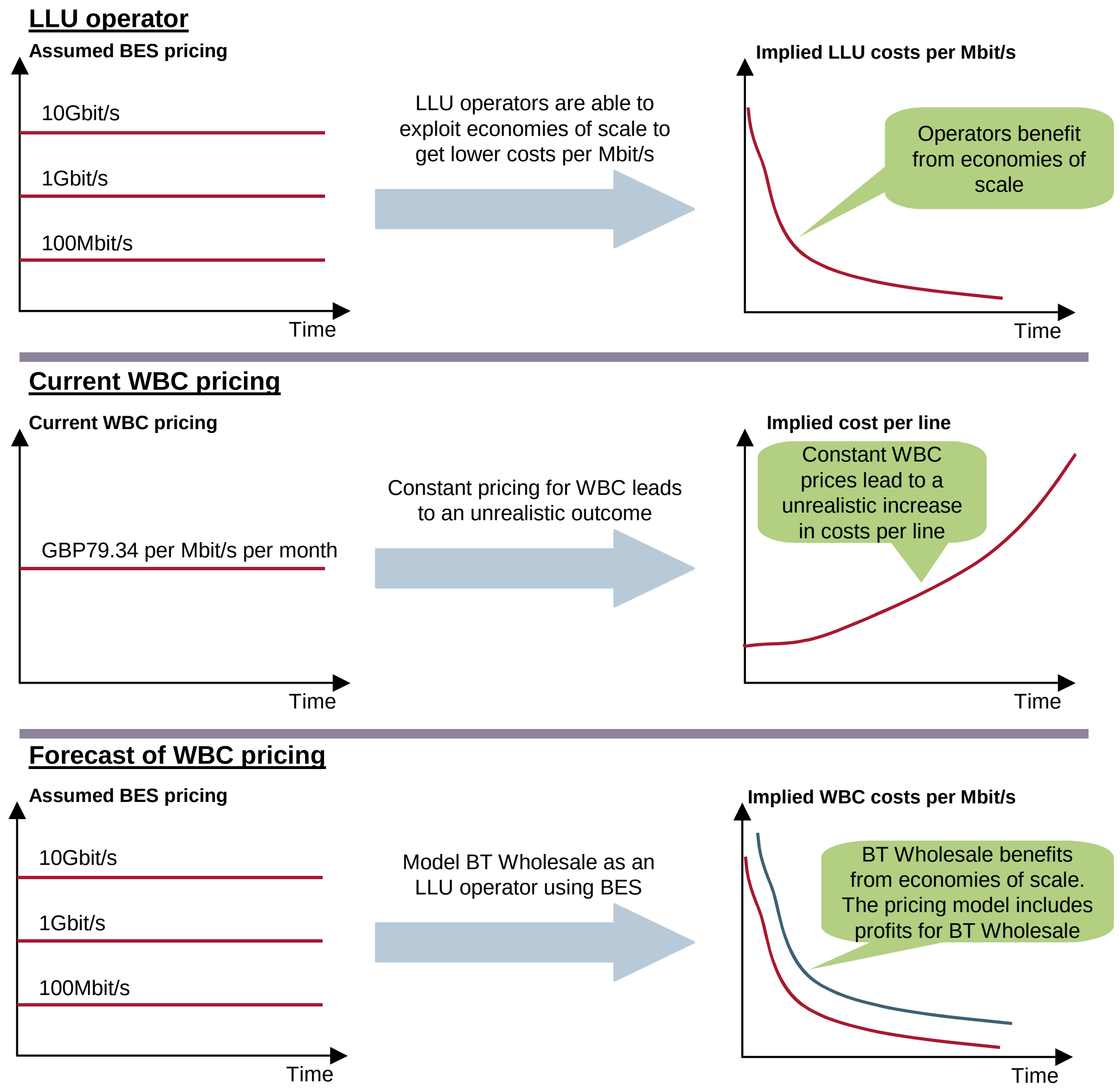

Figure 6.13: Methodology for forecasting WBC bandwidth prices [Source: Analysys Mason]

In this analysis it is also important to note that the unit costs per Mbit/s for BT Wholesale providing bitstream services are dependent on the level of demand, and any pricing projection is unique to a particular scenario. Our analysis is based upon a national average, though the differences in costs by exchange may lead to an element of geographic pricing in the future that we have not attempted to include.

Figure 6.14 shows the monthly cost per line for BT Wholesale, for each of the four scenarios, based upon our assumptions regarding the price decline for the bandwidth component in WBC. It is worth noting that the monthly costs per line in Scenario 3 are lower than for Scenario 2, despite the same monthly traffic per line. This is because BT Wholesale has a higher overall market share in Scenario 3, which leads to a higher utilisation of the backhaul network and hence lower costs (about GBP0.50 per line per month by 2018).

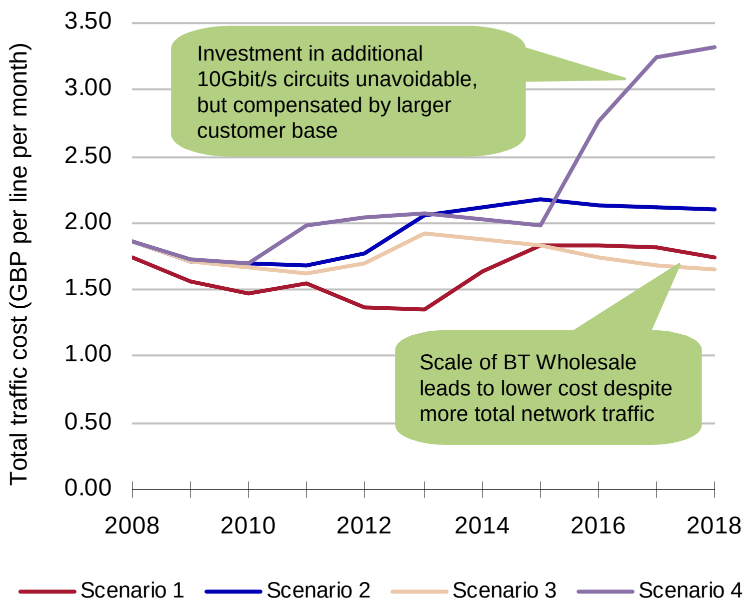

Figure 6.14: Total monthly traffic cost per line for BT Wholesale [Source: Analysys Mason]

Figure 6.15 below shows the market shares of BT Wholesale in the different areas under each of the scenarios. We have assumed geographically averaged prices for bitstream, though we have calculated that there are significant differences in the underlying costs for rural and urban areas – bandwidth costs in rural areas are up to four times as much per Mbit/s as those in urban areas.

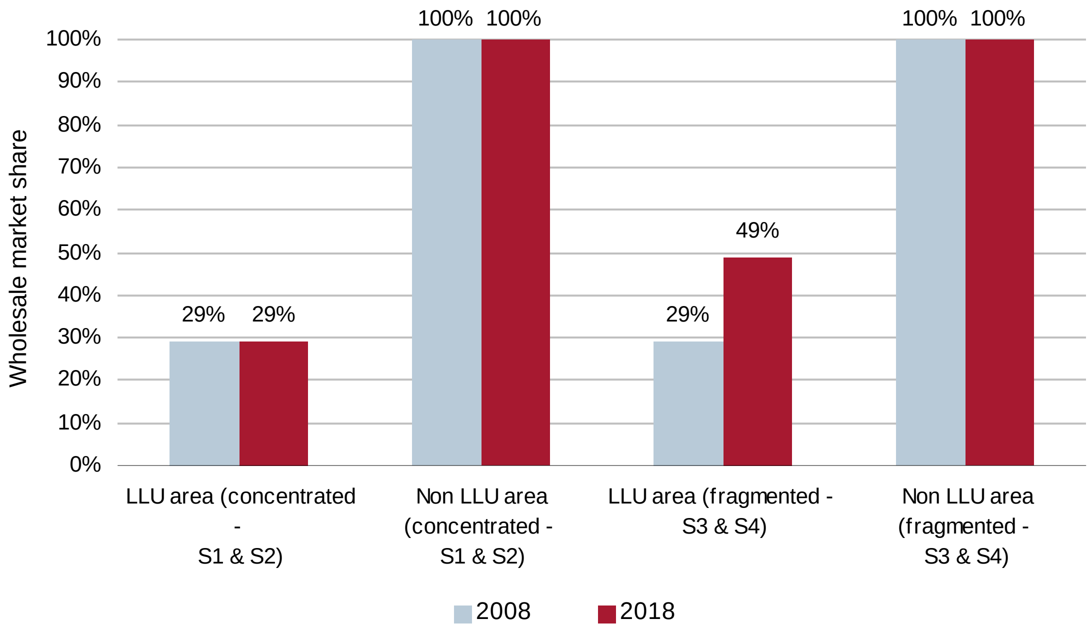

Figure 6.15: Market share of BT Wholesale in concentrated and fragmented market, and in LLU and non-LLU areas [Source: Analysys Mason]

The total backhaul costs of the network are then used to calculate the bandwidth prices charged by BT Wholesale. We have assumed that BT Wholesale will make a 30% margin on these costs. We have also adjusted the cost reductions to reflect the fact that operators are in a transition period towards WBC. As a result, the price per Mbit/s declines more slowly than the real cost per Mbit/s for BT Wholesale (particularly until the full migration to WBC in 2012).

Figure 6.16 below shows our forecast of the bitstream bandwidth charge for the period modelled. Comparing the results to Figure 6.9 on page 44, it can be seen in the first years the cost per Mbit/s per month declines more slowly than for an LLU operation, due to the product migration. After this, the bandwidth charge follows a similar general trend.

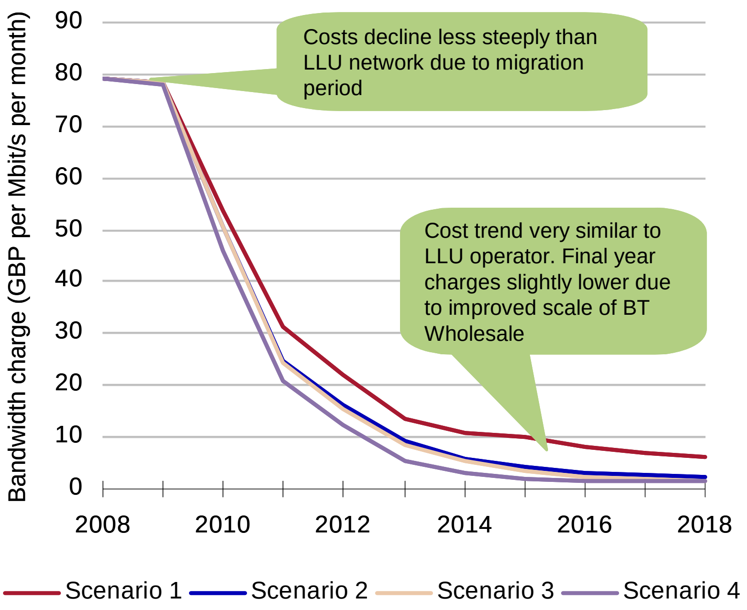

Figure 6.16: Monthly bandwidth charge per Mbit/s by BT Wholesale for bitstream operators [Source: BT Wholesale (for 2008 charge only), Analysys Mason (post-2008)]

Based on this methodology, our forecasts for the monthly costs per line for a service provider using bitstream are shown in Figure 6.17 below, for each of the four scenarios.

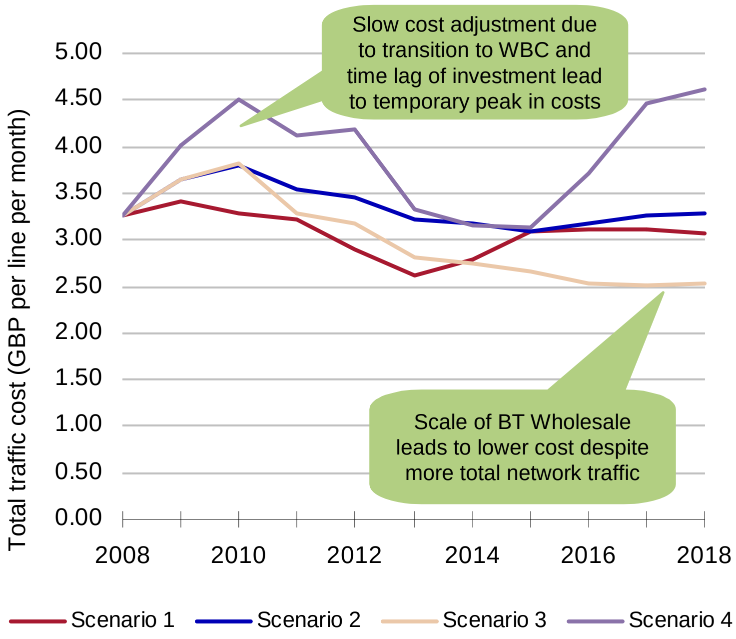

Figure 6.17: Total monthly cost per line for a bitstream operator [Source: Analysys Mason]

Starting from a cost of about GBP3.25 per line per month, costs initially rise in most scenarios, as bandwidth demand outpaces the migration to the more cost-efficient WBC product. In **Scenario 1**, the cost per line per month falls quickly after 2011 as the economies of scale of larger circuits are exploited, and there is not need for additional upgrades until around 2013. In the final years, the increase in traffic per household leads to the monthly cost per line rising back to the initial levels. The costs for **Scenario 2** remain fairly stable over the period. In **Scenario 3**, we observe a cost decrease in the final three years due to the improved scale of BT Wholesale, and higher subscriber numbers for the bitstream operator due to market fragmentation. This leads to Scenario 3 ending up with a lower monthly cost per line than Scenario 1. In **Scenario 4**, costs rise significantly during the initial year until the rollout of 21CN is completed in 2012. The cost then fall as the lower cost base is exploited. In the later years the costs rise quickly as higher-capacity circuits are required to support the WBC-based network.

BT Wholesale also offers a managed service called **Wholesale Broadband Managed Connect (WBMC)**. This provides an even more comprehensive solution than WBC, and essentially removes the necessity for an alternative operator to run its own core network. We believe that WBMC is likely to be predominantly purchased by BT Retail, although it may also be an option for very small operators. We have not considered WBMC in detail, as we do not expect that this would yield significant insights beyond our analysis of WBC-based services.

6.2.3 Summary of base case results for each type of service provider

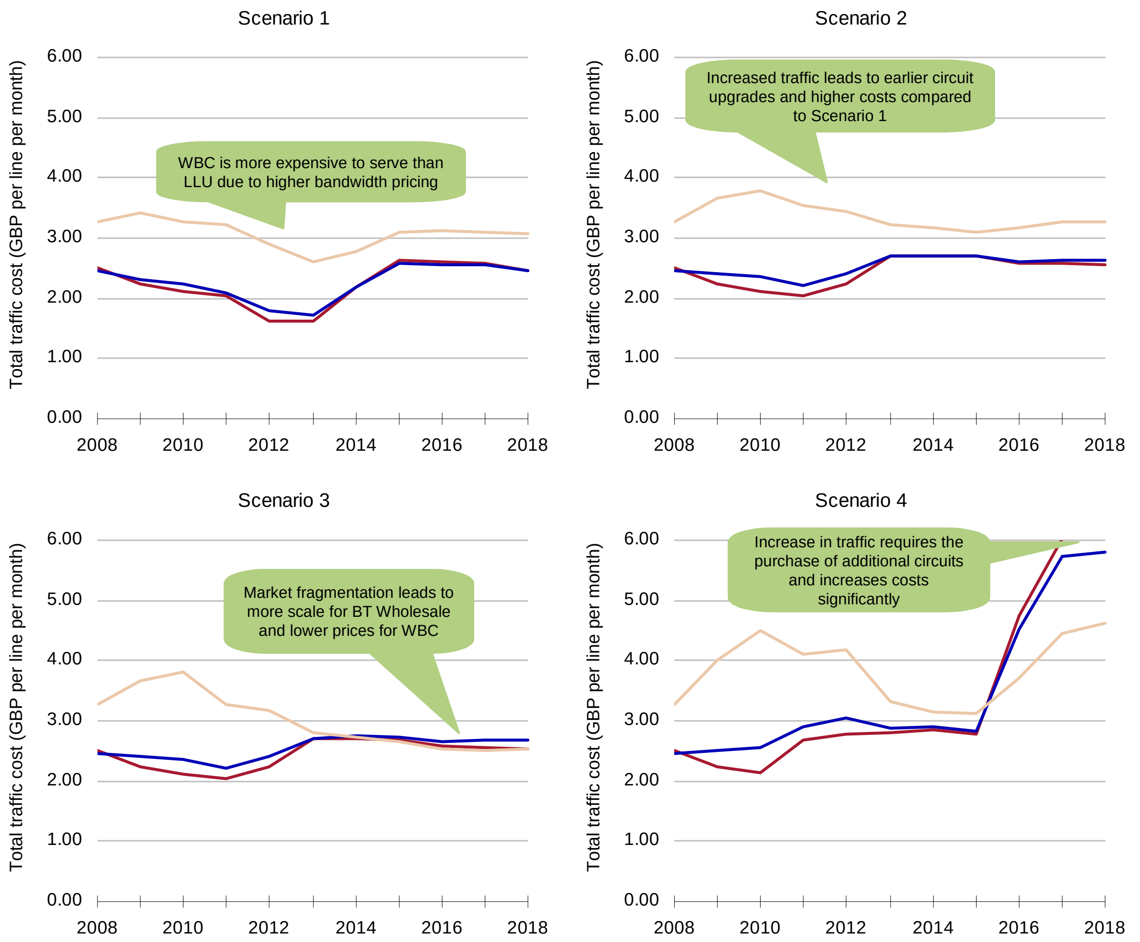

Figure 6.18: Overview of the total monthly cost per line for each technology choice and type of operator in Scenarios 1 to 4 [Source: Analysys Mason]

Figure 6.18 provides a summary of results for the total monthly costs per line in Scenarios 1 to 4 under the base case, in which no technical solutions are deployed. This allows us to draw a number of conclusions:

- **In most scenarios, the monthly cost per line does not increase significantly between 2008 and 2018**. For bitstream operators , we expect costs in the final year to remain very close to GBP3.25 per line per month in Scenarios 1 and 2. The cost development for LLU operators is very similar: despite a certain degree of price volatility over the period modelled, costs in 2018 are roughly at the same level as in 2008 for Scenarios 1 to 3.

- **For bitstream operators the monthly costs per line of fall in Scenario 3 compared to Scenario 2**. Bitstream operators benefit from a more fragmented market, which leads to better economies of scale for a bitstream network in Scenario 3, with monthly costs falling from about GBP3.25 per line in 2008 to GBP2.50 in 2018. These economies of scale arise also because there are more lines on the BT Wholesale network that in Scenario 2, leading to more favourable bandwidth pricing.

- **Scenario 4 shows two spikes in network costs**. For bitstream operators, because the amount of traffic per line increases faster than bitstream prices decline due to the transition towards the more cost-efficient WBC, costs temporarily rise to about GBP4.00 per line per month between 2010 and 2012. In the final two years, costs then rise again for both LLU and bitstream players, for LLU roughly doubling to about GBP6.00 per line per month, and for bitstream increasing to GBP4.50 per line per month. We expect that operators will employ technical solutions to reduce network traffic at this stage.

- **Bitstream services are more expensive than LLU in Scenarios 1 and 2**. For Scenario 1, there is a fairly constant difference of around GBP0.50 to GBP1.50 per line per month between bitstream and LLU services.

- **Bitstream services become cheaper than LLU in the later years of Scenarios 3 and 4.** As BT Wholesale would benefit from a more fragmented market, WBC charges fall significantly in Scenarios 3 and 4, making bitstream a cheaper option than LLU. This becomes especially apparent in the final year of Scenario 4, where monthly costs for bitstream are around GBP1.50 lower per line. In contrast, LLU is significantly cheaper than bitstream services in the early years.

6.3 Potential technical solutions to minimise cost increases due to traffic growth

Through our stakeholder consultations and research into the available technologies, we have identified four technical solutions that will help to minimise the cost increases due to traffic growth: traffic shaping, multicasting, content caching, and the use of DWDM in the backhaul network. These are discussed further below. Note that the cost assumptions detailed below are estimates from Analysys Mason.

6.3.1 Traffic shaping

Traffic shaping is a technical solution which limits the bandwidth available to specific applications. It is commonly used during busy periods to limit the capacity that is used by peer-to-peer networks. These types of traffic are targeted by traffic shaping as they are not time-critical and the traffic can be delayed to quieter times of day.

Traffic shaping is not suitable for all types of application supported by broadband networks. Applications such as video streaming and VoIP are **time-critical** (i.e. any delay in delivering the data will severely affect the user experience), whilst others such as file downloads are less time critical (i.e. a delay will make the user experience worse, but will not severely impact it). The level of acceptable delay varies greatly from one application to another, although is generally highest for applications that take a long time to complete. Real-time applications such as VoIP and video streaming cannot be traffic shaped without impacting the user experience.

Within our traffic forecasts the application that we believe is most suitable for traffic shaping is **peer-to-peer (P2P)** downloads. For Scenario 1, P2P traffic represents 51% of traffic in the busy hour in 2008. As P2P downloads typically take many hours to complete it is possible to slow down P2P traffic during the busy network hours, leaving the download to be completed during less busy periods. When modelling the impact of traffic shaping, we have assumed that an aggressive traffic shaping policy during network busy hours could reduce P2P traffic by **95%**.

To deploy traffic shaping, a service provider needs to install new equipment in its network. We have assumed that a service provider needs to install traffic shaping servers in the core node at a capital cost of GBP50 000 each.

Such technical solutions are already employed by many service providers, although the details of the solutions deployed can vary widely across service providers. In the UK, Carphone Warehouse has publicly announced its co-operation with Sandvine,[39] which provides hardware and software for traffic shaping.

6.3.2 Multicasting

Multicasting allows the same stream of data to be delivered in a broadcast manner to many users at the same time. The most commonly cited potential for multicasting is for the delivery of linear (broadcast) TV over broadband networks. However, in the context of UK broadband networks, multicasting is only an efficient delivery mechanism if many people on the same exchange simultaneously watch the same content. Due to the average size of exchanges and the fragmentation of the TV market, this means that the scope for deploying multicasting is likely to be limited to only a handful of major TV channels.

Most modern IP network equipment is capable of supporting multicast traffic, although there may be a need for CPE upgrades. We estimate that deploying servers to support a multicast solution would give rise to an incremental cost per core node of GBP50 000. We assume that the cost will remain constant over the period modelled, with new equipment being deployed at regular intervals to keep up with growth in demand. Current CPE may not be able to support multicast solutions, although as the penetration of video-capable CPE is still low we have not included any costs for the replacement of existing CPE.

When multicasting is deployed we have assumed that operators are streaming 20 channels. The efficiency of multicasting varies across the scenarios; in the concentrated content scenarios (**Scenarios 1 and 2**) multicasting is able to reduce traffic from broadcast TV streams by about **70%**, though additional capacity must be provisioned for the channels being multicast. In the

[39] Source: http://www.sandvine.com/news/pr_detail.asp?ID=134

fragmented content scenarios (**Scenarios 3 and 4**) we have changed the reduction in traffic to **60%** to reflect the reduction in the efficiency of multicasting caused by the more fragmented nature of the content. We have assumed that the bandwidth required per channel increases over time as HD penetration rises.

6.3.3 Content caching

In all the scenarios, spontaneous streaming of video (traffic from services such as *iPlayer*) grows to become the largest traffic category. The content typically consists of the most popular films, or TV programmes that have been broadcast within a recent time window (e.g. the last seven days). By deploying content caches within the network it is possible to store the video files closer to the end user so that the data does not have to be sent across the whole network each time it is viewed. As most of the traffic-related costs in the network of a service provider derive from the backhaul, caching of content at the local exchange could make a significant reduction in the traffic on the backhaul network.

However, the current network architecture of most broadband networks will make it difficult to locate caching servers at the local exchange, due to the position of the broadband remote access server (BRAS), which is generally located in the core network.[40] We have examined the technical challenges involved in the deployment of content caching at the local exchange, and conclude that in order to make this possible, the BRAS will need to be moved to the exchange. Further details of our technical analysis are provided in Annex D.

Moving the BRAS to the exchange is assumed to cost an incremental GBP5 per line. In addition, a content server will be required at each exchange, at a capital cost of around GBP10 000. This server will need to be replaced every four years. Once content caching is active we have assumed that in the concentrated scenarios about **40% of spontaneous video traffic can be removed** from the backhaul network.[41] We have used our own estimates of the efficiency of caching for the different types of spontaneous traffic. The size of a cache required, and the proportion of content that could be reasonably cached has been estimated based on high-level research on the 'long tail' of each traffic category (e.g. DVD downloads, *iPlayer* rankings, *YouTube* statistics).[42]

40 The BRAS sits in the core network, and aggregates user sessions from the access network. It is at the BRAS that a service provider can inject policy management and IP QoS.

41 The efficiency of exchange-level caching will again vary between the concentrated and fragmented scenarios.

42 For example, the 'top 20 account for nearly 75% of all iPlayer downloads; see http://www.guardian.co.uk/media/2008/may/20/bbc.digitalmedia?gusrc=rss&feed=media

6.3.4 Higher-capacity backhaul using DWDM

Current backhaul solutions typically use a single fibre per backhaul circuit, whereas core connections more often use dense wavelength division multiplexing (DWDM) technology that allows multiple connections to be provisioned over a single fibre. However, DWDM equipment is relatively expensive (partly due to the low volumes of equipment required by the industry), and so it is not cost-effective to deploy it closer to the end user. Over time, however, it may become cost-efficient to deploy DWDM in the backhaul network, dramatically increasing the amount of capacity available for a relatively low incremental cost. However, it should be noted that the deployment of DWDM would require widespread access to dark fibre. For this reason – and the high equipment costs associated with DWDM – our modelling of the technical solutions does not include DWDM. Nevertheless, DWDM could have an important role to play in the longer term.

6.4 Impact of technical solutions

Our earlier analysis demonstrated that for most of the scenarios, the monthly cost per line does not rise significantly as traffic increases. However, for the most aggressive demand scenario (Scenario 4) there is a considerable increase in costs in the final years. This section provides our quantitative analysis of the impact of the technical solutions that may be deployed to reduce traffic. From our own technical analysis, borne out by our consultations with stakeholders, we believe that **traffic shaping, multicasting and content caching** are the solutions that operators are most likely to consider.

We here mainly focus on the **cost savings for an LLU operator**. Details of the potential cost savings for BT Wholesale, a bitstream operator and a hybrid LLU/bitstream operator are provided in Annex E.

6.4.1 Impact of technical solutions on traffic levels

Each technical solution focuses on a particular traffic type. Figure 6.19 shows the mix of traffic categories over the modelled period for Scenarios 2 and 3. The trend is similar for all the scenarios, with the role of the TV-related categories increasing in the higher-demand scenarios, as highlighted in Section 4. It is important to note that overall traffic in the network increases dramatically over the period modelled, so the total traffic, in kbit/s, per category is much higher in 2018 than in 2008.

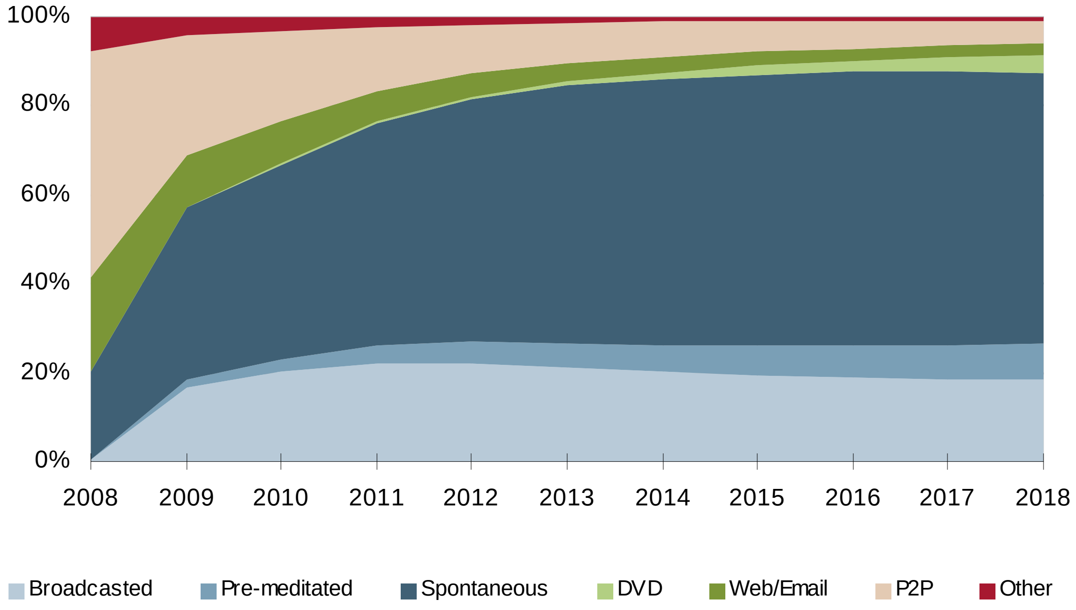

Figure 6.19: Mix of traffic categories in Scenarios 2 and 3 [Source: Analysys Mason, Cisco]

As Figure 6.19 shows, for all four scenarios the major categories of traffic will be peer-to-peer (P2P), broadcast video and spontaneous video traffic. Our three proposed technical solutions directly tackle these categories: traffic shaping for P2P, multicasting for broadcast traffic, and exchange caching for spontaneous video traffic. Figure 6.20 gives a first insight into the scale of the traffic reductions that may be achieved, and the points in time at which it is likely to be cost-effective to deploy each of the solutions.

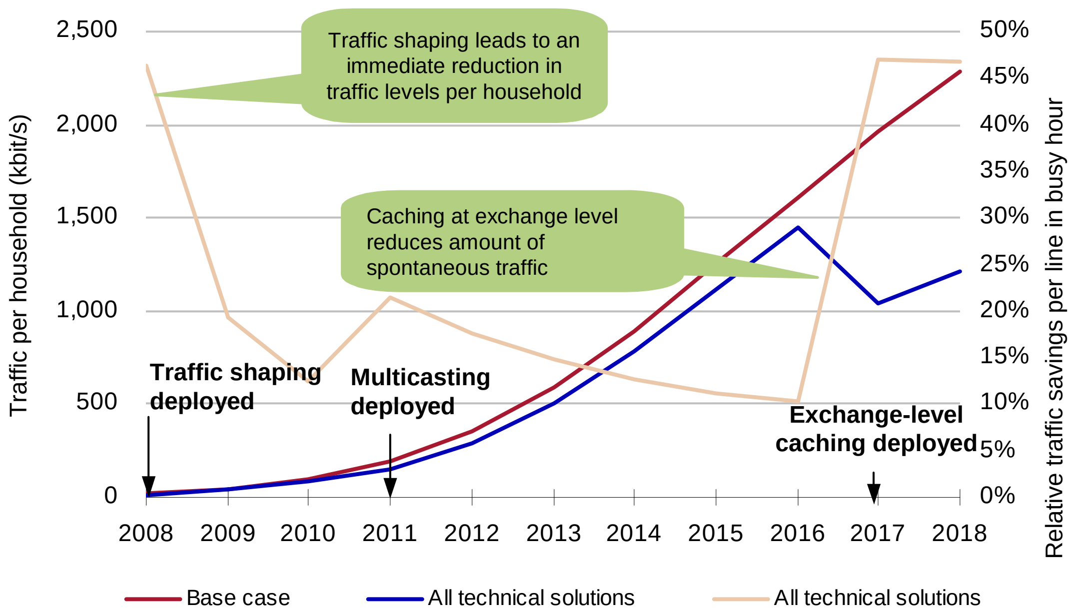

Figure 6.20: *Possible reduction in traffic for a hybrid LLU/bitstream operator employing all technical solutions in Scenario 4 [Source: Analysys Mason]*

Three main conclusions can be drawn from Figure 6.20:

- Sizeable traffic reductions can be achieved in the first years by shaping P2P traffic. This solution is in fact already deployed by some service providers
- Exchange-level caching can significantly reduce traffic in the final two years. However, the high deployment costs mean that it will not be commercially viable to deploy this solution until the later years of the period studied.
- As each technical solution targets a different traffic category, the optimal deployment time for each one will vary.

The following section examines the business case for these solutions in more detail, and considers whether the potential savings to be made by reducing traffic levels justify the necessary investment in the technical solutions.

6.4.2 Impact of technical solutions on network costs

Each solution requires an investment, which must be assessed against the cost savings that can be achieved due to the resulting traffic reductions. We have assessed the business case for each solution to determine the optimum time when each solution should be deployed, based upon our traffic forecasts for each scenario. This has been done on an incremental basis by comparing the net present value (NPV) of the costs for each technical solution with our base case in which no traffic limitation is used. This allows us measure the effectiveness of each solution in reducing total network costs. A schematic profile of this approach is given in Figure 6.21.

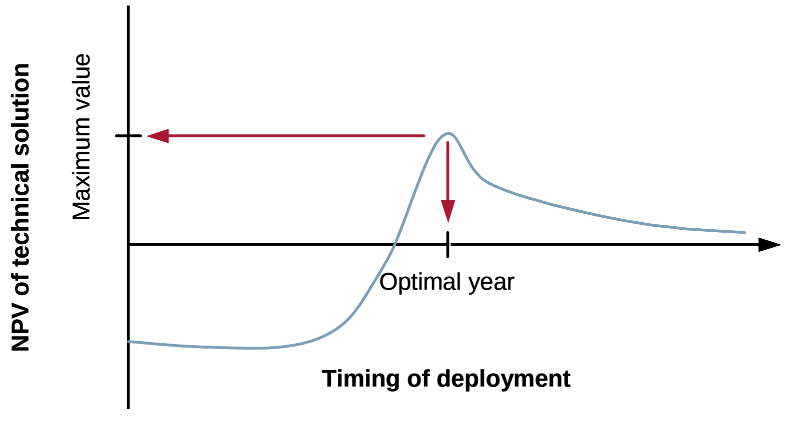

Figure 6.21: Approach used to determine optimal year to deploy a particular technical solution [Source: Analysys Mason]

The business case for a technical solution relies upon delaying the point at which it becomes necessary to upgrade from one speed of backhaul circuit to another as traffic grows. Figure 6.22 below shows the bandwidth requirement for a typical exchange in Scenario 1 for an LLU operator without any technical solutions deployed, and the total capacity purchased.

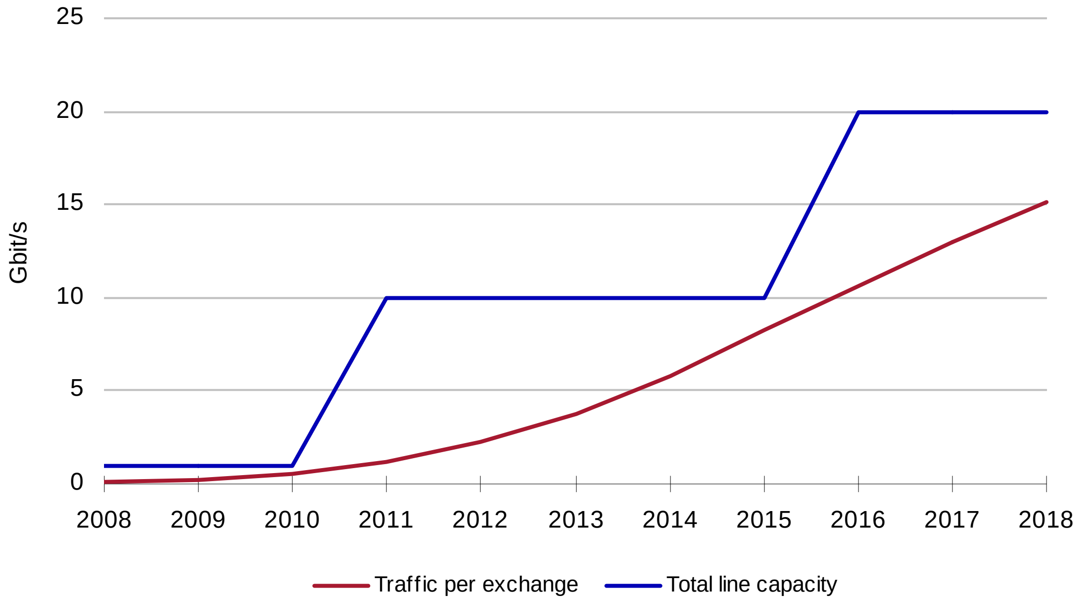

Figure 6.22: Traffic and capacity per exchange for an LLU operator in Scenario 1 [Source: Analysys Mason]

It can be seen that once an upgrade in circuit speed happens, it is typically several years until another upgrade is required, due to the large additional capacity provided by each upgrade. Because of this, it is only desirable to deploy a technical solution at the point where an upgrade would otherwise have been required. In the example above it would not be attractive to deploy a solution between 2011 and 2014.

Figure 6.23 lists our estimates for the optimal deployment years for a large alternative operator using LLU. (It should be noted that, due to the dynamics explained above, optimal deployment times can shift by a number of years with small changes to the assumptions.) The table shows that, while the effects of traffic shaping are immediate and occur across all scenarios, multicasting and exchange-level caching only become a economically viable in later periods. Exchange-based caching would become viable earlier if deployment costs were reduced significantly, or the levels of traffic increased significantly faster than in our scenarios.

	Scenario 1	*Scenario 2*	*Scenario 3*	*Scenario 4*
Traffic shaping	2008	2008	2008	2008
Multicasting	-	2014[43]	-	2012
Exchange-level caching	-	-	-	2016

Figure 6.23: Optimal deployment year of technical solutions for an LLU operator [Source: Analysys Mason]

For a **bitstream operator**, we have assumed that multicasting and exchange-level caching would be bought from BT Wholesale as add-ons to the standard product package. To calculate when these solutions would become available in this way, we have carried out the same analysis as above, but for BT Wholesale instead of an LLU operator. This shows that BT Wholesale would have a positive business case for deploying exchange-level caching at an earlier stage due to its larger scale. However, as BT Wholesale also serves smaller exchanges, it needs higher traffic volumes for multicasting to be attractive, and it would therefore deploy multicasting at a later stage.

To determine the cost for a bitstream operator to use these additional service options, we have assumed a simple pricing model based on the incremental costs per line for BT Wholesale to deploy multicasting and exchange-level caching.

Traffic shaping

The use of traffic shaping to reduce P2P traffic has the greatest impact in the early years of the period modelled, when P2P makes up the greatest proportion of total traffic. This is shown in Figure 6.24 below. It can be seen that in the first year, traffic shaping almost halves the monthly cost per line to about GBP1.30. While this is a significant improvement, it does little to mitigate the concerns regarding Scenario 4, as P2P is less significant in this scenario.

43 In Scenario 2, the operator is able to achieve marginal cost savings in the core network. Due to increased content fragmentation, this effect is not replicated in Scenario 3 and leads an operator to not deploying multicasting in this instance.

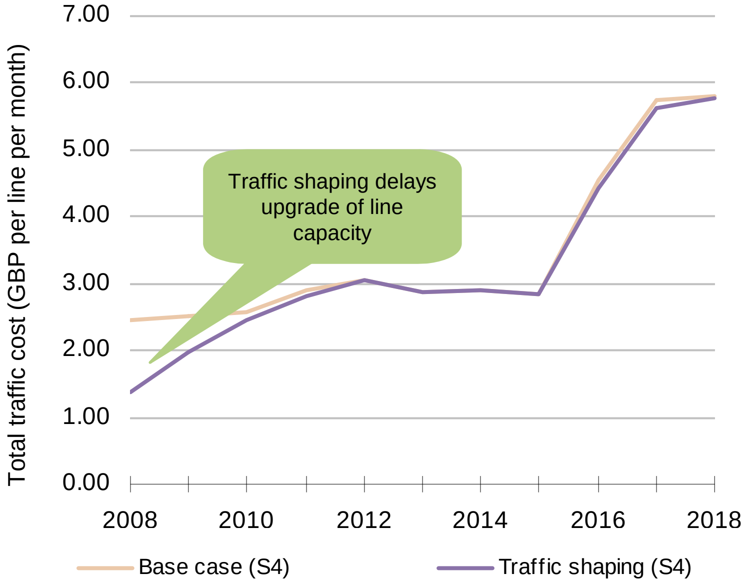

Figure 6.24: Total monthly cost per line for an LLU operator employing traffic shaping [Source: Analysys Mason]

Multicasting

As discussed in Section 6.3.2 above, multicasting is a technical solution designed to reduce the number of simultaneous broadcast streams to IPTV customers. We have assumed that 20 channels are broadcast via multicasting. We have calculated that the optimal time to deploy multicasting in Scenario 4 is 2012, but it would in have its greatest impact in 2015, where it delays the upgrade to multiple 10Gbit/s circuits, as shown in Figure 6.25 below. Over this period, it leads to significant savings relative to the base case (where no technical solutions are deployed). Again, this is due to the postponement of upgrades to backhaul and core network capacity. However, our sensitivity tests for Scenario 4 indicate that multicasting will be unable to significantly postpone the increase in costs in the final years.

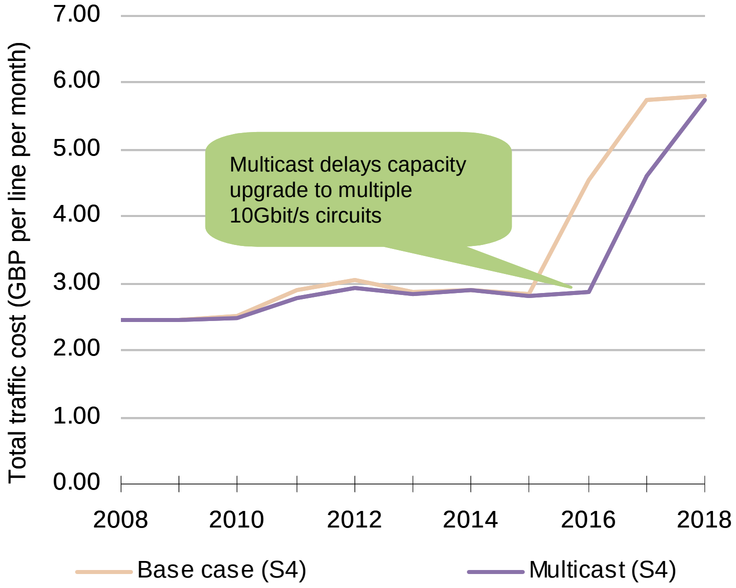

Figure 6.25: Total monthly cost per line for an LLU operator employing multicasting [Source: Analysys Mason]

Content caching

Exchange-level content caching is the most capital-intensive technical solution, but can also deliver the highest level of cost savings as it tackles spontaneous video traffic, the category which is primarily responsible for the increase in costs in the final two years of Scenario 4. Figure 6.26 below shows the considerable reduction in costs achieved by caching in Scenario 4. In contrast to the base case, where costs rise to nearly GBP6.00 per line per month by 2018, the total monthly costs rise to about GBP3.20 per line per month. We therefore expect operators to implement this technical solution if faced with a traffic increase of the level forecast for Scenario 4.

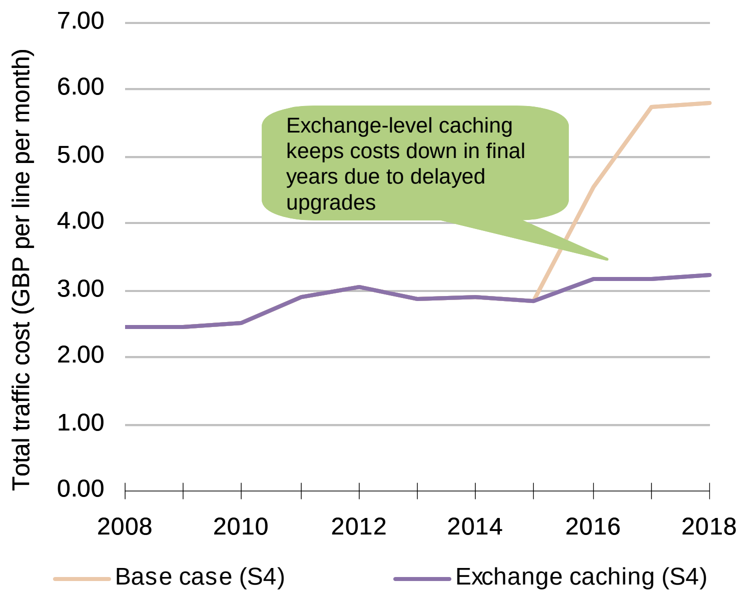

Figure 6.26: Total monthly cost per line for an LLU operator employing exchange-level caching [Source: Analysys Mason]

Under our basic assumptions on the cost of exchange-level caching, it would only be cost-efficient for alternative operators to use it from 2016 onwards. However, it is possible that new advances in caching technologies may significantly reduce deployment costs. Examples of companies innovating in this area include Edgeware[44] which launched a solution for content caching that has already been implemented by TeliaSonera during the 2008 Summer Olympics to support traffic from on-demand online streaming.[45]

To assess the impact of future innovation in this area we have also considered a sensitivity where the caching server costs are reduced to GBP1000. In this sensitivity we have also assumed that the additional capex to move the BRAS is not incurred (or is incurred via natural equipment replacement cycles). The results are shown in Figure 6.27 below. In this sensitivity the model predicts that it would be optimal for content caching to be deployed in 2011 under Scenario 4. This is due to the costs of deploying caching being low enough that it is desirable to deploy caching at the point where backhaul circuits would have to have been upgraded from 1Gbit/s to 10Gbit/s. In the base case, content caching is deployed to delay a migration from one 10Gbit/s circuit per exchange to multiple 10Gbit/s circuits per exchange.

It can be seen that the earlier deployment of caching in 2011 compared to 2016 leads to significantly lower costs per line per month from 2011 until 2013. The cost reduction arises because an earlier deployment of caching delays the purchase of additional backhaul circuits by two years. In the final years considered the cheaper caching solution has slightly lower costs due to the lower operating costs assumed.

---

44 http://www.edgeware.tv/

45 http://www.lightreading.com/document.asp?doc_id=163371

Similar modelling shows that under the same cost assumptions it becomes attractive to deploy caching in the other scenarios, which have lower demand. This occurs between 2012 and 2014.

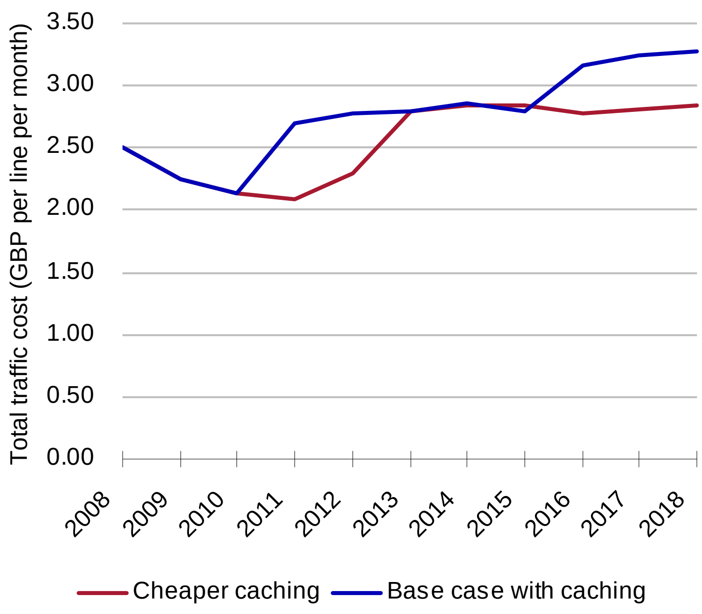

Figure 6.27: Impact of sensitivity with lower capital costs for content caching (Scenario 4) [Source: Analysys Mason]

It is also possible to cache content in the core network, though this would have no impact on the backhaul network (which, as seen earlier, is subject to the greatest increases in costs due to additional bandwidth requirements). Therefore, we have not quantified caching of content in the core network.

Deploying all three technical solutions

The technical solutions are each most effective at different stages of the period we have modelled. While traffic shaping tackles P2P issues in the early years, multicasting is most effective in intermediate periods around 2013, and exchange-level caching is at its best in the final two years. We have therefore run a final case to examine the total savings when deploying all technical solutions at their optimum times. The results for Scenario 4 are shown in Figure 6.28 below.

With all technical solutions, the monthly costs almost triple over the period modelled, from slightly over GBP1.30 per line in 2008 to around GBP3.20 per line in 2018. However, the increment from today’s estimated starting point for the base case (GBP2.40 per line per month) is only around GBP0.80 per line per month. It should be possible for operators to compensate for this, especially given that most of the increase in traffic is due to new applications that can potentially be turned into profit streams. Section 7 discusses this issue in more detail.

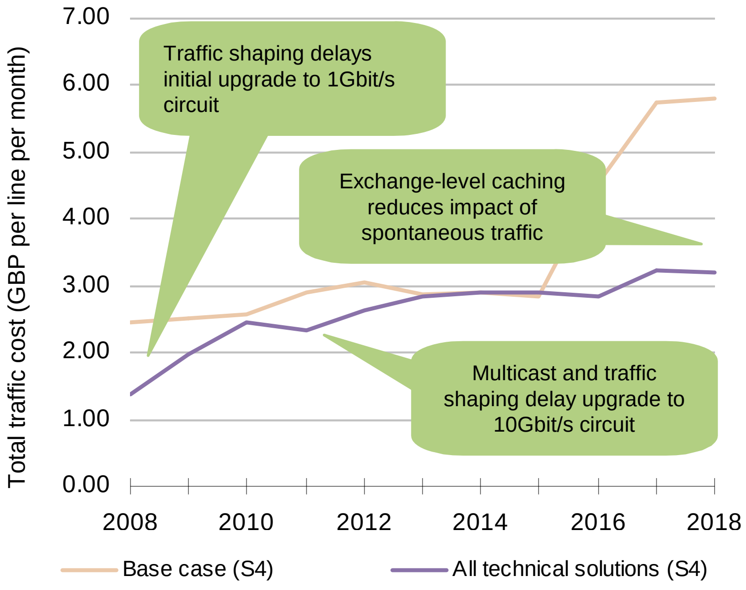

Figure 6.28: Total monthly cost per line for an LLU operator employing all technical solutions [Source: Analysys Mason]

6.5 Commercial impact of increased traffic

To assess the impact of increased network costs, it is useful to compare these with the costs currently experienced by service providers. It is important here to recognise the differences between actual operators: some have lower pricing, and typically attract lower-usage subscribers, while others have higher pricing and attract subscribers who generate more traffic. There is therefore a range in the costs experienced by service providers at present.

We believe that the costs modelled with and without traffic shaping deployed provide a reasonable lower and upper bound for the costs per subscriber per month experienced at present. We have therefore used these two estimates of costs in 2008 as the baseline for our analysis of how increased traffic may impact upon service providers. These baseline costs are shown alongside the forecast costs when deploying all technical solutions across all four scenarios in Figure 6.29 (for an LLU operator) and Figure 6.30 (for a bitstream operator).

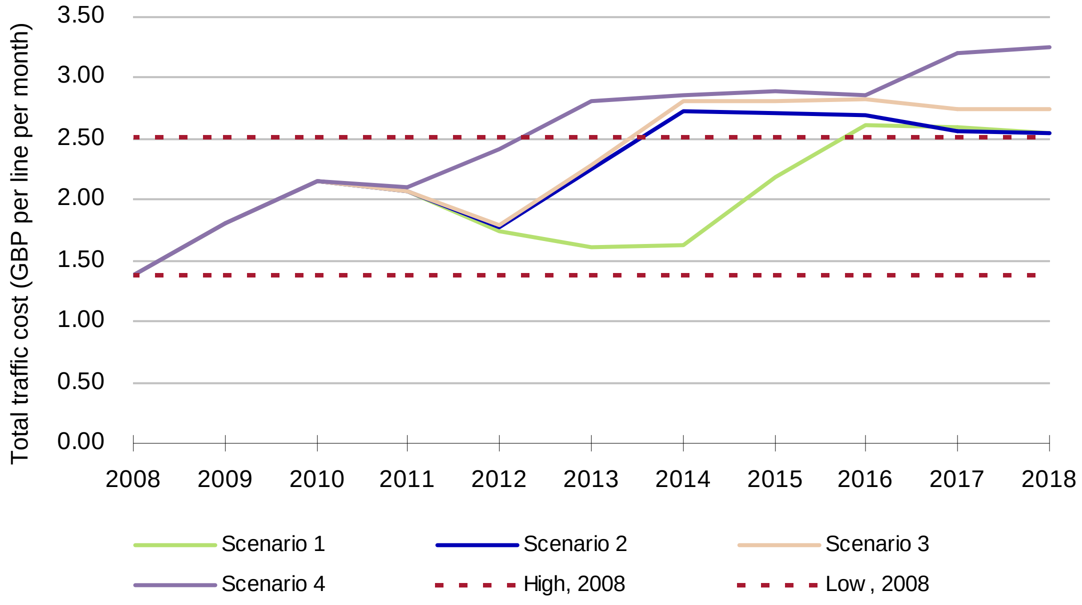

Figure 6.29: Overview of the total monthly cost per line when deploying all technical solutions in Scenarios 1 to 4 for an LLU-based service provider [Source: Analysys Mason]

For an LLU operator, in Scenarios 1 to 3 the cost per line per month rises to around GBP2.50 to GBP2.75, and in Scenario 4 increases to GBP3.25. This is significantly less than the peak of almost GBP6.00 per month in the case without any technical solutions deployed.

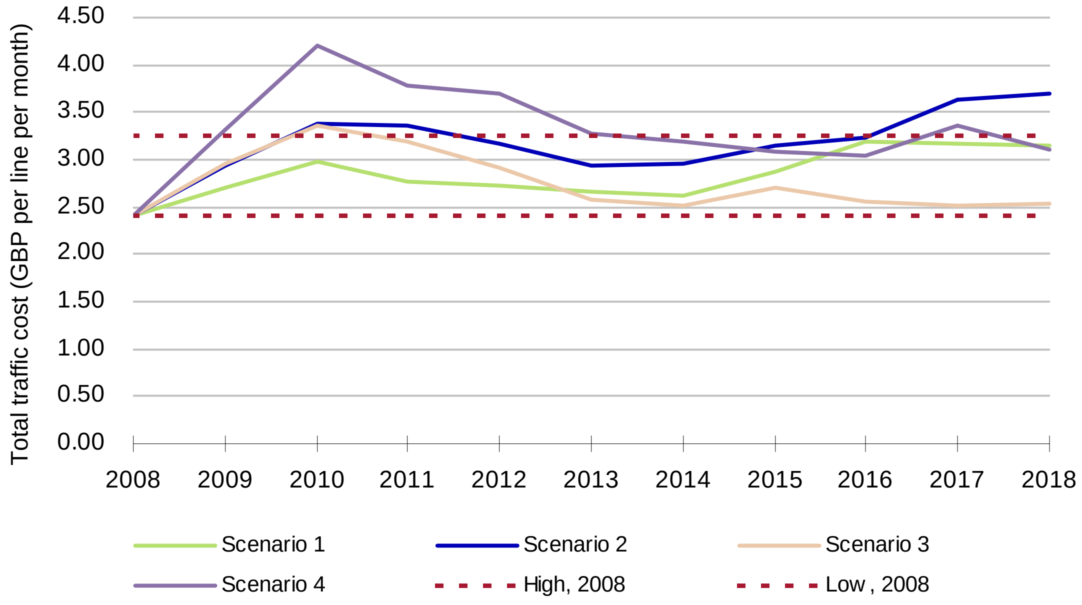

Figure 6.30: Overview of the total monthly cost per line when deploying all technical solutions for Scenarios 1 to 4 for a bitstream-based service provider [Source: Analysys Mason]

For a bitstream operator, the costs in Scenarios 1 and 2 rise to around GBP3.10 per month per line, slightly less than the higher estimate of costs in 2008. Again Scenario 4 has the highest costs, reaching around GBP3.70 per month per line in 2018. The relative increase when compared to other scenarios is less than for an LLU operator, due to the fragmented market leading to greater economies of scale over the bitstream network, which we have assumed will lead to lower prices. This effect is also seen in Scenario 3, which although having the same traffic as Scenario 2 is over GBP0.50 per month per line less expensive.

However, for bitstream operators the peak costs generally occur in 2010. This is due to the migration to 21CN still being incomplete, which does not allow such operators to fully exploit the economies of scale from fibre-based backhaul until after 2012.

In summary, there are two situations where we believe the increase in costs may be significantly above the current cost base (for an operator with higher backhaul costs).

The first situation occurs in Scenario 4, where the costs for an LLU operator rise above the baseline of GBP2.50 per line per month to reach around GBP3.25 per line per month in 2018. A similar effect is also seen for a bitstream operator in Scenario 2, but it is less pronounced. This increase in costs under Scenario 4 for LLU and Scenario 2 for bitstream is because the very high levels of online video consumption lead to the deployment of multiple 10Gbit/s backhaul circuits at each exchange, even when all of the technical solutions are used. Scenarios 3 and 4 for bitstream operators have similar total network costs, but due to the higher market share of bitstream operators in these scenarios the costs per line are less than in Scenario 2. However, if the prices of BES from Openreach were to fall, or higher-speed circuits were to become available, this would reduce the costs over time. We believe that it is reasonable to assume that either a decrease in prices or the availability of new products would be able to offset most, if not all, of this increase in costs. The sensitivity assuming lower costs for deploying content caching also leads to a reduction in costs in 2018 to around GBP2.80 per month per line, which is only slightly above the range for baseline costs in 2008.

The second situation occurs for a bitstream-based operator in Scenario 4 in the period from 2010 until the migration to WBC is complete. This is due to service providers having to purchase legacy bitstream products from BT Wholesale. These products do not offer the same economies of scale as WBC. It is under Scenario 4 that this increase above the baseline is most significant, with monthly costs being around GBP1.00 more per line than the high baseline in 2010. However, at this point in time there may be a demand constraint which means that the traffic is less than forecast. In Scenarios 2, 3 and 4 HD content is assumed to be around 10-20% of the total during 2010 to 2012. At this point the availability of high-speed access networks may be too limited to support widespread use of HD services. If the growth of HD content was to be more skewed towards later years the potential spike in costs that we have identified for bitstream operators in 2010 to 2012 may be much more limited.

The costs in all scenarios rise significantly above the baseline for an operator with lower usage (and hence lower costs). It may be possible to limit the impact of this by modest increases in

ARPU, or by attracting customers with lower usage profiles than the average. However, in the medium term it is likely that for online video to grow significantly, with all operators supporting this type of usage, the costs of backhaul networks will increase to levels above those currently experienced by the operators with the lowest cost base.

However, as mentioned earlier, in the longer term the prices of backhaul products from Openreach may fall, or higher-speed services may become available (through the deployment of DWDM). Even a modest reduction in prices each year from Openreach could bring the monthly costs per line significantly closer to our lower baseline (i.e. broadly in line with today's costs).

7 Evolving business models

As discussed in the previous section, the growth in broadband traffic, largely from video applications, could lead to increases in network costs for service providers, particularly if they do not deploy more advanced technical solutions. If technical solutions such as traffic shaping, multicasting and content caching are deployed, the increases in network costs can be largely limited. However, under some conditions there will still be an increase in costs that may need to be recovered via additional revenues.

In a highly competitive market such as the UK broadband market, many operators have low profit margins, which mean they find it challenging to absorb any cost increases. They are also under competitive pressure not to increase their prices. If operators are unable to increase prices, and their costs increase, they will have to seek new revenue streams from new business models. One example of this is the controversial trials of Phorm by BT Retail.[46] If this technology is deployed, it will allow BT Retail to generate additional advertising revenues. Other major service providers, such as Virgin Media and Carphone Warehouse, have also expressed an interest in Phorm.

In the context of online video services, is may also be possible for service providers to capture additional revenue from both advertising and subscription sources. During the stakeholder consultations, and our research into the case studies for new business models (presented in Annex C) we have identified two broad types of business model that may allow service providers to generate additional revenue, to help fund the network investments required to support high-quality online video services.

7.1 Retail business models

A retail model is perhaps the most obvious way for a service provider to generate additional revenues from online video services. The most commonly discussed retail business model is a retail IPTV offering such as BT Vision and Tiscali TV. Such services have commonly focused on retailing premium content, especially sports and films. However, an important feature of the BT Vision service is the subscription-based 'catch-up TV' service that offers access to previously broadcast content from the BBC and Channel 4. The services are available free of charge via the public Internet, but the BT Vision subscription service offers a premium service with content accessible on the TV, at a guaranteed quality of service. It is also conceivable that such business models could be extended to other online video services such as YouTube. In addition to subscription or usage revenue from the consumer it may also be possible for service providers to

46 Phorm is a new technology platform that can be used to monitor Web users' traffic in order to target advertising, with service providers capturing some of this revenue. Phorm has raised a number of privacy issues following trails by BT that have highlighted the need to obtain opt-in from consumers for any eventual service.

provide higher-quality content via their own portals, which could then be funded through advertising.

By offering access to video services over a dedicated platform, service providers may be able to charge additional fees for a wide range of video services, and use the revenue to fund additional investments in network capacity and/or technical solutions.

Historically, however, service providers have not been particularly successful in selling a high volume of content to their subscribers. It may therefore be more appropriate to consider business models where service providers are able to capture part of the retail revenues generated by content owners. Such business models could be classified as wholesale business models, and are discussed in the next section.

7.2 Wholesale business models

Service providers may be able to generate additional revenue from online services by offering wholesale services to other organisations. These wholesale services could include:

- dedicated bandwidth for specific services
- prioritisation of specific services
- provision of multicast services for live video streams
- caching of content closer to the consumer.

Wholesale services such as these could be used by content owners to ensure that their content is delivered in a reliable and high-quality manner to their paying customers. Business models of this type are often referred to as ‘two sided’ as they generate revenue from both end users and other businesses. We are seeing increased interest in such business models from all parts of the value chain, though there is still a large amount of cultural change and learning required before they can be widely and successfully adopted.

One prominent example of these new wholesale business models is the Amazon Kindle (currently only available in the USA). This device is an e-book reader that has a built-in wireless connection to the Sprint network that can be used to download written content directly from Amazon. The novel part of this business model is that the consumer of the e-books also has a billing relationship with Sprint. We believe that the retail revenue that Amazon generates is then used to pay for wholesale capacity from Sprint for delivery of the digital content. Such a model could easily be extended to digital downloads of DVDs and music.

CDNs already operate global networks that allow content owners to improve the delivery of their Web-based content to end users. However, these networks typically only extend to the edge of a service provider’s broadband network. For this reason, they do not provide any caching deep near the edge of the network (e.g. at the exchange), and they do not use any dedicated bandwidth over the service provider’s network. However, a new business model could emerge in which CDN providers would partner with individual service providers to ensure that there is dedicated capacity in the core and backhaul networks of service providers. Under this model the CDN providers would be able to aggregate wholesale services from service providers and then sell national, regional or international services to content owners. It is likely that this would provide a smoother transition in business model for content owners, and reduce complexity for them in delivering their content over many different networks.

7.3 Potential scale of revenues from new business models

Our technical and economic analysis has shown that in a scenario with a very substantial increase in online video, the rise in costs for the backhaul network is of the order of GBP1.00 per line per month when all technical solutions are deployed, and GBP3.00 otherwise. Because it may be difficult for some service providers to recover this increase in their cost base from existing revenues, they may need to pursue the new business models discussed. We have not carried out a detailed analysis of the revenues that a service provider could retain from such business models, as these models are not yet mature. However, in the following paragraphs we discuss two different business models that both suggest there should be reasonable amounts of incremental revenue that service providers could capture.

In recent years there has been a large increase in the use of online DVD rental services (e.g. LOVEFiLM), where consumers choose DVDs online for delivery by post. This business model involves postage fees for the delivery and return of the DVDs. If DVDs are delivered by the Royal Mail, the costs of final delivery to the consumer are around GBP0.158 per item[47] (plus additional costs for sorting and returning DVDs). If DVDs were to be delivered digitally, it seems reasonable to assume that a network operator could potentially capture a similar amount of revenue per transaction.

Similarly, the catch-up TV service from BT Vision charges subscribers GBP3 per month for access to content that is available free of charge elsewhere, although at a lower quality. As the content is also available for free on the Internet, we believe that this content is likely to be provided free of charge to BT, and so it seems reasonable to assume that a large proportion of the GBP3 per month could be passed onto the network operator.

Such online video services are still in their infancy, but we believe that if they grow significantly the additional revenue from subscribers, or advertisers, will be significant enough that even a small percentage of it would be enough to fund network upgrades (e.g. backhaul capacity and/or technical solutions). We therefore believe that service providers should be able to cope with the rise in network costs due to an increase in traffic, particularly if they seek to exploit new revenue streams which help them to capture some of the value from the content that they are helping to deliver to the consumer.

---

47 We have assumed that items are delivered using the WalkSort service from the Royal Mail; see http://www.royalmail.com/portal/rm/jump2?catId=400047&mediaId=600102&keyname=WALKSORT

8 Conclusions and implications for Ofcom

Key findings from stakeholder interviews

The main messages that came out of our discussions with stakeholders were as follows.

- Demand for online video is growing and this growth is expected to continue, with streaming becoming the predominant method of video delivery in the future.
- Backhaul in broadband networks is currently a bottleneck, although LLU operators can exploit economies of scale to offer additional capacity at lower cost than bitstream operators.
- The access network may currently be a bottleneck to offering higher-quality videos, although the NGA investments expected from BT and Virgin Media show that the market is beginning to address this bottleneck.
- Technological solutions such as multicasting and caching can limit the impact of increased traffic, although caching solutions that require more intelligent servers closer to the end user face technical challenges.
- Business models are likely to evolve so that service providers can capture additional revenue from video services; at present, there is no clear, favoured model.

End-to-end delivery of high-quality video

The end-to-end delivery of content often involves data traversing multiple networks, sometimes across different countries or even continents. CDNs play an important role in ensuring that content can be delivered with a high level of QoS from the host server to the edge of the service provider's network, which comprises backhaul and access elements. The main bottleneck to high quality end-to-end delivery of video therefore lies in the service provider's networks.

The backhaul network typically has capacity that is shared between many end users, with each service provider using its own engineering rules to dimension the total capacity available. Due to the recent growth in the broadband market, and the drive towards lower prices due to competition, many of these backhaul networks are running close to maximum utilisation. As a consequence, for some end users this part of the network may be a bottleneck for video services at present.

The access network may also become a bottleneck for video services, particularly for the delivery of HD content. An analysis of access networks is outside the scope of this study, although the geographic extent of this bottleneck will depend on the NGA deployments from BT and other operators.

Future demand scenarios

We have used a scenario planning approach to develop demand forecasts for broadband traffic over the next ten years, focusing on the growth of traffic from online video services. Our analysis shows that over the next decade the level of peak-hour bandwidth demand could increase by a factor of more than 10 (in our lowest demand scenario), up to a factor of almost 100 (in our most aggressive scenario). The majority of this growth will come from online video services that are streamed directly to the end customer.

Technical and economic analysis

Our analysis focused on network costs that are traffic-related, and therefore excluded the costs of the access network, which largely depend on the number of lines deployed, not the bandwidth carried.

In order to ensure that services such as video or voice are delivered with a high level of QoS, service provider can either (a) deploy additional bandwidth, or (b) reserve bandwidth specifically for those applications. The choice between these two is essentially driven by the relative costs of bandwidth and servers respectively. Most core and backhaul networks are based upon optical fibre, so deploying incremental bandwidth is a relatively low-cost option as it is possible to exploit economies of scale. In addition, purchasing additional bandwidth is a simpler option for network operators than prioritising specific types of traffic, and it also avoids having to provide a lower-quality service for other applications during busy periods.

Some of the key results of our analysis are summarised below.

- The main cost that is traffic-driven is the backhaul link between the local exchange and the core network.

- LLU-based operators typically use fibre-based backhaul products and are able to exploit significant economies of scale that help to limit the cost increases under most scenarios (although there are still significant increases in costs under the most aggressive scenario). We assume the unit prices of backhaul products (e.g. BES) remain unchanged over time.

- Operators using bitstream-based services would face extremely large increases in costs if traffic increased without a significant reduction in the price of those wholesale products. The forecast cost increases – under current bitstream (WBC) pricing – are so large that they might limit the growth of online video services.

- BT Wholesale will use fibre-based backhaul products in its 21CN network, and this offers the prospect of lower bitstream prices due to the economies of scale that will become available to BT Wholesale once 21CN is complete and all service providers have been migrated to WBC.

- We have illustrated the impact of potential future prices of bitstream products based upon an estimate of the costs incurred by BT Wholesale, by taking as inputs Openreach fibre products for backhaul (including an allowance for additional costs and profits). We believe that WBC prices per Mbit/s could fall drastically over time if traffic volumes increase, i.e. following similar economies of scale to today's Ethernet-based backhaul products.

- As the WBC roll-out is still underway, it may not be possible for service providers to benefit from these economies of scale in the near term. If this is the case, the current prices of bitstream services may mean that the rise in costs associated with growth in online video consumption are prohibitive, in which case bitstream operators may contend their network capacity more, impacting the user experience for video services.

- Once bitstream services are able to exploit economies of scale in the backhaul network, it should be possible for wholesale prices of bitstream services to decline. However, for this to occur the reduction in costs per Mbit/s for BT Wholesale would need to be passed on to service providers. As BT Wholesale's biggest customer is BT Retail, we believe that the incentives should exist for BT Wholesale to pass on these cost savings. However, there may be timing issues associated with how rapidly this occurs, and this could limit the ability of retail service providers to offer a service that allows customers to consume as much online video content at the same quality as customers on LLU networks.

- The introduction of technical solutions such as traffic shaping, multicasting and content caching at the exchange would allow service providers to reduce the cost impacts of increased video traffic. The various solutions offer varying levels of benefit for different traffic types. Traffic shaping would bring cost savings throughout the timeframe considered. However, under our base case the business case for investing in multicasting only becomes positive in the middle years of our analysis; and for content caching at the exchange this only occurs in the final years. However, if the costs these technical solutions were to fall significantly, it may become economical to deploy them significantly earlier.

We have compared the forecast network costs with those currently experienced by service providers. The results for the cost per line per month[48] when deploying all technical solutions that are commercially attractive are show below in Figure 8.1 for LLU, and Figure 8.2 for LLU. The 'low 2008' benchmark represents the current costs for an operator using traffic shaping, while 'high 2008' represents the costs without traffic shaping.

48 The total monthly traffic costs include backhaul, core network and IP Transit costs but exclude costs of the access network that are independent of bandwidth usage

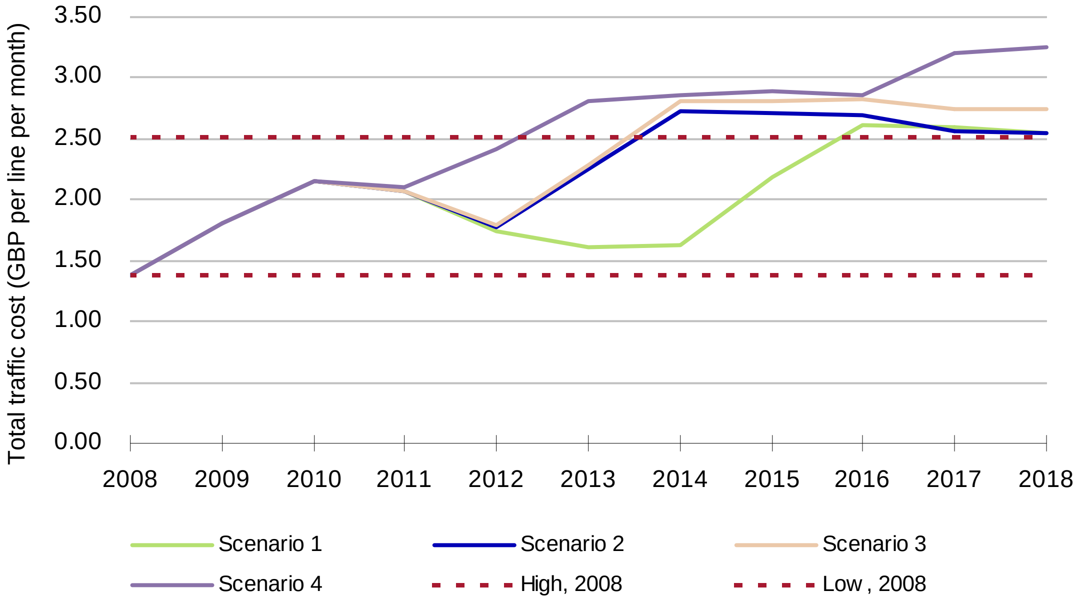

Figure 8.1: *Overview of the total monthly cost per line when deploying all technical solutions for Scenarios 1 to 4 for an LLU-based operator [Source: Analysys Mason]*

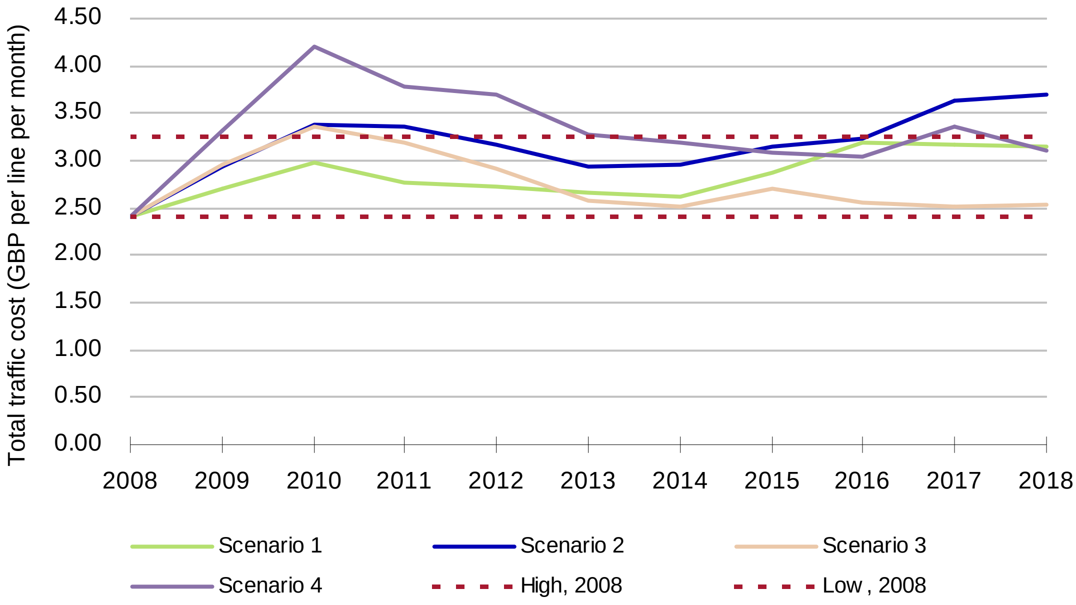

Figure 8.2: *Overview of the total monthly cost per line when deploying all technical solutions for Scenarios 1 to 4 for a bitstream-based operator [Source: Analysys Mason]*

If all three technical solutions are deployed, the increase in network costs by 2018 is not significantly above the high baseline for 2008 in scenarios 1, 2 and 3 for LLU operators. Under Scenario 4 there is a reasonable increase above the upper baseline by 2018.

For a bitstream operator the costs increase above the baseline in two periods: 2010–12 under Scenario 4, and in the final years under Scenario 2. The increase during 2010–12 is due to the incomplete migration to 21CN which means it is not possible to exploit the economies of scale possible with WBC backhaul products. The higher costs for Scenario 2 in the final years are due to the high traffic levels per line and the lower total traffic levels due to a lower market share for WBC operators when compared to Scenarios 3 and 4.

Our demand modelling has not assumed any demand constraints within access networks. However, limited availability of NGA may mean that HD take-up is slower than forecast and this would limit the impact of the increased costs for bitstream operators in 2010–12. During this period the proportion of HD under Scenario 4 is assumed to be 10–20% of all video traffic.

Technology advances in content caching may also make it cheaper to deploy this kind of technical solution. Our modelling indicates that this could limit the cost increase to levels similar to our upper baseline costs per line per month for 2008.

We have not considered the possibility of either new revenue streams or a reduction in the price of products supplied by Openreach in this analysis. It appears reasonable to assume that a combination of these two factors would reduce the impact of increased network costs to a level which can be supported by operators.

Evolving business models

If service providers were to require additional revenue streams to support online video services, we have identified two broad types of business model they might adopt:

- **Retail business models** involve the service provider charging additional fees to its customers for high-quality access to video content. Current examples of this business model include BT Vision and Tiscali TV. Of particular interest is the catch-up TV service from BT Vision. This gives users access to video content that can already be obtained free of charge directly from the BBC and Channel 4, although the BT service provides this content to the TV set, at a guaranteed quality.

- **Wholesale business models** involve payments to the service provider (possibly via a CDN provider) from content owners down the value chain, for services that help to ensure their content is delivered with a high QoS. Wholesale business models are currently less mature and may take a number of years to develop.

It is possible that these retail and wholesale business models could also include advertising revenue. In the case of the retail business model, the service provider would deal directly with advertising agencies, but in the wholesale model advertisers would have a relationship with the content owners.

Implications for Ofcom

Based on the conclusions above, we believe there are five areas which could have regulatory implications for Ofcom. We do not believe that any of these areas require immediate action.

- **A delay in the migration to 21CN-based bitstream products** may have a negative impact on service providers that use current bitstream products, as growth in consumption of video services could be held back due to prohibitive costs of backhaul capacity to support them on the legacy core network. We believe that the migration to 21CN will be important in enabling significant take-up of online video services at prices that are reasonable for consumers.

- **Video traffic could be accommodated by increasing the total bandwidth available**, and it is not essential to deploy advanced technologies to prioritise video traffic over other types of traffic in order to ensure a high QoS for video services.

- If video services are to continue to grow without leading to significant increases in costs to service providers, **there will have to be a significant reduction in the cost per Mbit/s of bitstream products**. This should be achievable once BT Wholesale has fully migrated to 21CN by exploiting the economies of scale associated with fibre-based Ethernet services, and the associated cost savings are passed on to service providers.

- Even in the most aggressive demand scenario (Scenario 4) the cost implications may not be excessive if **future bitstream pricing benefits from the economies of scale** that fibre-based backhaul products offer unbundlers today (as outlined in the point above), and if there are **technological advances in Ethernet services** that further reduce the cost per Mbit/s (e.g. through the availability of 100Gbit/s equipment).

- Finally, **innovative business models might be limited by regulation**: if the ability to develop and deploy novel approaches was limited by new regulation, this might limit the potential for growth in online video services.

Annex A: Key issues in the definition of demand scenarios

We have identified 11 key issues that have been evaluated in the definition of our demand scenarios:

1: Consumption At present, most content is consumed on the PC, but devices like the Apple TV, Xbox 360 and the Nintendo Wii (with BBC iPlayer) enable consumers to access online content via their TV. Increased consumption via the TV of on-demand services delivered over IP networks is inevitable, and may lead to consumers demanding higher-quality content (as most PC-based video content is currently of a lower quality than broadcast TV).

2: Shift to on-demand TV Traditionally, TV content has been consumed in a linear manner, but the popularity of services such as iPlayer and devices like Sky+ suggest that consumers may be moving away from linear broadcast TV to a different model where they can choose exactly when they view the content. On-demand content places additional loading on networks as it requires substantially more capacity when compared to a linear broadcast network (e.g. DTT).

This issue primarily aims to address the on-demand viewing that currently takes place via true video-on-demand (VoD) and services such as iPlayer. Planned time-shifting (i.e. a pre-meditated act of recording) will also be considered, accessed via devices such as Sky+.

3: Number of simultaneous viewers Historically, many people in the same household watched the same TV programme at the same time. However, this pattern has been changing as the number of TV sets in a household has increased, and with the advent of services such as Sky Multi-room and iPlayer. If this trend towards a larger number of simultaneous media streams in each household continues, it will place additional capacity requirements on broadband networks (i.e. multiple simultaneous streams).

4. Streaming versus downloading Online video content can be delivered either by the downloading of a file that is then played back later, or can be streamed at the time of consumption. In the past, the most common way of accessing online video content was via P2P networks that used the download model. However, there is now growing evidence that users have a clear preference for streaming services, even though they can be of a lower quality.

Streaming outs a higher demand on the delivery networks: streamed content must be delivered continuously, and any break or slow-down in delivery is experienced immediately and directly by the viewer. Downloaded content, by contrast, can be delivered over a longer time period (e.g. overnight) – iPlayer 'pre-booking' is one example of this approach.

The use of caching technology may lead to a hybrid approach where content is pushed to a partition on the hard drive (e.g. Sky Anytime on the TV).

5: High-definition (HD) content

The content industry is slowly moving towards production in HD, which places a significant additional load on the network due to the larger file sizes involved.

6: Fragmentation of content providers

At present, most content is delivered via a small number of aggregators (e.g. iTunes, YouTube and iPlayer). However, this could change to a situation where many independent channels stream their content from independent sources. A more fragmented content market of this kind might make it difficult to implement caching deep in the network, due to increased costs (and more limited economies of scale).

7: International versus local

A shift in the source of content from UK-hosted content to more globally fragmented content (e.g. YouTube or niche online channels) could have an impact on networks. However, it is likely that local UK content will remain the main source of content in future.

The role of content distribution networks may help in the case of larger content owners, as they can host their content in the UK.

8: Structure of ISP industry

The UK broadband market is consolidating, with 75% of UK broadband subscribers currently being served by four ISPs. This consolidation has largely been driven by the shift from bitstream products to LLU, which allowed service providers to exploit economies of scale in their networks. However, this may change in the future, especially if bitstream-like products become the predominant wholesale product over future NGA networks.

A more fragmented set of ISPs might give rise to different technical issues and solutions.

9: Growth of non-video traffic

The growth of non-video traffic affects the level of contention on the network, and this will affect the delivery of video services in the future.

10: Linear content broadcast over IP networks

At present, broadcast TV is delivered via analogue, DTT, satellite and cable, with very little linear TV being consumed via IP-based networks. However, moves by broadcasters (including the BBC and ITV) to 'simulcast' their content indicates that there may be a significant increase in the amount of linear broadcast content that is delivered via IP networks.

11: Shift away from physical DVDs to a download-based model	The use of DVDs has grown quickly in recent years, displacing video cassettes. The increase in online video may lead to content traditionally watched on DVDs being downloaded. Services from *iTunes*, *LOVEFiLM* and *Netflix* indicate that this new download-based business model is beginning to gain momentum.

Annex B: Demand scenarios

B.1 Demand quantification parameters

This annex provides a summary of the quantitative parameters that we have assumed in our model for each of the traffic demand scenarios defined in Section 4.2. We have divided our set of input parameters into those that are common to all scenarios (such as demographic assumptions) and those that vary across scenarios (such as HD penetration).

B.1.1 General parameters

The following parameters have been used consistently across all scenarios to determine the future busy-hour bandwidth requirements per household:

Parameter	*Base year (2008)*	*Final year (2018)*	*Source**
Daily TV viewing (minutes per person)	216	*Scenario-dependent*	BARB (2008)
Daily online minutes	6.3	*Scenario-dependent*	ComScore (2008)
Total TV and online video consumption	221.6	221.6	Analysys Mason estimate
Total video transactions per year	1 079 534	1 210 612	Euromonitor, European Audiovisual Observatory
DVD share of total video transactions	93.48%	100%	Euromonitor, European Audiovisual Observatory
Share of downloaded DVDs in total transactions	0.01%	*Scenario-dependent*	Analysys Mason estimate
Busy-hour share (TV)	11.75%	11.75%	BARB
Busy-hour share (*iPlayer*)	7.68%	9.73%	BBC (2008)
Busy hour share (*YouTube*)	5.44%	5.99%	Gill et al. (2007)
Communal viewing (linear TV)	65%	55%	Analysys Mason estimate
Communal viewing (on-demand TV)	40%	40%	Analysys Mason estimate
Communal viewing (broadcaster online)	25%	35%	Analysys Mason estimate
Communal viewing (alternative online)	5%	5%	Analysys Mason estimate
SD bandwidth (Mbit/s)	2	2	Analysys Mason estimate
HD bandwidth (Mbit/s)	10	8	Analysys Mason estimate
Broadcaster streaming bandwidth (Mbit/s)	0.5	2	BBC (2008)
Alternative streaming bandwidth (Mbit/s)	0.3	1.5	Analysys Mason estimate
Broadcaster download bandwidth (Mbit/s)	1	8	BBC (2008)
Non-video traffic CAGR	–	23%	Cisco (2008)
UK population	61 457 600	65 861 400	UK Statistics (2008)
UK households	26 277 890	28 950 158	UK Statistics (2008)
Broadband penetration	63%	80%	Analysys Mason Research

* All values for 2018 are Analysys Mason estimates, partially based on forecasts provided by the respective sources.

Figure B.1: Assumptions for the general parameters of the demand model [Source: various]

B.1.2 Scenario-specific parameters

The following parameters have been applied to the different scenarios to determine the busy-hour bandwidth requirement per household:

Parameter		*Base year (2008)*	*Final year* (2018)*
Growth in take-up of on-demand TV			
	Scenario 1	11%	20%
	Scenario 2	11%	40%
	Scenario 3	11%	40%
	Scenario 4	11%	60%
Proportion of consumption of on-demand video that is spontaneous			
	Scenario 1	25%	25%
	Scenario 2	25%	35%
	Scenario 3	25%	35%
	Scenario 4	25%	45%
HD penetration			
	Scenario 1	1%	5%
	Scenario 2	1%	50%
	Scenario 3	1%	50%
	Scenario 4	1%	90%
Proportion of linear content broadcast over IP networks			
	Scenario 1	0.01%	5%
	Scenario 2	0.01%	10%
	Scenario 3	0.01%	10%
	Scenario 4	0.01%	15%
Share of DVDs downloaded via IP networks			
	Scenario 1	0.01%	5%
	Scenario 2	0.01%	10%
	Scenario 3	0.01%	10%
	Scenario 4	0.01%	30%

Figure B.2: Assumptions for the general parameters of the demand model [Sources: various]

* All values for 2018 are Analysys Mason estimates partially based on forecasts provided by the respective sources.

B.2 Demand scenario results

The figures in this annex are complementary to those provided in Section 5. We have included them in order to provide a clearer explanation of the differences between the scenarios.

Figure B.3 to Figure B.5 show the forecast evolution of video consumption per household in minutes per day. From these it can be seen that we assume a significant shift away from linear broadcast television content.

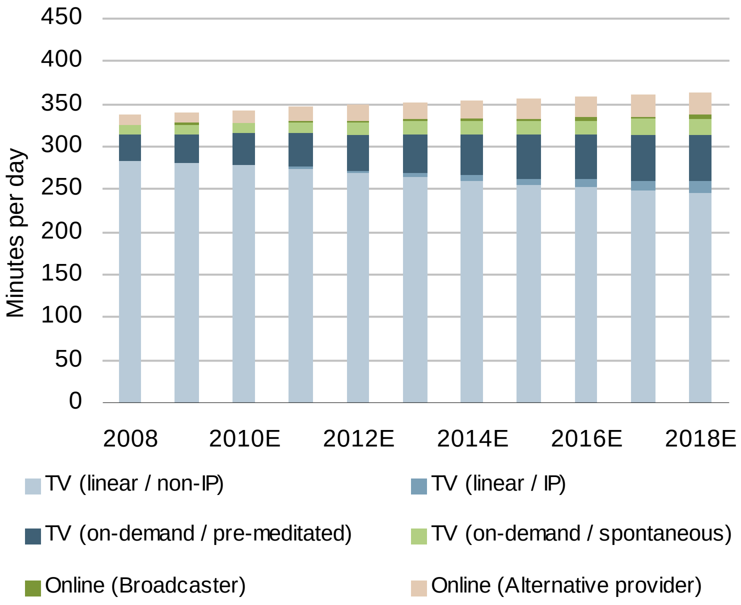

Figure B.3: Video consumption per household for Scenario 1 [Source: Analysys Mason]

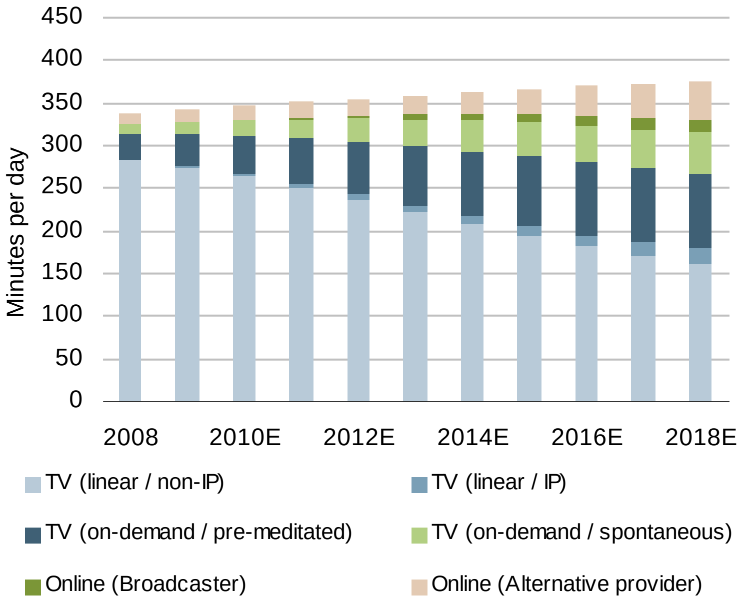

Figure B.4: Video consumption per household for Scenarios 2 and 3 [Source: Analysys Mason]

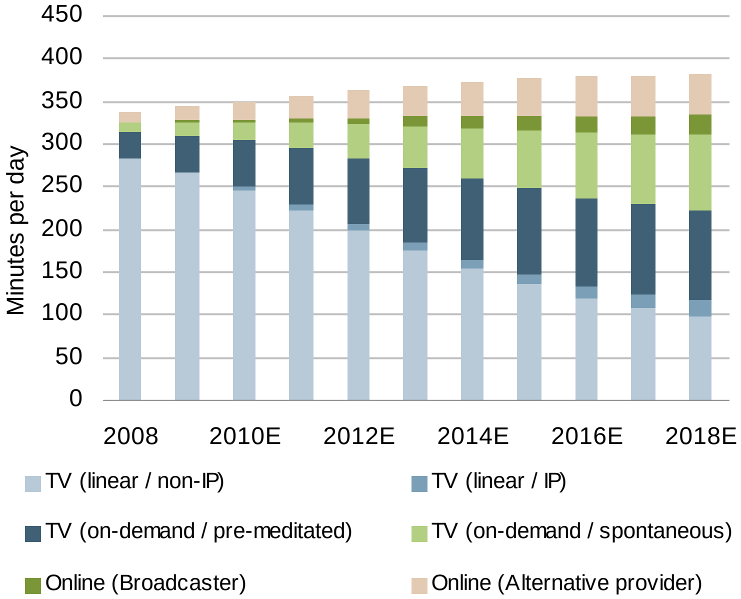

Figure B.5: Video consumption per household for Scenario 4 [Source: Analysys Mason]

Figure B.6 to Figure B.8 show the resulting monthly traffic forecasts by traffic categories. Again, they highlight that on-demand traffic is a key driver of traffic growth, especially when pre-meditated traffic is also taken into account.

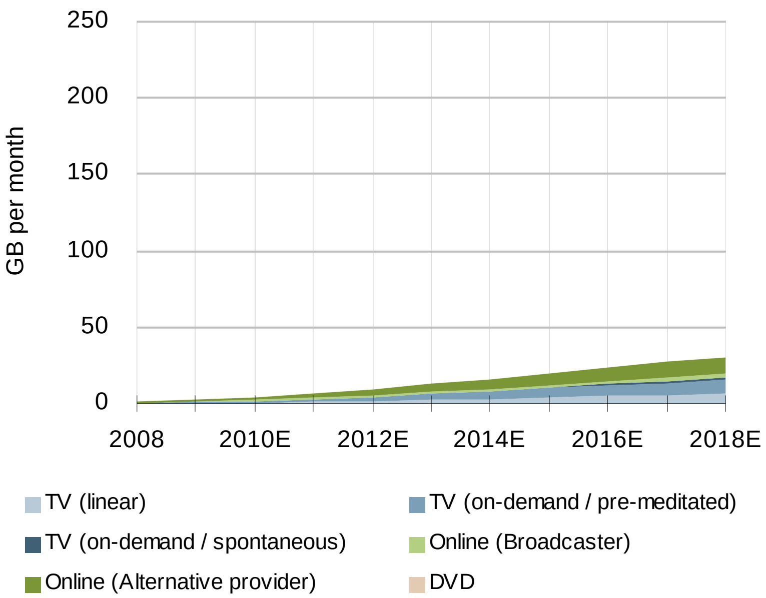

Figure B.6: Composition of video traffic for Scenario 1 [Source: Analysys Mason]

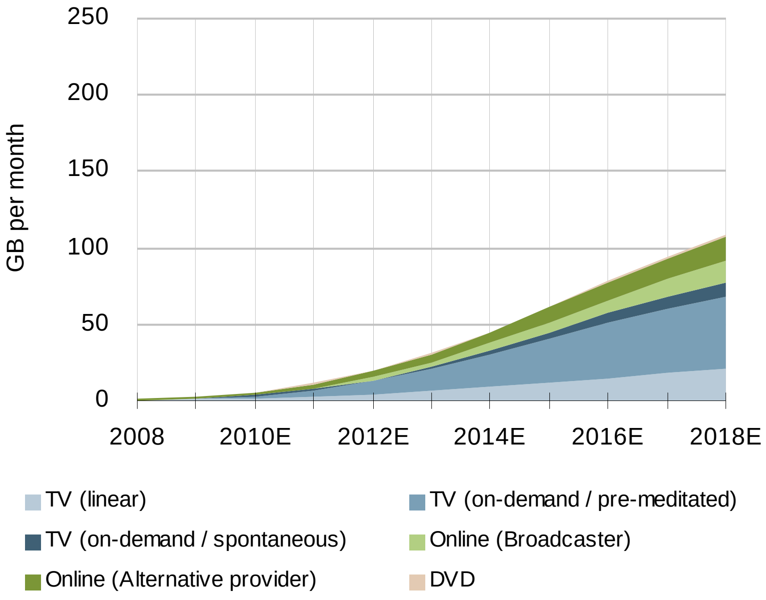

Figure B.7: Composition of video traffic for Scenarios 2 and 3 [Source: Analysys Mason]

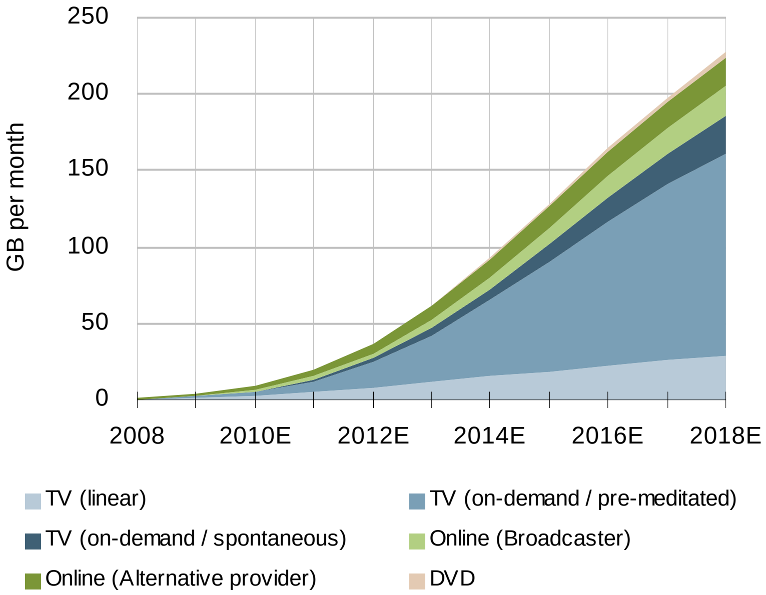

Figure B.8: Composition of video traffic for Scenario 4 [Source: Analysys Mason]

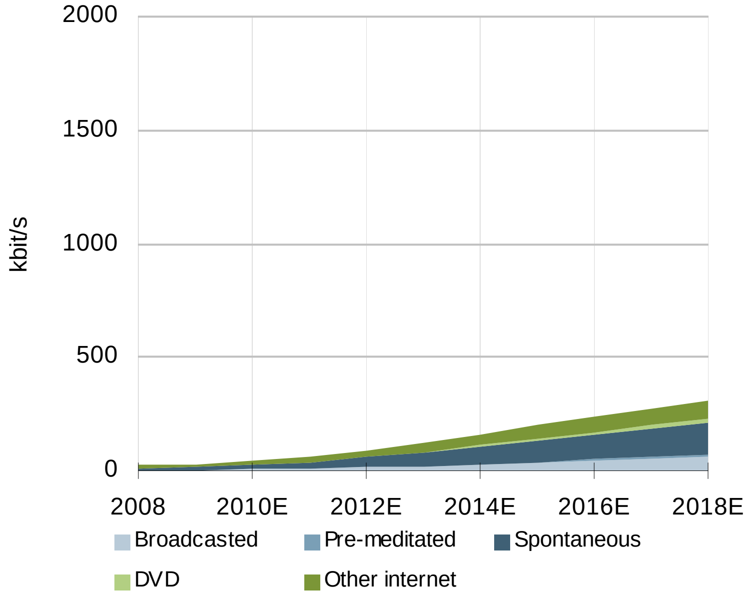

Figure B.9:Composition of busy-hour bandwidth for Scenario 1 [Source: Analysys Mason]

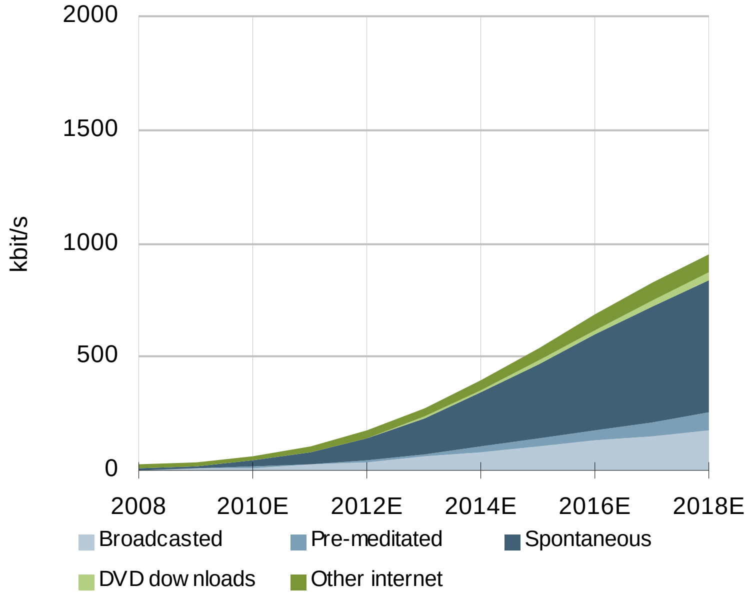

Figure B.10: Composition of busy-hour bandwidth for Scenarios 2 and 3 [Source: Analysys Mason]

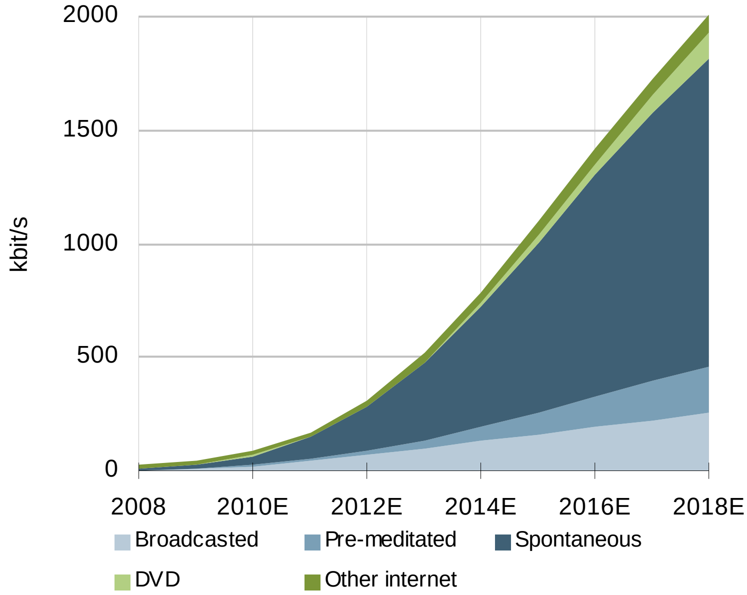

Figure B.11: Composition of busy-hour bandwidth for Scenario 4 [Source: Analysys Mason]

Annex C: Case studies of companies and services relevant to evolving business models for online video

In this annex we present seven case studies that are relevant to the ways in which business models are evolving to support online video.

C.1 Akamai

Akamai provide a global content distribution network (CDN). It sells services to content owners to ensure that its content is delivered quickly and reliably across the globe. Akamai was launched in August 1998 as a pioneer in content delivery services. It now provides a range of managed services supporting rich media content, dynamic transactions and enterprise applications online.

Services offered

Akamai's product portfolio includes *digital asset solutions, dynamic site solutions* and *application performance solutions*. The table below summarises the range of solutions associated with each product.

Product	*Solution*	*Description*
Digital Asset solutions	Akamai Media Delivery	Helps media providers deliver and monetise media assets quickly and effective
	Akamai Stream OS	A single point of control for producing, publishing, and delivering rich media, and essential reporting tools to support online business models
	Electronic Software Delivery	Delivers any type of software over the Internet effectively and reliably
Dynamic site solutions	Dynamic Site Accelerator	Ensures high performance and reliability of dynamically rendered, personalised Web sites
	Dynamic Site Accelerator Enterprise	Handles the most complex Web sites – increasing scale, reach and performance without added infrastructure
Application performance solutions	Web Application Accelerator	Improves performance and reliability of Web-based applications
	IP Application Accelerator	Improves the performance and reliability of any IP-enabled application

Figure C.1: Overview of Akamai's service portfolio [Source: Akamai[49]]

49 See http://www.akamai.com/html/about/facts_figures.html

In the following, we focus only on those services which are directly relevant to online video content providers. These services are included in the Akamai Media Delivery solution:

- Streaming – live or on-demand streaming services supporting a number of leading media players such as Apple QuickTime, Microsoft Windows Media, RealSystem G2 and Adobe Flash Streaming, for both narrowband and broadband use.

- NetStorage – outsourced content storage. The service includes enhanced connectivity to a number of ISPs, redundancy and mirroring services.

- Media framework – resource for developing video player applications using the Adobe Flash video format.

- Media downloads – HTTP download facility allowing the end user to download large video files more efficiently, by providing a straightforward software interface and a pause feature.

- Digital rights management – service allowing secured delivery and billing of media content. The solution provides a range of options including pay-per-view, subscription-based billing, limited usage, no replication.

- Reporting and analytics – in parallel to the range of media delivery services offered, Akamai provides content service providers with performance-measuring tools allowing close monitoring of results.

Technology and user experience

Akamai's EdgePlatform is one of the world's largest distributed computing platforms. It is a network of more than 34 000 secure servers equipped with proprietary software and deployed in 70 countries.

These servers reside within approximately 950 of the world's networks monitoring the Internet in real time – gathering information about traffic, congestion and trouble spots. Akamai uses this intelligence to optimise routes and replicate data dynamically to deliver content and applications more quickly, reliably and securely. Akamai's approach involves:

- eliminating long routes whenever possible – by replicating and delivering content and applications from servers close to end users around the world, instead of from centralised servers. Akamai calls this delivering from *the edges of the Internet.*

- optimising routes – by mapping paths across the Internet to avoid trouble spots, compressing content, and replicating packets to ensure fast, complete delivery.

Value chain and charging model

Akamai's Media Delivery solution is positioned as an underlying technical solution throughout the value chain, as shown in Figure C.2 below.

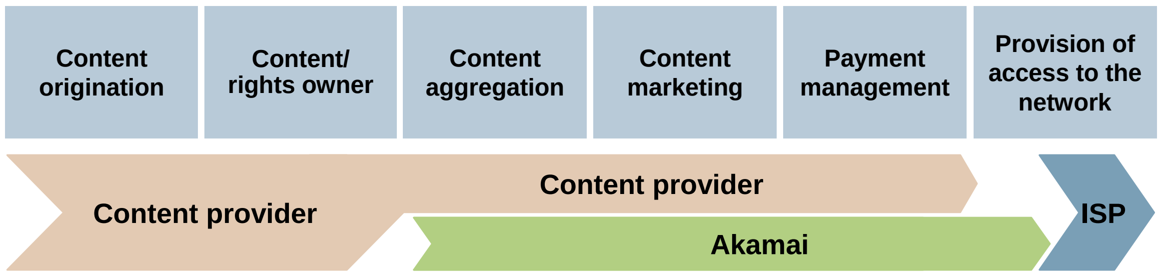

Figure C.2: Position of Akamai's Media Delivery solution in the value chain [Source: Analysys Mason]

The table below gives an overview of how Akamai's Media Delivery solution services fit into the value chain.

Value chain step	*Corresponding services*
Content aggregation	NetStorage
Content marketing	Media Framework
Payment management	Digital Rights Management
Provision of access to the network	Streaming, Media Downloads, NetStorage

Figure C.3: Akamai's Media Delivery solution in the value chain [Source: Analysys Mason]

Akamai has no direct relationship with the end user. The end user experiences the content provider's brand and interface at all times. Akamai acts as an end-to-end technology solution provider, dealing exclusively with content owners.

Future perspectives

Since it started as a content delivery service provider back in 1998, Akamai has developed to adapt to the latest technologies and business models. Today, Akamai claims to deliver 20% of the world's Internet traffic.

Over the past two years, Akamai's revenues have more than doubled, reaching USD187 million in Q1 2008. Akamai's EBITDA margin has increased from 37% in Q1 2006 to 47% in Q1 2008, as illustrated in Figure C.4.

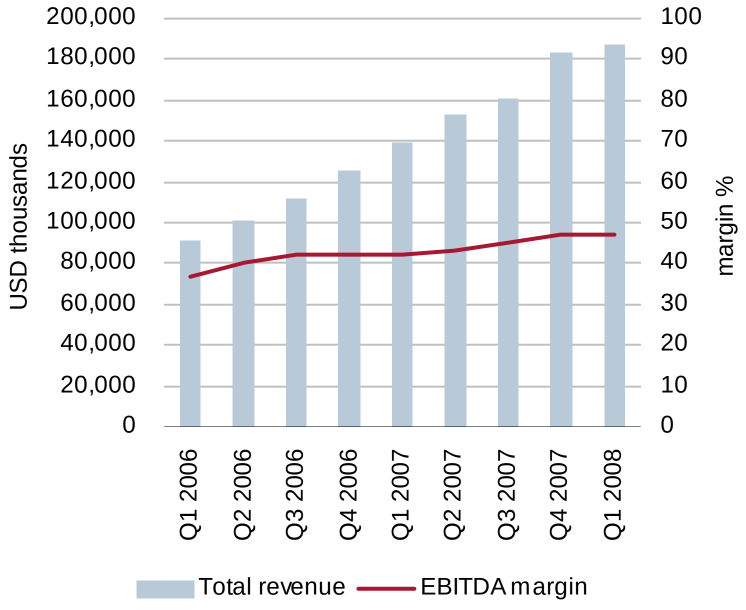

Figure C.4: Evolution of Akamai's revenues and EBITDA margin between Q1 2006 and Q1 2008 [Source: Akamai, Q1 2008 quarterly results]

C.2 Hulu

Hulu is an online video portal where users can watch streaming TV content. It was founded in March 2007 by leading global media companies NBC Universal and News Corp. It launched as a beta version in the USA in October of the same year.

Services offered

Hulu is an online video service offering TV shows, films and video clips at Hulu.com and other partner Web sites. Some of Hulu's content includes popular television shows such as The Office, The Simpsons and Family Guy. Hulu's content is free of charge and legal, and is 100% funded by advertising. Advertising can being targeted at specific customer segments thanks to personal information provided by users when signing up. Hulu services are only available from the USA.

Technology and user experience

Hulu provides content through a streaming solution using Flash 9.0. Videos cannot be downloaded, but can be streamed as many times as wanted. The video bitrate is automatically being adjusted between 480kbit/s and 700kbit/s depending on the user's bandwidth. Some content is available in a higher resolution using 1000kbit/s streams. For this content, users with sufficient bandwidth can manually activate the higher-resolution feature in the online media player interface. Hulu also offers a few examples of HD content, listed in a dedicated library.

The user experience includes advertising that is interspersed throughout the show in the form of 15- to 30-second breaks. Users typically get between three and six advertising breaks in a half-hour show (which equates to around 22 minutes of non-promotional content).

Value chain and charging model

As illustrated in Figure C.5 below, Hulu sits in the middle of the value chain for online media content distribution. Hulu is being granted content rights distribution from parent companies NBC and News Corp. Hulu intends to extend its content by securing partnerships with further content rights owner such as Sony Pictures[50] and American Public Broadcasting Services (PBS)[51].

Hulu works both as a content aggregator and distributor, by offering content on its own Web site, Hulu.com, and on a range of distribution partners' Web sites, including AOL, Yahoo!, Comcast, MSN and MySpace. Public sources[52] assume the revenue to be split as followed:

- content partners keep 70% of gross advertising revenue
- distribution partners keep 10%
- Hulu keeps either 20% or 30%, depending on whether a distribution partner is involved.

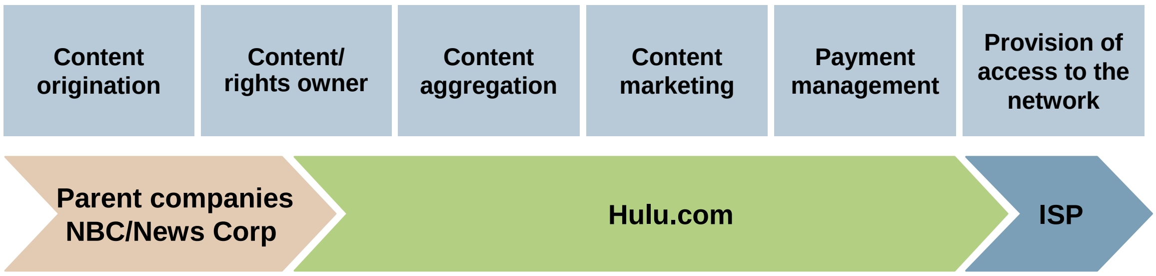

Figure C.5: Position of Hulu in the value chain [Source: Analysys Mason]

Moreover, according to press sources, the cost of advertising is 15% to 30% cheaper on Hulu.com than advertising on its parent company's Web site (NBC.com) and that of its main competitor (ABC.com). This is partly due to Hulu's brand name being less powerful and also to the more restricted options offered to advertisers by Hulu.com. In particular, advertisers claim it is not possible to choose to advertise in a specific show on Hulu.com.

50 See http://www.hulu.com/partners

51 See http://www.hulu.com/companies/101

52 See http://www.alleyinsider.com/2007/10/hulus-exclusivi.html

Future perspectives

Hulu has developed a strong position thanks to backing from parent companies NBC and News Corp. In less than a year it has secured distribution partnerships with major Internet players such as AOL and MSN, providing Hulu with access to a wider audience and consequently increased revenues.

In May 2008, Hulu made it into Nielsen Video Census' Top Ten Online Video brands, as shown in the table below. Between April and May 2008, Hulu saw usage increase by 27%, growing from 63 million to 80 million video streams. In addition, unique users increased by 13%, showing that Hulu users are spending more time on the site.

Video brand	*Total streams (millions)*	*Unique users (millions)*
YouTube	3 842	67.8
Fox Interactive Media	328	18.4
Yahoo!	223	23.2
MSN	168	10.0
Nickelodeon Kids	143	5.8
ESPN	124	5.7
Turner Sports	91	6.1
CNN Digital Network	90	4.5
Hulu	80	2.7
ABC.COM	80	6.1

Figure C.6: Top Ten Online Video brands in May 2008 [Source: Nielsen[53], May 2008]

C.3 Deutsche Telekom's Bill-It-Easy

Bill-It-Easy is an online payment handling service provided by Deutsche Telekom's International Carrier Sales & Solutions[54] (ICSS) division to ISPs and mobile network operators.

Deutsche Telekom's Bill-it-Easy launched in February 2007 through a partnership with electronic and mobile payments specialist Dimoco[55] (formerly Montax). Bill-it-Easy was originally developed and launched by Montax in 2003. While Deutsche Telekom has taken over marketing to ISPs and MNOs as part of the partnership, Bill-It-Easy is still marketed to content providers by Dimoco[56].

53 See http://www.alleyinsider.com/2008/6/nielsen_people_watching_less_youtube_less_video_but_more_hulu

54 See http://www.deutschetelekom.com/icss

55 See http://www.dimoco.de/en/produkte_en/payment_en/webbilling.html

56 Source: Deutsche Telekom press release from 28 February 2007, http://ghs-internet.telekom.de/dtag/cms/content/ICSS/en/331684

This service illustrates ways in which service providers and content owners can partner to share revenue from a single transaction to cover costs of both content and networks.

Service offered

With Bill-it-Easy, Deutsche Telekom provides ISPs and MNOs with a simple way to get a share of content revenues and enhance their service portfolio offering. As illustrated below, the service amends the traditional value chain and corresponding charging models in favour of ISPs and MNOs (see '*Value chain and charging model*' below for further details).

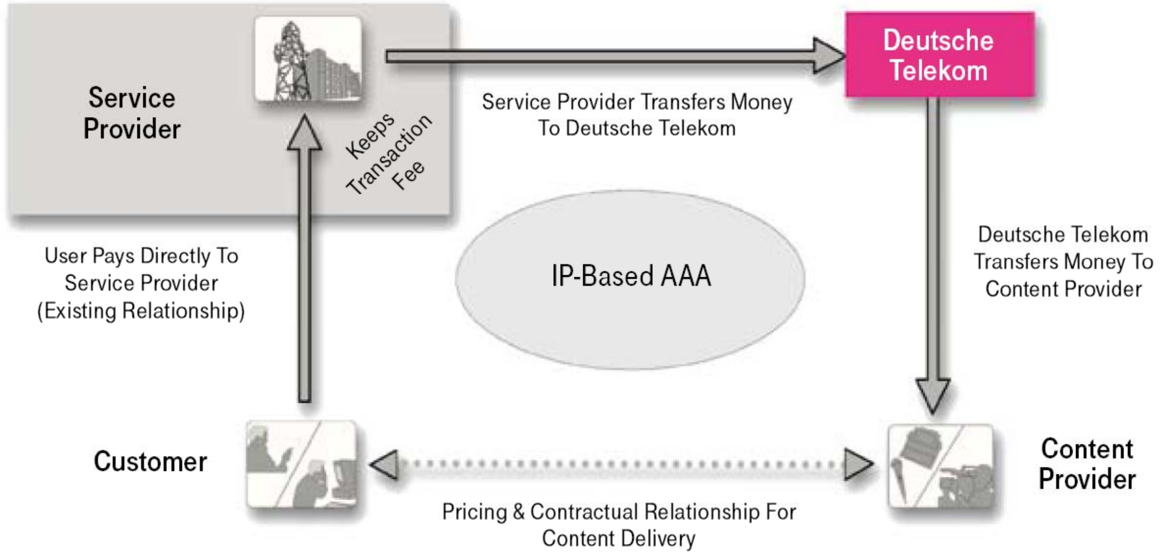

Figure C.7: The Bill-it-Easy model [Source: Deutsche Telekom]

On the end-user side, Bill-It-Easy translates into a facility to buy content online without providing any personal or payment details. The user connects to a secure interface from its ISP or MNO's portal, using a login name and password. The user may then buy content seamlessly from Bill-It-Easy content providers' Web sites. ISPs and MNOs are encouraged to promote content partners in order to maximise chances of sales. Content on offer through Bill-It-Easy includes in particular:

- adult content and betting services, for which users are unwilling to provide personal or credit card details for privacy reasons
- more conventional content types, such as video clips or MP3, involving micro-payments for which users are also unwilling to give credit card details.

Technology and user experience

Bill-It-Easy is based on the technology developed by Dimoco. Payment transactions are being operated by Dimoco, as part of the partnership.

Billing is based on subscriptions, time (minutes, seconds) or events (per click). The service is available for both mobile and online transactions. It comes with a range of add-on services including in particular, reporting, call centre and database management.

This service makes buying content an easier process for the end user as content bought on Web sites using Bill-It-Easy is billed automatically and anonymously on one of the end user's existing invoices (whether from its ISP or MNO).

Value chain and charging model

Bill-It-Easy allows Deutsche Telekom to position itself as a Payment Manager, as illustrated below.

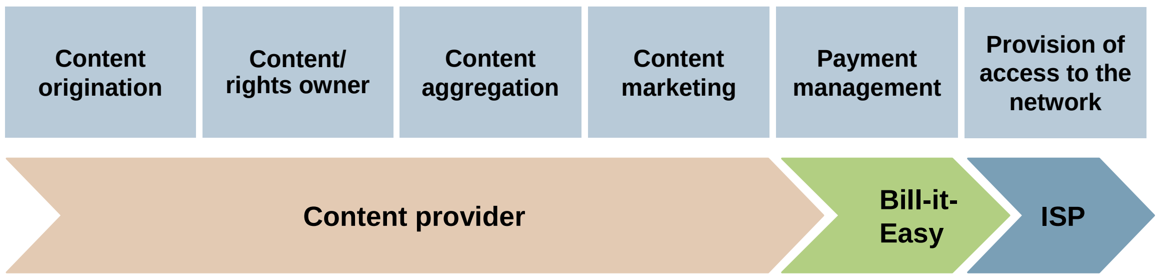

Figure C.8: Position of Bill-It-Easy in the value chain [Source: Analysys Mason]

By simplifying the transaction process for the end user, Bill-it-Easy allows ISPs and MNOs to take a share of the revenue from content delivered over their networks.

In particular, contracting the service with Deutsche Telekom rather than Dimoco makes sense for ISPs using Deutsche Telekom's wholesale services and MVNOs using Deutsche Telekom's mobile network, since these already have a commercial relationship with Deutsche Telekom. Figure C.9 below illustrates the content services charging model with and without Deutsche Telekom's Bill-It-Easy.

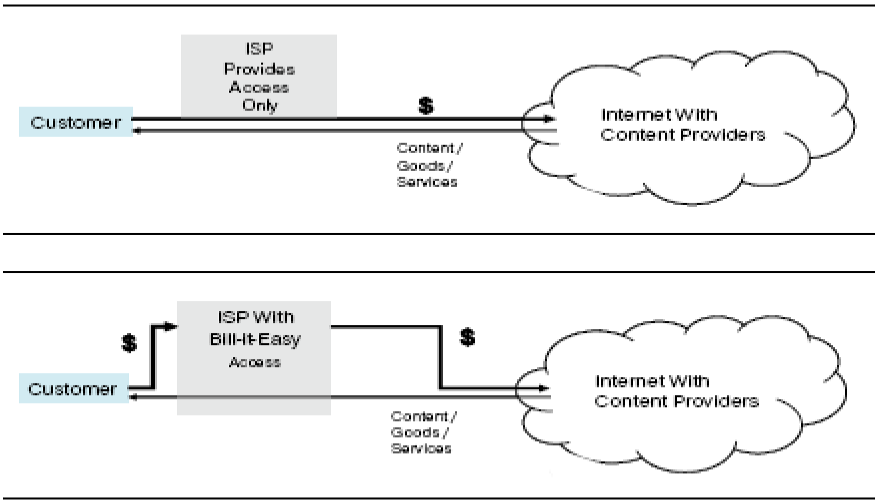

Figure C.9: Charging model without and with Bill-It-Easy [Source: Deutsche Telekom]

Future perspectives

As part of the agreement announced in February 2007, Dimoco is responsible for commercial relationships with content providers. However, Deutsche Telekom ICSS is also offering a range of services to content providers and is well placed to take over commercial relationships with content providers.

Services listed by Deutsche Telekom ICSS as provided to content and media providers include:

- basic services – Internet access via IP transit
- managed services – private connections to the Internet exchanges (IP-VPN Layer 2)
- value-added services – peering circuits worldwide, transatlantic IP backbone capacity, VoIP services
- enabling services – Bill-It-Easy, content delivery and content clearing.

C.4 Dailymotion

Dailymotion defines itself as the ‘world’s largest independent video entertainment website’, and is a direct competitor to YouTube, allowing users to ‘view, publish and share’ videos.

Dailymotion was founded in March 2005 in France, but now operates tailored Web sites in 10 countries[57] and is available in 17 different languages. In particular, Dailymotion launched a Web site in the USA with a dedicated content and management team in July 2007.

Services offered

Dailymotion services include online viewing, publishing and sharing of videos. All videos may be watched free of charge, thanks to an advertising-supported model.

There are three types of video content available, depending on the content owner category:

- Personal videos are uploaded by basic users – these videos may be shared in a restricted circle of users or made available for public diffusion
- Creative content is uploaded by MotionMakers – these videos are being reviewed by Dailymotion's editorial team before release. These videos must be original content produced by the MotionMaker. MotionMakers benefit from unlimited uploads, both in terms of size and duration
- Official content is uploaded by Official Users (that is, media companies belonging to Dailymotion's content partners). Latest deals secured in this area include leading international media brands such as CNN International[58] or Warner Bros Television[59].

Content is organised in channels (e.g. news, music, humour, sports, etc.) and content type is identified through a labelling system[60]. Users may use a jukebox function to broadcast selected channels and/or content type, in a more traditional fashion.

In addition, Dailymotion also provides video upload services to users of partners' Web sites, including among others major Internet brands Facebook[61] and eBay[62].

57 As of July 2008, Dailymotion's countries of operation included Belgium, France, Germany, Greece, India, Italy, the Netherlands, Poland, Spain, the UK and the USA.

58 Dailymotion press release from June 2008, http://www.dailymotion.com/press/CP_Dailymotion_-_CNN.pdf

59 Warner Bros press release from June 2008, http://www.dailymotion.com/press/WBTVG_Digital_Partners_Release_FINAL.pdf

60 Personal videos have no label, while Creative and Official content are labelled with a dedicated logo in the top-left hand corner of each miniature preview.

61 See http://www.dailymotion.com/factory/facebook

62 Dailymotion press release from September 2007, http://www.dailymotion.com/press/Dailymotion_and_Ebay.pdf

Technology and user experience

Dailymotion streams video content using Flash technology, but develops its own coding technology. Since February 2008, Dailymotion also offers the possibility to upload High-Definition content. Videos may not be downloaded.

Dailymotion is interconnected directly with large ISPs to provide easier access to its video content. Dailymotion operates an open peering policy[63] so that any entity operating its own autonomous system may apply for interconnection with Dailymotion.

In summer 2007, Dailymotion entered into a public dispute with French alternative operator Neuf Cegetel (Neuf). The growing bandwidth required between the ISP and the content provider led to Neuf blocking part of Dailymotion's content. In answer response to the blockage, Dailymotion redirected Neuf users to their ISP's customer service, as illustrated in Figure C.10.

Translation: Dear users, As a result of numerous reactions, we have noted that your ISP's network (Neuf Cegetel) seems to be restricting your usage of our service. We therefore encourage you to contact its customer service on 08 92 79 00 09 (EUR 0.34/min). *Dailymotion* remains perfectly available to all other ISPs' subscribers!

Figure C.10: Banner involved in dispute between Dailymotion and Neuf in summer 2007 [Source: ARCEP]

The dispute was eventually settled without additional public details. Dailymotion and Neuf now have a distribution agreement, so Dailymotion's Creative content is available on Neuf's IPTV service.

Another example of partnership with ISPs is the Telecom Italia deal secured in Italy at the end of 2006, whereby Dailymotion's content is made available as a sub-domain to Telecom Italia's ISP's portal Alice[64]. As part of this agreement, it is possible that Dailymotion will have directly collocated servers into Telecom Italia's network.

In order to ensure legal diffusion of content, Dailymotion has been investing in the implementation of content rights protection technologies, including Signature, a fingerprint technology developed by the French National Audiovisual Institute (INA) and Audible Magic in the USA.

63 See http://peering.dailymotion.com

64 See http://dailymotion.alice.it

Dailymotion's content is available on a range of devices thanks to its aggressive partnership strategy, including:

- television through Neuf's IPTV offer
- mobile phones through deals with French mobile network operator SFR
- portable media player through a deal with Archos on its WiFi devices.

Advertising is present in several forms on Dailymotion, but does not intrude in the user experience. According to press releases, advertising breaks may happen at the start, at the end or during videos, but this feature is still fairly uncommon in practice. In addition, ad banners may be positioned on top or on the sides of selected pages. Official users may customise their dedicated page, so that the entire background converts into an advertising space. Moreover, some content published by official users is entirely promotional. Such content includes previews of computer games or shots of the latest mobile phone handsets. Financial details for advertising deals with official users are not publicly available.

Value chain and charging model

Dailymotion acts as an interface between content providers and ISPs, by providing a platform to distribute video content. Content providers may be individual users, individual creators (MotionMakers) or businesses (Official Users). Figure C.11 illustrates Dailymotion's position in the video distribution value chain.

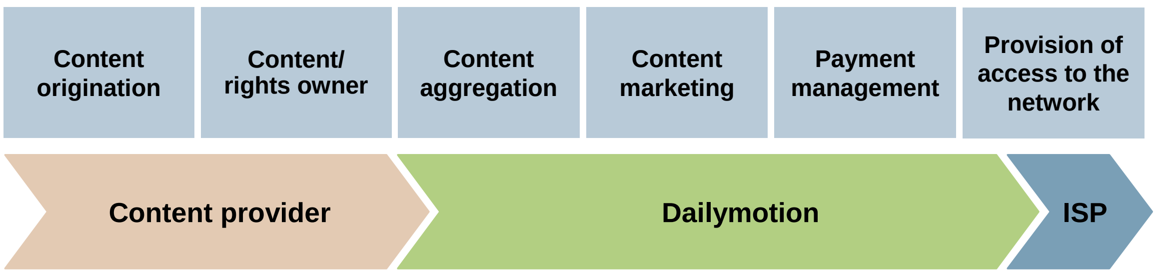

Figure C.11: Position of Dailymotion in the value chain [Source: Analysys Mason]

While Dailymotion is known to have multiplied partnerships for various purposes, very little information has been made public regarding the financial details. In July 2007, Dailymotion stated in a press release[65]: 'Revenue sharing agreements are available to media companies as well as individual content creators through the MotionMaker program'. The range of partnerships covers the following:

65 See http://www.dailymotion.com/press/dailymotion_us_launch.pdf

Partnership on	*Partner*	*Examples*
Content distribution	Media group	Warner Bros Television Group (June 2008)
	TV channel	CNN International (June 2008)
Hardware distribution	ISPs	Telecom Italia (December 2006)
		Neuf (February 2008)
	MNOs	SFR (August 2007)
	Portable multimedia player vendor	Archos (June 2007)
		iPhone (August 2007)
Software distribution	Community Web site	Facebook (launch date not available)
	Market place Web site	EBay (September 2007)

Figure C.12: Overview of Dailymotion partnerships [Source: Dailymotion]

Future perspectives

Dailymotion will need to keep multiplying partnerships in order to reach more users and stimulate an increase in traffic. Even though it is the second online video sharing Web site worldwide, Dailymotion is still far from becoming a credible challenger to YouTube. As illustrated in Figure C.13, Dailymotion is currently only attracting a 1% share of global Internet users, compared with up to 18% for YouTube (and closer to 20% in recent months). Over the last year, YouTube has increased its Internet user reach by 4%, while Dailymotion has remained stable.

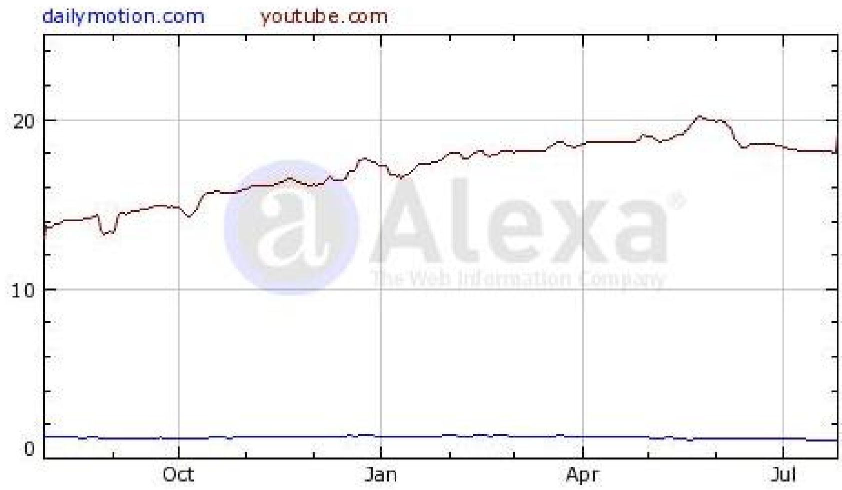

Figure C.13: Trend in Internet users reach (penetration) between August 2007 and August 2008 [Source: Alexa]

Advertising is still in its early stages on Dailymotion. It needs to develop its main source of revenue further, in order to be able to support the costs of supporting its video coding, hosting and transferring activities. This will be key to Dailymotion which, unlike *YouTube*, cannot rely on strong backing from a parent company in case of failure.

C.5 Amazon Unbox

Amazon Unbox is an online video download service launched by Amazon.com in September 2006 in the USA.

Services offered

Amazon Unbox is a video download service, including TV shows and films. Content offered include a mixture of latest box-office releases and popular American series, with older films, documentaries and shows.

Content is available for purchase or rental. Rental allows the user to keep content for up to 30 days, but content must be watched within 24 hours of starting to view it. The very latest releases are only available for rental, while series and non-premium content is only available for purchase.

The service is only available in the USA.

Technology and user experience

To be able to use the service, users need to download the proprietary media player *Amazon Unbox Player* using DRM. Videos may be downloaded in three formats, including standard PC/laptop format, TiVo DVR format and a portable format.

A feature allows users to start a download on a remote desktop (e.g. on the home PC from work), as long as that desktop is online, with the Amazon Unbox Player already installed.

An indication of download time for a 1.5Mbit/s DSL connection is provided for each film or show. However, user reviews indicate that download time is extremely variable, which stops users from knowing when the video will be ready to watch. A feature allows users to watch content once a sufficient proportion of a given video has been buffered. This proportion varies depending on the speed of the user’s connection and the length of the video.

In addition, users report a fair number of bugs and crashes, due to the service’s poor resistance to network instability.

Value chain and charging model

Amazon Unbox offers a video download platform to Internet users. Its position in the value chain is illustrated below.

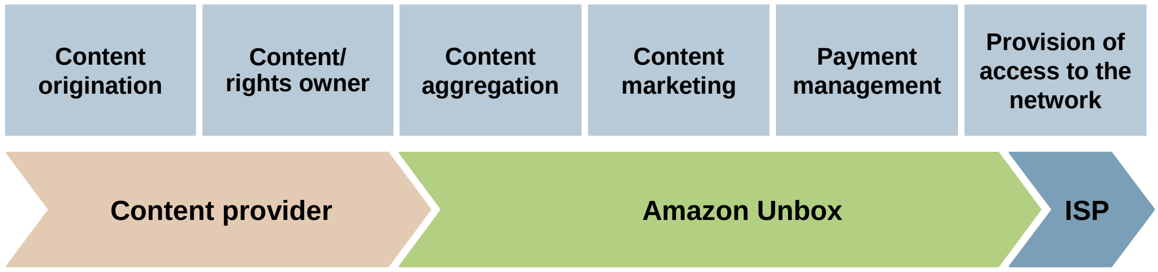

Figure C.14: Position of Amazon Unbox in the value chain [Source: Analysys Mason]

Amazon Unbox has a direct commercial relationship with the end user. Content may be purchased or rented. The following table gives an overview of Amazon Unbox pricing.

Content type	*Rental[66] price (USD)*	*Download price (USD)*
Films – latest releases	2.99 – 3.99	9.99 – 14.99
Films – older releases	Not available	1.99 – 9.99
Series (per episode)	Not available	1.99

Figure C.15: Overview of Amazon Unbox pricing [Source: Amazon Unbox]

Future perspectives

Amazon's video download service failed to attract large numbers of customers, due to extensive download times and lack of simplicity in the transaction process. In answer to current market developments going for streaming-based rather than download-based solutions, in July 2008 Amazon introduced a limited beta version of a new service dubbed Amazon Video On Demand. The service, based on a streaming solution, lets customers rent or buy ad-free films and TV shows. Users may watch the content instantly within their Web browser, without the need to download any proprietary application.

C.6 *Sky Anytime* TV and Sky Player

Sky Anytime is a service that pushes content to the Sky+ device, and Sky Player is Sky's online catch-up TV service (similar to iPlayer).

Sky Player was launched as Sky Anytime on PC by BSkyB ('Sky') in the UK in January 2006 and was rebranded as Sky Player in June 2008. A TV version of Sky's Video on Demand (VoD) service was subsequently launched in February 2007, dubbed Sky Anytime TV.

66 Rental allows the user to keep content for up to 30 days, but content must be watched within 24 hours after viewing is started.

Services offered

Sky Player offers online video content to both Sky and non-Sky subscribers. Content offered includes a range of films, series, as well as sports, news and children's shows. Content is available for download, for either rental or purchase.

Sky Anytime TV is a VoD service available to Sky TV customers owning a Sky+ or a Sky HD digital video recorder (DVR). Sky Anytime TV downloads a range of programmes selected by Sky, and customers may watch these programmes according to the content packages ('mixes') they have already subscribed to. Sky Anytime is a complementary service.

Technology and user experience

Users are required to download the Sky Player application to use the service. Content may only be downloaded (with the exception of news services, which are available through streaming).

Content downloaded with Sky Player is protected by Microsoft digital rights management (DRM) software, which prevents unauthorised viewing and automatically deletes the file once the licence to view expires. Content downloaded through Sky Player service may only be watched on a PC.

Sky Anytime TV uses a dedicated hard-drive space on Sky+ and Sky HD digital video recorders (DVRs) to download store up to ten programmes at a time. These are downloaded over the satellite network overnight on a weekly basis. This space is reserved for Sky Anytime content and may not be used by customers to record programmes of their choice with the standard recording feature. There is no waiting time for watching the programmes since these are already stored on the user's DVR. If not saved by the user in their personal storage space, Sky Anytime programmes are automatically deleted when the next download happens. Sky Anytime may be disabled by the user, but this does not make the reserved storage space available for personal usage.

Value chain and charging model

As illustrated in Figure C.16 below, Sky occupies a large part of the video content distribution value chain, with an involvement going from content rights ownership to provision of access to the network. This value chain is valid for both Sky Player and Sky Anytime TV services. For content delivery to non-Sky customers the provision of access to the network role would be assumed by another ISP.

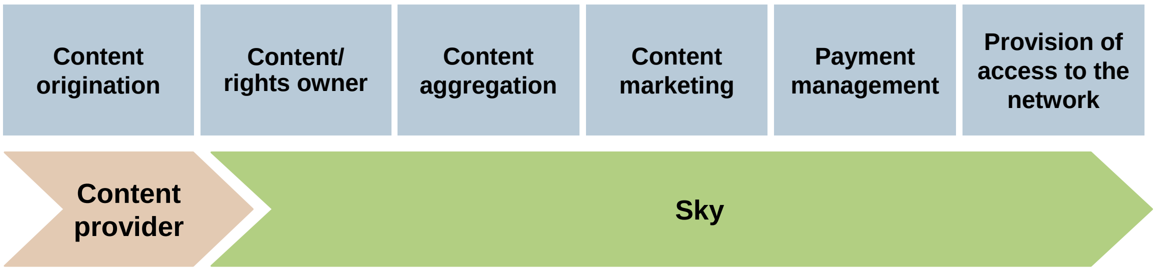

Figure C.16: Position of Sky in the value chain (for content delivery to Sky customers) [Source: Analysys Mason]

Pricing for content offered through Sky Player varies depending on the user's Sky subscription level: some content will be available free of charge, while further content can be purchased on a 'pay-per-view' (rental) or 'buy-to-download' (purchase) basis. Figure C.17 gives an overview of offering available to Sky and non-Sky customers.

Subscription	*Films*	*Sports*	*Other shows*
None	Not available	Sky Sports Highlights Pack at GBP5 per month	From GBP1 per show
Basic	About 200 films available at GBP3.99 per film	Sky Sports Highlights Pack at GBP5 per month Live Sky Sports TV on PC at GBP10 per month	From GBP1 per show, Sky News included

Figure C.17: Availability and pricing of content available to Sky and non-Sky customers [Source: Sky, July 2008]

Sky customers with specific content packages ('mixes') on top of their basic subscription are entitled to access to further free online content on Sky Player. This content is summarised in the table below.

Subscription	Movies	Sports	Other shows
Movies mix	500 additional films[67]		
Sports mix			
News and Events mix		Selected sporting moments from ESPN Classic	
Multiroom subscription		Live Sky Sports TV on PC	
Variety Mix			Series from Sky One
Knowledge Mix			Documentaries from National Geographic
Style and Culture Mix			Lifestyle and culture shows from Sky Arts and Sky Real Lives

Figure C.18: Overview of online content offered free of charge as part of specific Sky 'mixes' [Source: Sky, July 2008]

Sky Anytime TV is free of charge, but serves a marketing purpose. The content available to a given customer corresponds to that customer's content packages subscriptions. However, a complete range of content is downloaded for all customers; customers wanting to watch content outside their subscription are recommended to upgrade.

Future perspectives

At the end of Q1 2008, around two years after launch, Sky Player reported 2 million film downloads and 1 million sports and entertainment downloads, equivalent to more than 4000 a day. For a popular show such as Ross Kemp in Afghanistan, Sky Player only generates a 2% share of overall Sky viewing[68].

In March 2008, Sky Anytime TV was available to about 2 million households, corresponding to almost 60% penetration of all Sky+ and Sky HD households. Sky Anytime TV is claimed to be the sixth most viewed channel in households where it is available, corresponding to a 4% share of viewing for Ross Kemp in Afghanistan.

This compares with a 75% share for traditional broadcast viewing and a 12% share for personal recordings.

---

67 The free 500 films come in addition to and do not include the 200 films already available at GBP2.99 per film as part of the basic subscription.

68 Source: Sky Bear Stearns Media Conference 2008, SKY IN THE UK ENTERTAINMENT& COMMUNICATIONS LANDSCAPE.

C.7 BT Vision

BT Vision is an IPTV service that is exclusively available to BT Retail broadband subscribers. It uses a combination of Freeview and pay-TV services over a customer set-top box.

Services offered

BT Vision offers both broadcast content via DTT (i.e. Freeview and Setanta sports), and on-demand content. The on-demand content includes a film library, sport, US and UK shows, children's TV and music videos. The on-demand content also include a BBC catch-up service that is similar to iPlayer. BT Vision is available to all BT Retail customers of the BT Total Broadband service. There is no additional rental for the service and packages of content are optional. A free set-top box offers Freeview for digital TV channels and a hard drive for live recording: so most material will come from digital transmissions to a TV aerial – only the on-demand material needs special treatment via broadband.

Technology and user experience

To deliver a high-quality on-demand video service over the broadband network three technical aspects are important:

- giving the customer an assured 1.6Mbit/s channel for the session
- good-quality video compression of content
- caches located in the core network to store and forward live and recorded material.

The assured 1.6Mbit/s channel over the customer's broadband link is set up for the duration of the programme. It still allows simultaneous, best-effort Internet browsing for other devices using the link but ensures that the 1.6Mbit/s video channel is given top priority. Without this assured channel any live consumption of high-bandwidth video content is at the mercy of congestion caused by capacity limitations, which can result in freezing of the flow of material or a reduction in the quality of the video and audio streams. These limitations are the output capacity of the content servers, or restrictions in bandwidth in any part of the chain – which can be exacerbated by sudden peaks of demand. In the case of BT Vision, the assurance of the bandwidth is a function of IP Stream advanced services (downstream Quality of Service) which BT Retail rents from BT Wholesale.

BT Retail has chosen to compress its video stream content for transmission at 1.6Mbit/s, which is sufficiently high to match the quality of a Freeview channel but sufficiently low that it can be delivered to a higher proportion of BT Retail's broadband customers. The highest quality offered is MPEG4 – H.264. As with Freeview, the quality of pictures of fast-moving action (e.g. football matches) has limitations, with blurring of the edges of images.

BT has chosen to place the caches close to the ten BT IP Stream nodes in the core network. This choice may have been determined by the location of the Broadband Access Servers (BRAS) (see Annex D for more information).

The building blocks of the on-demand service are:

- a single BT Retail Head End feed content to the caches with updates to libraries and live video located at Telehouse in Docklands.
- caches (the Stream Node) to store and manage content which is streamed through the Retail Traffic Manager (RTMan) into BT Wholesale's aggregation points, the BRAS. The Stream Nodes and RTMans are sited close to each BRAS.
- a management system to communicate with the ADQ system and provide management of on-demand requests; to analyse and manage traffic (Retail Traffic Manager). Deep packet inspection ensures that a customer's service is not throttled by the Retail Traffic Manager (RTMan) – this traffic does not qualify for use towards monthly broadband download limits.
- BT IP Stream (rate adaptive up to 8Mbit/s, minimum 2Mbit/s required) from BT Wholesale provides the broadband access from the customer's Home Hub through the DSLAM and on to the BRAS. Its key components are:
  - network provider application driven quality of service (NP-ADQ), which provides the capability for a 1.6Mbit/s assured channel. Once this is enabled, the end user will be able to 'request' to watch a video and, generally within two seconds, that capacity will be set up. The residual capacity remains usable for 'best effort' applications. BT Retail has a real-time interface to BT Wholesale systems. 'Call' blocking is needed to stop demand exceeding backhaul or server capacity (<0.01%) which would otherwise degrade the service of those customers already receiving a video stream.
  - BT Central Plus, which gives access from the BRAS directly over the BT IP Backbone to the Internet at Telehouse without going via the service provider (i.e. BT Retail) network.

The BRAS, RTMan and Stream Node are located on the same ten core nodes.

The diagram below illustrates the key building blocks of BT Vision's on-demand service:

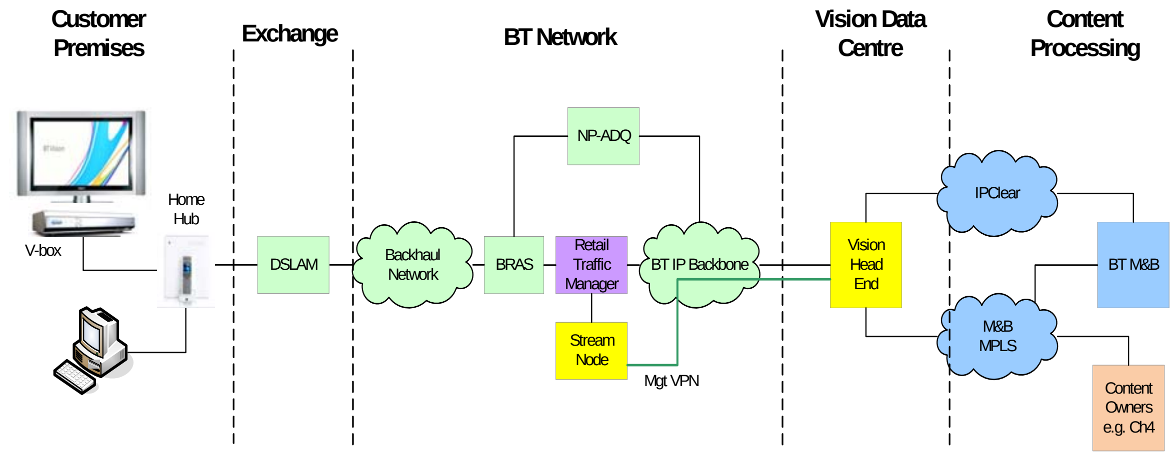

Figure C.19: *Network diagram for BT Vision [Source: Analysys Mason]*

The detailed steps in the process for setting up an on-demand video session are:

- The BT Vision customer requests an immediate on-demand video session, and this message is sent to the BT Vision head end at Telehouse
- The head end requests (from the NP-ADQ) a 1.6Mbit/s assured bandwidth channel from the home hub to the BRAS
- A message is sent back to the head end to say whether it has been successful
- The head end sends the Internet address of the stream node (cache server) to the V-box
- The set-top box initiates the video session
- The content flows from the stream node to the V-box
- The NP-ADQ returns the broadband to its default (best efforts) state at the end of the booked session or on request from the head end.

Value chain and charging model

BT Vision's position in the value chain is similar to a pay-TV operator using a satellite or cable based infrastructure.

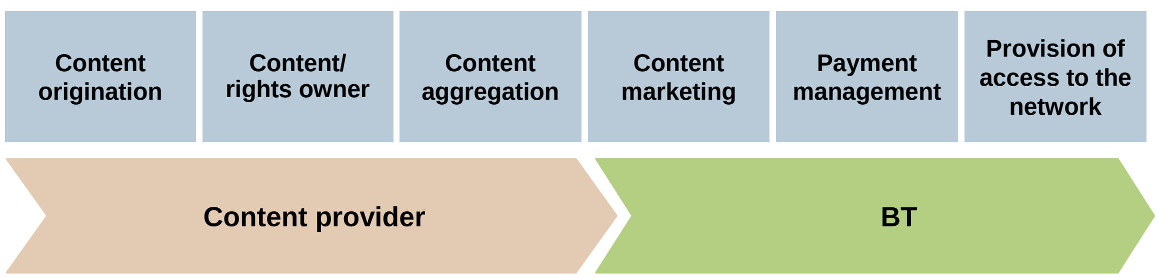

Figure C.20: *Position of BT Vision in the value chain [Source: Analysys Mason]*

The paid-for content on BT Vision is charged via either pay-per-view or subscription-based viewing packs. The pay-per-view content begins at GBP0.29 for music content, with TV shows starting at GBP0.79, and films ranging from GBP1.99 to GBP3.95 each. There is a variety of viewing packs that cover either specific types of content or bundles of content.

TV Replay is an add-on to the TV Pack which allows access to the last seven days of content from the BBC and Channel 4. TV Replay costs GBP3 per month (in addition to the GBP6 per month for the TV Pack). The TV Replay add-on is similar to the BBC iPlayer and the 4oD service from Channel 4, though it is worth noting that these services are free of charge on all other platforms. The TV Replay service used to be free of charge on BT Vision, but this was changed during 2008.

Future perspectives

At the end of June 2008, BT reported that it had 282 000 customers for BT Vision, with over 80% of new customers choosing to take a subscription package at the time of sale. BT stated that recent increases in the amount of content available (including football) have had a positive impact on subscriber numbers. Within the wider context of the UK pay-TV market, BT Vision has a small market share and it remains to be seen whether it can expand the business to a similar scale to Sky and Virgin Media. BT Vision currently only offers HD content to download and is unlikely to offer streaming HD content until its next-generation access network is deployed. The impact of the lack of streaming HD content has yet to be observed.

Annex D: Technical challenges in implementing caching at the exchange

The classical ADSL aggregation network uses a BRAS to aggregate and authenticate end-user connections. The end user connects using a point-to-point protocol (PPP) session between the network CPE and the BRAS within which all IP traffic transits. We understand that in the majority of UK broadband networks the BRAS is located in the core network – which typically has 20 or fewer sites. In the case of networks which offer wholesale services (e.g. the BT Wholesale network) the BRAS also has an important role in identifying the traffic from different service providers that are being supported.

When the aggregation network uses a BRAS, the BRAS performing the PPP termination is the first IP-capable node. If IP equipments such as caches or multicast servers are placed deeper and in a more distributed fashion than the BRAS, the outgoing traffic from those servers will have to be sent back to the BRAS first. This traffic is then sent on the PPP sessions to the end-user device.

There are two primary ways of modifying the network architecture so that a content cache can be efficiently located deeper in the network:

- move the BRAS deeper in to the network
- use a second IP session that bypasses the BRAS.

If the BRAS is moved deeper into the network this can involve either investing in a new BRAS that sits alongside the DSLAM in the exchange, or the purchase of a DSLAM with an integrated BRAS. The choice between these options may depend upon existing asset replacement cycles, and could also be affected by the future availability of other access technologies such as VDSL (which may lead to service providers preferring a separate BRAS). Whichever detailed solution is implemented, additional capital investments will be required.

By using a second IP session from the CPE it is possible to route specific types of traffic that need to be cached separately, thereby avoiding the BRAS which would be located in the core network. The second connection from the network CPE to the DSLAM could be either bridged or routed. The choice is very important, because the complexity of implementation and the service offered are not equivalent.

In a bridged mode, the network CPE would be equivalent to having two independent network CPEs, and there would be no cross traffic. This would be suitable for a closed environment IPTV solution. However, it is problematic when the end-user devices need Internet access (e.g. a setup box which would browse the Internet). This approach would not be suitable for services which need content to be delivered to a PC.

The alternative is to have a routed second connection. In this case, the network CPE acts as a router and has two IP connections to the rest of the network. The complexity of the network CPE increases, but so does the flexibility as it is much easier to control (even remotely) which way the traffic should be routed. The routeing table in the CPE will decide whether the data should be sent to the PPP link at the BRAS or the cache and multicast-enabled servers. Routeing information can be acquired dynamically on the second link through the use of DHCP options.

A schematic network diagram with a second IP session is shown in Figure D.21. In the absence of a second IP session, the traffic from the caching and multicast servers would need to pass through the BRAS as well.

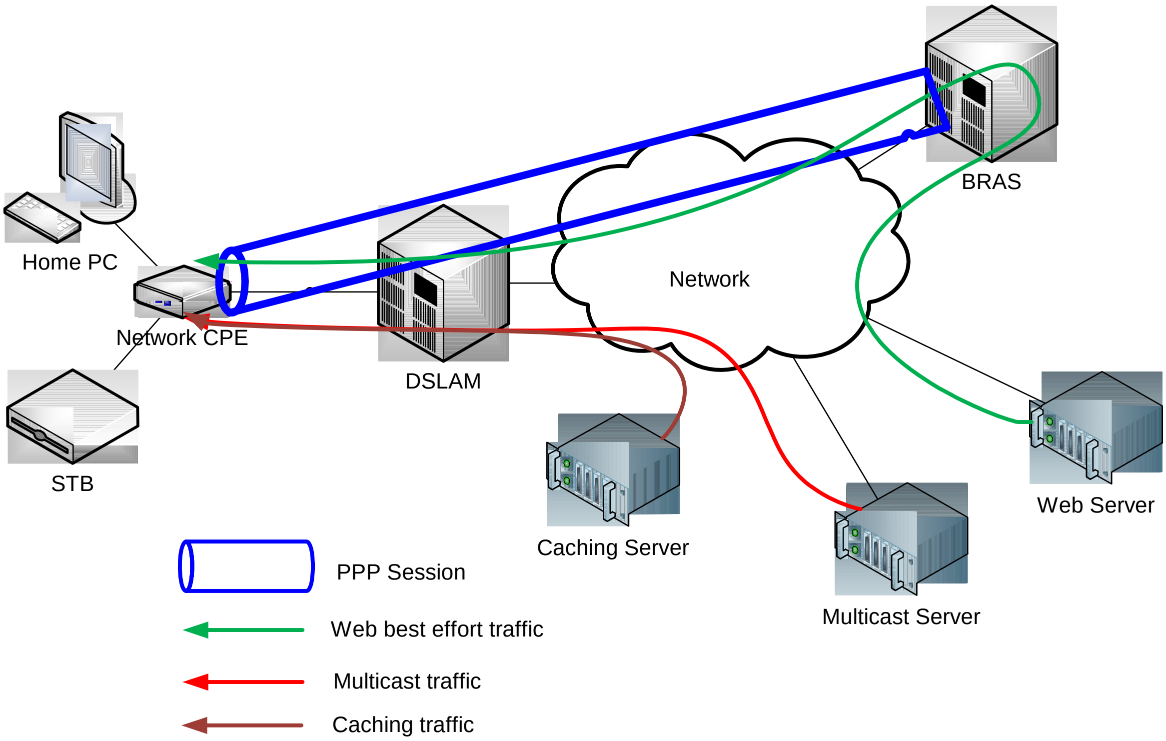

Figure D.21: *Network design with a second IP session [Source: Analysys Mason]*

Whichever approach is used for a second IP session will involve the use of new type of CPE, that may need to be standardised across the industry. Because of the complexity in replacing CPE, we believe it is more likely that a solution will be deployed that solely involves upgrades to the network. Our modelling of caching at the exchange therefore includes an allowance for costs of a new BRAS at the local exchange that could then route traffic which is to be retrieved from a cache collocated at the exchange.

Annex E: Results from technical and economic analysis

The following figures replicate the results of our analysis of the efficiency of the technical solutions, as carried out in Section 6.4.2. They compare the total monthly traffic cost per line for the base case with that involving the deployment of all technical solutions. The costs are higher in the final years as the same capacity is required, but the technical solutions involve operating costs. In practice, an operator may choose the remove the technical solutions at this point.

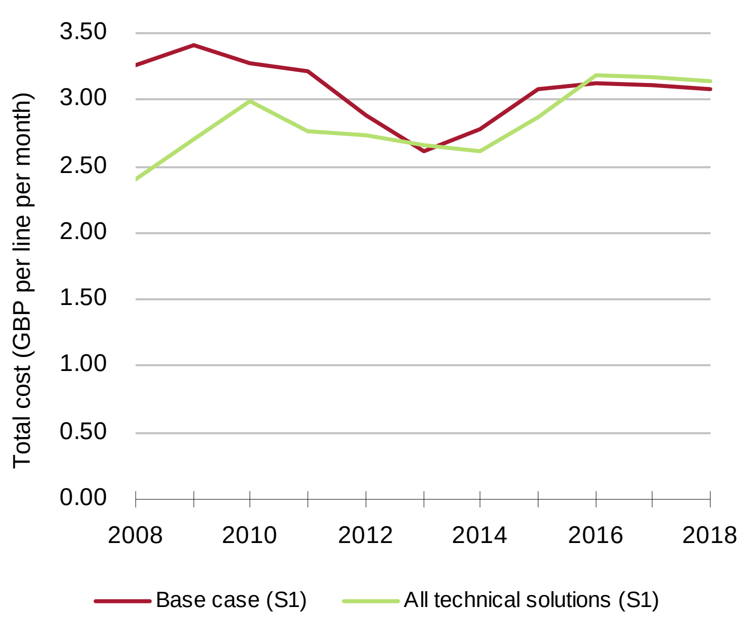

Figure E.1: Total monthly cost per line for a bitstream operator employing all technical solutions in Scenario 1 [Source: Analysys Mason]

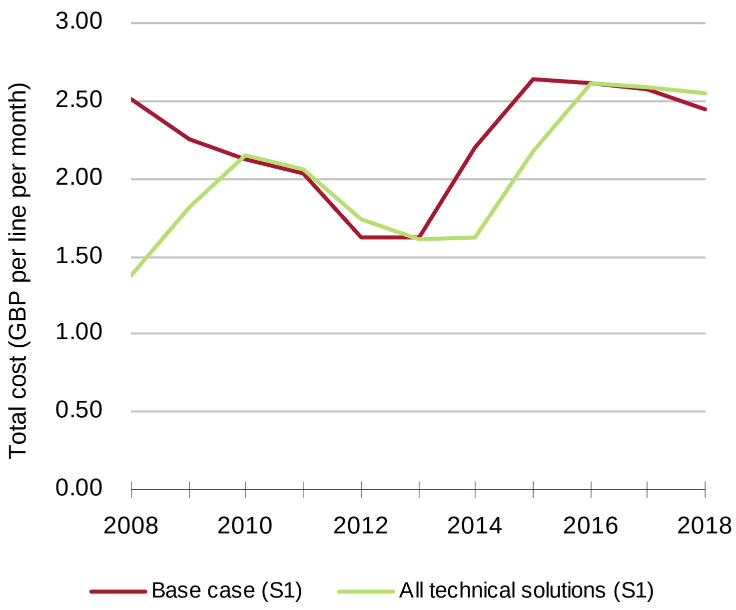

Figure E.2: Total monthly cost per line for an LLU operator employing all technical solutions in Scenario 1 [Source: Analysys Mason]

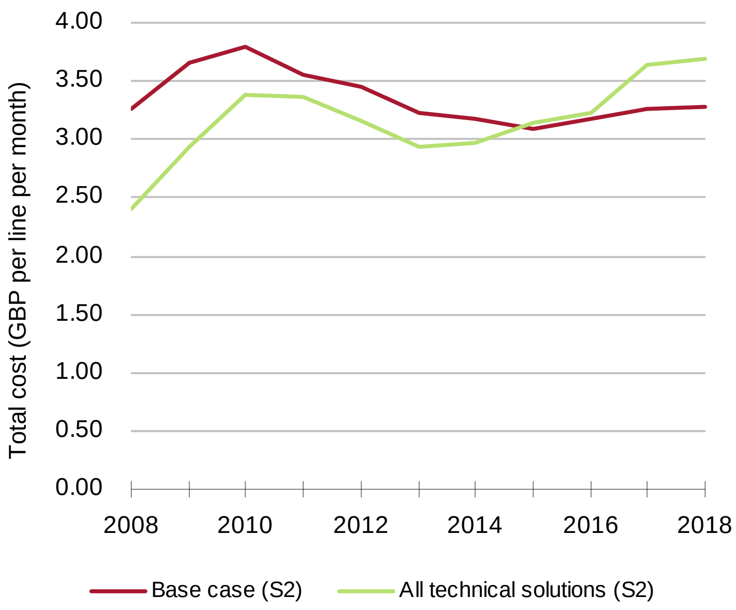

Figure E.3: Total monthly cost per line for a bitstream operator employing all technical solutions in Scenario 2 [Source: Analysys Mason]

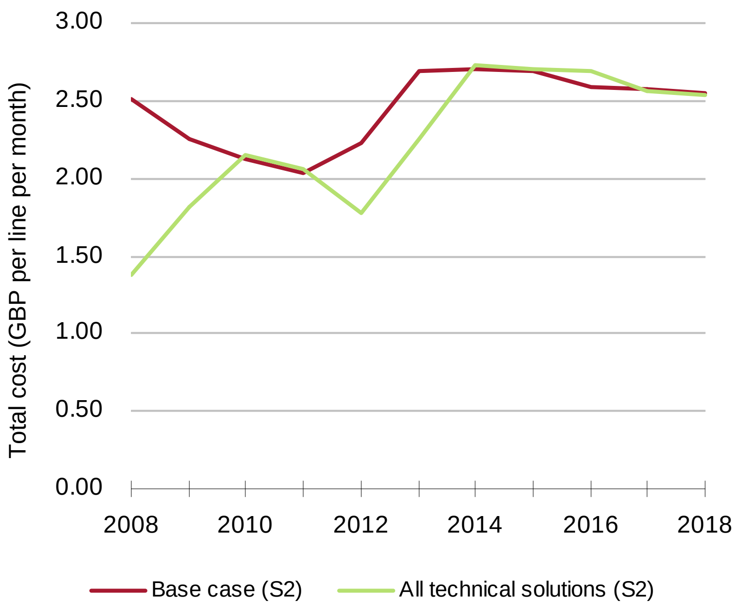

Figure E.4: Total monthly cost per line for an LLU operator employing all technical solutions in Scenario 2 [Source: Analysys Mason]

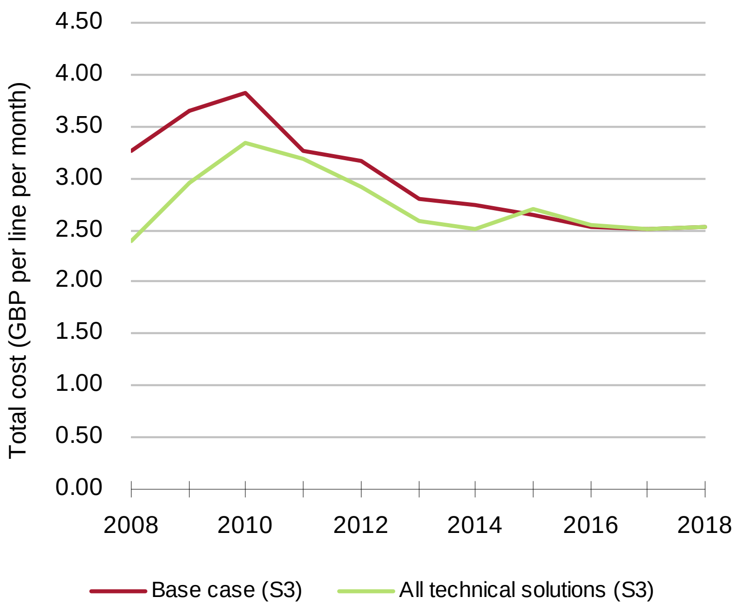

Figure E.5: Total monthly cost per line for a bitstream operator employing all technical solutions in Scenario 3 [Source: Analysys Mason]

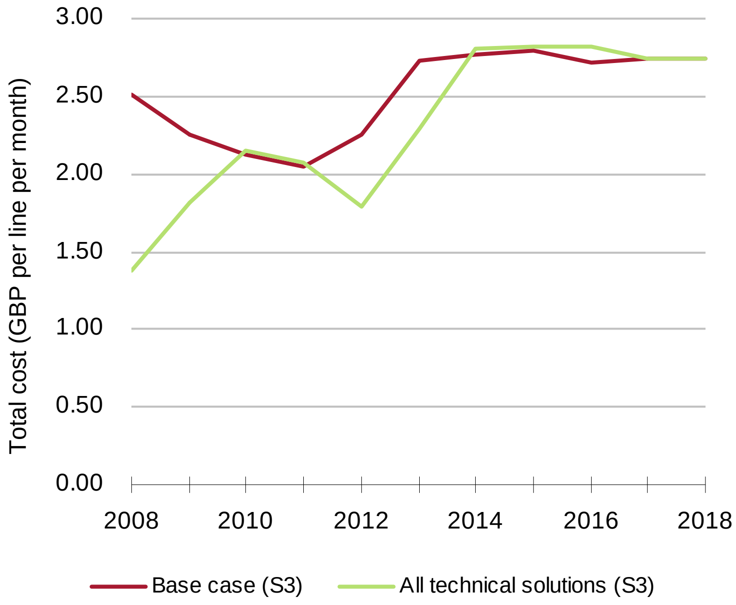

Figure E.6: Total monthly cost per line for an LLU operator employing all technical solutions in Scenario 3 [Source: Analysys Mason]

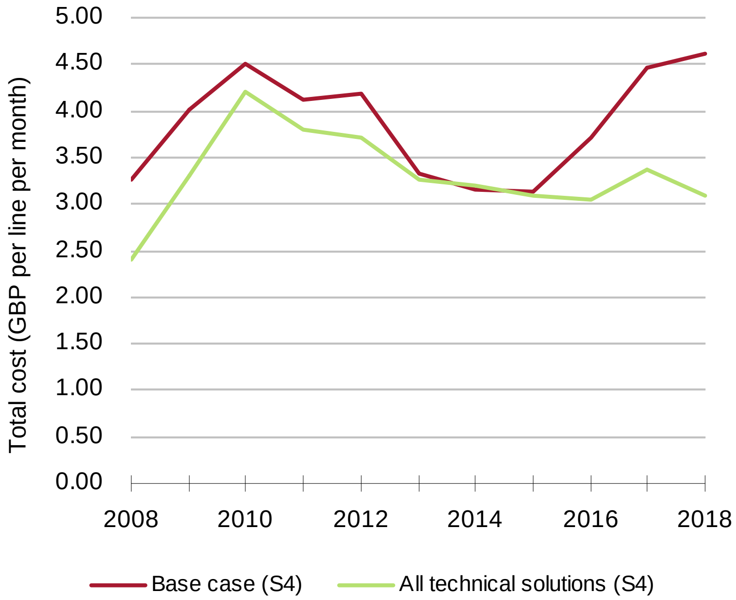

Figure E.7: Total monthly cost per line for a bitstream operator employing all technical solutions in Scenario 4 [Source: Analysys Mason]

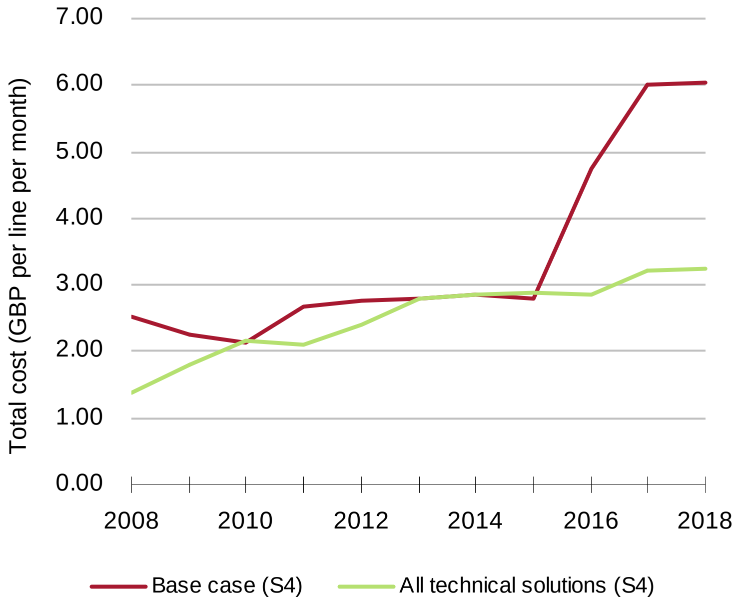

Figure E.8: Total monthly cost per line for an LLU operator employing all technical solutions in Scenario 4 [Source: Analysys Mason]

Annex F: Glossary

- **21CN:** the next-generation core network being deployed by BT.
- **bitstream:** a wholesale product, typically from an incumbent such as BT, that allows other operators to provide broadband connections on a wholesale basis. Bitstream does not require significant investment in infrastructure from alternative operators.
- **caching:** storage of content closer to the end user to reduce loads on networks by not having to transfer it across all of the network each time it is requested.
- **content distribution network (CDN):** a network that is designed to provide high-quality delivery of content from the servers of content owners to the final service provider. By combining caching servers and dedicated links, CDNs are able to provide a higher quality of service than the public Internet.
- **dark fibre:** fibre-optic cables that are rented on a wholesale basis without any equipment attached to them to 'light' the fibre.
- **dense wavelength division multiplexing (DWDM):** a technology that allows different 'colours' of light to be sent down fibre optic cables. This allows a single fibre to support total data rates in excess of 100Gbit/s.
- **Internet protocol (IP):** the protocol used for transferring packet-based data that underpins the Internet.
- **IP transit:** a service that allows a service provider to access the public Internet. IP transit is typically provided by large global network operators who charge smaller operators for data that transits their global networks.
- **IPTV:** Internet Protocol TV is a generic term for TV delivered over IP networks. In the context of this report we consider IPTV to be TV services delivered over a proprietary platform from an operator who also provides the broadband connection. Examples of this service include BT Vision and Tiscali TV.
- **local loop unbundling (LLU):** a suite of products supplied by incumbent operators (e.g. BT) to allow other operators to place their equipment in the telephone exchange and rent the copper access line to the customer's premises.
- **multicasting:** a technology that allows data to be broadcast over IP networks. This means that popular content that is being requested by many users at the same time (e.g. live TV) only has to be sent once across the network. Without multicasting, the data would have to be sent separately for each user.

- **next-generation access (NGA):** new access technologies that typically provide over 30Mbit/s of capacity to the end user. NGA technologies involve deploying fibre significantly closer to the customer than in ADSL-based networks.

- **next-generation network (NGN):** a core network that is completely based upon IP and that carries both voice and data over a single network. BT's 21CN is an example of an NGN.

- **peer-to-peer (P2P):** a set of network protocols and applications that allows users to share files via a distributed network with no central servers. It is often used to share copyrighted content without the permission of the copyright holder.

- **traffic shaping:** a technical solution which limits the bandwidth available to specific applications. It is commonly used during busy periods to limit the capacity that is used by peer-to-peer networks. These types of traffic (typically downloads) are targeted by traffic shaping as they are not time critical and the traffic can be delayed to quieter times of day.

- **VDSL:** Very high bitrates digital subscriber line (VDSL) is a technology that allows data rates of up to 100Mbit/s over very short copper lines. It is often deployed in conjunction with fibre to the cabinet (FTTC), where fibre is deployed within 500m of the customer premises.

- **video on demand (VoD):** a video service that allows users to watch content whenever they wish. It is most commonly used for films.

- **Wholesale Broadband Connect (WBC):** a bitstream product offered by BT Wholesale that uses BT's NGN.

- **Wholesale Broadband Managed Connect (WBMC):** a product from BT Wholesale that is similar to Wholesale Broadband Connect but also provides a managed connection to the public Internet.