FINAL REPORT for Ofcom

New service developments in the broadcast sector and their implications for network infrastructure

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## Abbreviations used

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<th>Abbreviation</th>
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<tr>
<td>AVC</td>
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<td>CDN</td>
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<td>eMBMS</td>
<td>Evolved multimedia broadcast multicast services</td>
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1 Executive summary

This document is the final report of a study carried out by Analysys Mason on behalf of Ofcom to assess the impact of developments in the UK’s broadcasting sector on the underlying network infrastructure. It is designed to inform and supplement the 2014 Infrastructure Report.

We note that DCMS recently ran a consultation to inform its digital communications infrastructure strategy. This considered a range of topics including existing and planned communications infrastructure; future demand scenarios; competition and regulation; and facilitating and encouraging investment. Whilst our report has been independent of that consultation, there is evidently some alignment on specific infrastructure matters.

This study is based on a comprehensive literature review, tested and further informed by a series of stakeholder interviews. The focus of this report is on network implications, and we do not seek to draw any conclusions on policy. As part of this study, we have evaluated traditional broadcasting networks, as well as IP networks used to deliver TV and video content, namely:

- DTT (managed by Arqiva)
- satellite (i.e. Sky, Freesat)
- cable (i.e. Virgin Media)
- home broadband (e.g. BT, TalkTalk, Virgin)
- mobile broadband (e.g. EE, Three).

We have considered both linear (traditional live broadcast, and streamed) content based on scheduled programming, and non-linear, on-demand content (catch-up TV and VOD). Furthermore, within the IP network sector, we include both operator-managed IPTV services, and OTT services provided by third-party content aggregators.

Our key findings are as follows:

- **4K** is about more than just the number of pixels – the increased pixel count (four times 1080p HD) will be imperceptible to the majority of viewers at normal viewing distances. However, a higher frame rate, better dynamic range, wider colour gamut, and high-definition audio are also key components of 4K and in combination these features do make for an improved viewing experience, especially of sport. In fact, the main driver for 4K is likely to be...

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1. Broadband networks operating using the Internet protocol.
2. Digital terrestrial TV.
3. Video-on-demand.
4. TV services delivered over broadband, offered by broadband service providers with end-to-end management of user-experience.
5. TV services provided 'over-the-top' of a third-party IP network, without end-to-end management of user-experience.
6. Also called ultra-high definition (UHD) TV.
New service developments in the broadcast sector and their implications for network infrastructure

live sports on linear TV; while for VOD services, 4K is a differentiator for some providers and may be an incremental revenue driver. 4K is already available on OTT, and satellite and IPTV are likely to launch services within two to three years. Overall, device limitations in terms of availability, price and take-up of devices with sufficient screen resolution affect potential 4K take-up across all platforms, and HEVC\(^7\) compression is needed to make delivery of 4K content more economic over all platforms.

- 4K services are already available on IP networks, and will be launched on satellite and cable within a 3-5 year timeframe; launch of 4K on DTT is unlikely before 2020 – Broadcast of 4K over DTT will require migration to DVB-T2\(^8\) and HEVC compression, which presents significant equipment compatibility challenges for migration. For satellite networks, delivery of linear 4K content is feasible in timeframe of three to five years without significant investment in infrastructure or STBs.\(^9\) The cable network will be able to support 4K linear programming once the MPEG-2\(^10\) transmission is switched-off. Based on the VDSL\(^11\) network specifications, IP networks should be able to deliver the required capacity for managed IPTV and OTT services, including 4K to most homes.\(^12\)

- Managed IPTV and OTT consumption will drive increased bandwidth requirements for home broadband services – consumers in the UK have access to a wide range of IPTV services, offering a range of content and with different pricing models and price points. OTT services are also prevalent, primarily for catch-up and on-demand services. Managed IPTV and OTT are complementary to broadcast viewing, but as their popularity increases, greater bandwidth in home broadband connections will be required.

- Video and TV consumption over mobile networks will experience considerable growth – the increasing availability of video and TV services for mobile devices and the falling costs of mobile data will drive consumption of video and TV services over mobile networks. The majority of this consumption will be on-demand or unicast based on OTT solutions will drive the consumption of these services over mobile networks. Mobile broadcast services may start to become commercially available from 2016–17, initially in localised areas such as sports stadiums.

- Rising levels of TV and video consumption will require operators to improve mobile network capacity – mobile data traffic is forecast to grow fourfold (2013-18), driven by video consumption. This will require a considerable increase in mobile network capacity.

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\(^7\) High efficiency video coding, an advanced compression technology.

\(^8\) Digital video broadcasting: second generation terrestrial – an advanced technical standard for the broadcast of DTT which provides a higher bitrate.

\(^9\) Set-top boxes.

\(^10\) Very-high-bit-rate digital subscriber line – a DSL broadband technology providing higher data transmission rates.

\(^12\) 95% of homes will receive a broadband connection of 24Mbit/s or more by the end of 2017
• **Roll-out of superfast broadband networks**\(^{13}\) to **99%** of households will enable more widespread adoption of TV and video services delivered over IP networks, either as a complementary or substitutional service to traditional broadcast. However, IP networks will face challenges in delivering like-for-like quality of service compared to traditional broadcasting networks as consumption behaviours start to converge. In particular, in-home connectivity will remain a challenge for ensuring end-to-end quality in the delivery of TV and video services over IP networks within a five-year timeframe.

• **Multicasting, caching and CDNs** can significantly ease capacity constraints for delivery of linear and on-demand content over IP networks and can be used to reduce the additional capacity provisioning required to support 4K services. Multicasting enables the delivery of a single stream of traffic per linear channel to multiple viewers (compared to unicast where each user request is delivered separately). Increasing network efficiencies can be gained by caching content closer to the end user. In particular, in-home caching of content could considerably reduce the volume of content being actively streamed over IP networks. Furthermore, CDNs\(^{14}\) can be used to ease the load on the fibre backbone and improve the customer experience through reducing latency and providing faster start-up times.

• **Over a five-year timeframe, hybrid models are likely to be the most economical means to meet the requirements for content consumption** in the UK, including high-capacity linear and on-demand services.

• **Deployment of LTE and LTE-A**, including carrier aggregation and small cell deployment will be required to support the growing demands on mobile networks – mobile network capacity will be significantly increased over the next five years, primarily by improving spectral efficiency through the use of LTE and LTE-A (including carrier aggregation) and through the deployment of small cells. Some additional spectrum may become available towards the end of our five-year timeframe. Small-cell deployment in particular will help to support TV and video consumption over mobile networks in areas of high traffic.

• **Caching and CDNs on mobile networks** can help to alleviate core network capacity requirements and improve the quality of service of video services over mobile networks – in a similar way to fixed IP networks, mobile broadband networks can alleviate the capacity requirements of delivering video and TV content and improve the quality of service through technologies such as caching and CDNs. The recent launch of a base station CDN product may drive take-up amongst mobile operators as video consumption increases. In the meantime, adaptive bitrates are commonly used to manage the quality of video delivered on mobile networks.

• **Device compatibility limitations will delay the launch of commercial mobile broadcast solutions for 1-2 years** – commercial mobile broadcasting solutions are likely to be launched from 2016 based on stadium solutions. Device compatibility will be an issue in the short term,

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\(^{13}\) Defined in the Infrastructure Report, 2013 Update (Ofcom, 24 October 2013) as "The next generation of faster broadband services, which delivers headline download speeds of greater than 30Mbit/s."

\(^{14}\) Content delivery networks use multiple servers deployed in data centres in various countries.
but chipsets are already becoming available. Content availability is likely to be limited in the near term, and will initially focus on major sports events. Nationwide mobile broadcast services based on broadcast solutions may start to become available towards the end of the five-year time horizon.

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In addition to these key findings, we summarise below our findings in relation to the specific set of questions posed by Ofcom:

1. **What are the key new service developments in the TV sector that have implications for the UK’s infrastructure?**

   We have identified three key service developments within the sector, namely:
   
   - a migration towards increasingly high-definition content
   - the emergence of managed IPTV and OTT as stand-alone services, and as part of a hybrid network delivery model
   - increasing consumption of TV and video services over mobile networks and the emergence of LTE broadcast.

2. **How will the network capacity required to deliver different resolution video services (including SD, HD, and 4K) evolve over time with improvements in digital compression and transmission technologies?**

   Over time, improvements in compression standards more or less offset improvements in video definition. However, transmission of 4K over HEVC today still requires around four times the capacity of SD over MPEG-2.\(^{15}\) Nevertheless, the HEVC standard is likely to become more efficient over the next five years.

   In addition, migration to more advanced transmission technologies, including DVB-T2 for DTT and DVB-S2 for satellite will enhance the capacity available using the same spectrum. On DTT, it will increase by 67%, for satellite around 30%.\(^{16}\)

3. **How well are these different capacity requirements likely to be compatible with different TV distribution platforms, from both a connection speed and network capacity perspective?**

   The ability to support 4K services varies by network. Superfast broadband networks are able to support 4K services using HEVC compression. The majority of legacy ADSL users will be able to access HD services, however, as of today; around 10% will be limited to SD content.\(^{17}\) 4K content is already available over IP in the UK.

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\(^{15}\) SD over MPEG-2 occupies 2.5-5Mbit/s, while 4K over HEVC occupies 8-20Mbit/s, see Section 3.2.4

\(^{16}\) See Section 4.2

\(^{17}\) See Section 4.3.2
Satellite networks have sufficient capacity to support 4K content on HEVC or even MPEG-4 AVC\(^\text{18}\), and are likely to be the next network on which 4K is supported. Similarly, cable networks will be able to support 4K, ideally using HEVC compression and after switching off their MPEG-2 transmission.

DTT networks will be able to support 1-2 4K channels (using HEVC compression) either on the temporary COM8 MUX or following the full migration to DVB-T2. However, end-user equipment compatibility will present limitations.

4. What are the likely timescales for the adoption of different TV distribution formats on different delivery platforms, in particular what are the likely service test and launch plans for 4k TV services on different delivery platforms in the UK?

4K services are already available in the UK over IP networks using OTT applications (YouTube, Netflix). We expect satellite and managed IPTV networks to be the next platforms to launch 4K from 2016-17, focusing on those with exclusive sports rights (i.e. Sky, BT Sport). Cable networks are likely to support 4K from 2018/19, but on the DTT platform 4K services are unlikely to be available within a five-year timeframe.\(^\text{19}\) Trials have already been undertaken on DTT, satellite and cable focusing on major sports events.

5. What are the different types of over the top and managed IPTV services available in the UK, including live streamed and on-demand services?

A wide range of managed IPTV and OTT services are available in the UK. These range from linear channels delivered over operator-managed IP networks to on-demand content provided over-the-top of a broadband network. Examples include TalkTalk, BT and EE’s managed IPTV services, OTT catch-up TV services such as iPlayer and 4OD, OTT linear TV services (based on retransmission of broadcast content), such as TVCatchup and VuTV, and OTT VOD services such as Netflix or YouTube.

6. What are the different types of converged broadcast and IPTV services available in the UK?

Converged or hybrid broadcast and IPTV services are offered by all the major players in the pay-TV market. Managed IPTV providers such as TalkTalk and BT offer hybrid DTT and IP services, offering both linear and on-demand content over IP. Sky and Virgin offer hybrid broadcast and IP services, using IP for on-demand content only. Arqiva enables channel operators to have a presence on the DTT platform (and EPG) whilst partially or fully delivering content over IP.

\(^{18}\) An advanced video compression technology which allows more efficient use of available bandwidth than the older MPEG-2 standard.

\(^{19}\) 4K launch on DTT could be earlier if COM8 (a temporary MUX) is used.
7. How well is the different delivery requirements for these different types of IPTV services (i.e. over the top and managed, streamed and on-demand, SD and HD etc…) being met by the UK’s broadband infrastructure?

Operator-managed linear IPTV services can be provided over superfast broadband or ADSL connections of 2Mbit/s or more (92% of households), using multicast technology. Superfast broadband connections will also be capable of managing widespread use of OTT services, however, ADSL networks may become congested and result in poor quality of service. By 2018, it is expected that 99% of households will be able to access superfast broadband services.20

8. To what extent is the delivery of these different types of IPTV services reliant on the use of specific delivery technologies such as content delivery networks, multicasting and superfast broadband?

As above, for delivery of HD and 4K content and consistent user experience at peak times, a superfast broadband service is required. Multicasting helps to alleviate backhaul network capacity for linear IPTV services and is used by all managed IPTV operators. Use of CDNs increases the quality of service and reduces core network transmission for on-demand and catch-up TV services. Content caching in the home may also become an important feature of TV and video delivery over IP networks.

9. What types of connected consumer devices such as tablet PCs, smartphones and games consoles are being used to access broadcast TV and on-demand video services in the home?

An increasing number of connected devices are being used to access broadcast TV and on-demand content in the home, including laptops, tablets and smartphones. This is being supported and enabled by OTT applications provided by the major pay-TV providers, including the Sky Go, Virgin Anywhere and BT Sport applications as well as third-party OTT applications (e.g. Amazon Prime, Wuaki.tv).

10. What are the implications of this type of use on the capacity and performance of in-home Wi-Fi networks and mobile networks?

Use of in-home Wi-Fi networks to deliver TV and video content can result in a poor quality of service owing to reduced signal strength where the router is a long way away from the consumption device and/or internal walls are constructed from a dense material such as concrete. The majority of managed IPTV providers require a fixed line connection, either Ethernet, powerline or coaxial cable. Where superfast broadband networks are used, TV and video consumption over IP should not significantly negatively affect use of Wi-Fi for other purposes, such as browsing.

Consumption of TV and video services over mobile networks may result in the congestion of a particular cell. This may impact use of other mobile broadband applications such as browsing, but will not impact voice services, which will use the 2G

20 See Section 4.1.1
network. Use of high-frequency small cells will help to offload video traffic from areas of heavy usage, leaving the macrocell network free for use by other applications. Use of LTE broadcast solutions will also alleviate capacity constraints on mobile networks.

11. How is the growth in mobile network capacity (supported by the use of smaller sized cells, more spectrum and more efficient delivery technologies such as 4G and multicasting) enabling the delivery of wider range of mobile video services and broadcast TV streams?

Significant increases in mobile network capacity enabled by the launch of LTE (subsequently LTE-A) and roll-out of small cells will enable mobile networks to support the growing demand for on-demand and linear video and TV content. In addition, in instances such as live linear TV viewing with stadia, LTE broadcasting solutions will enable mobile operators to efficient deliver video services without compromising the delivery of other mobile services (e.g. email, browsing).

12. Are their wider international developments in the broadcast TV, IPTV and mobile TV sectors that are likely to affect the future delivery of these services in the UK?

Beyond the current 4K service developments, 8K standards are being trialled in Japan, with the aim for launch in time for the 2020 Tokyo Olympics. We do not foresee launch of 8K services in the UK within a five-year timeframe. In addition, the application of nationwide LTE broadcast services is evident in South Korea where KT has launched 16-channel service. EE has already trialled LTE broadcast and commercial solutions focused on sports stadia are likely to be launched in 2016-17. The potential for OTT TV service take up is evident in the example of China, where around 69% of Internet subscribers make use of OTT services. Similar take-up levels could be seen in the UK, particularly with the use of catch-up TV services, however, these are likely to remain predominantly complementary to broadcast TV services. Similarly, the potential for IPTV service take-up is evident from the French example where penetration rates have reached around 40% of households. Based on current trends, take-up of IPTV services is likely to grow, however, we do not believe that managed IPTV services will reach the same levels as France owing to strong DTT, satellite and cable platforms.
2 Introduction

This report forms the conclusion of a study undertaken by Analysys Mason for Ofcom to assess the implications that new and emerging service developments in the broadcast TV sector will have for the UK’s network infrastructure. This is designed to inform and supplement the 2014 Infrastructure Report.

We note that DCMS recently ran a consultation to inform its digital communications infrastructure strategy. This considered a range of topics including existing and planned communications infrastructure; future demand scenarios; competition and regulation; and facilitating and encouraging investment. Whilst our report has been independent of that consultation, there is evidently some alignment on specific infrastructure matters.

As part of this study, we have evaluated both traditional broadcast networks, as well as IP networks used to deliver TV and video content, namely:

- DTT (managed by Arqiva)
- satellite (i.e. Sky, Freesat)
- cable (i.e. Virgin Media)
- home broadband (e.g. BT, TalkTalk, Virgin)
- mobile broadband (e.g. EE, Three).

We have considered both linear (live, streamed) content based on scheduled programming, and on-demand content (catch-up TV and VOD). Furthermore, within the IP network sector, we include both operator-managed IPTV services, and OTT services provided by third-party content aggregators.

Our study is based on a comprehensive review of existing literature and analysis on these topics, further informed by and tested against a series of stakeholder interviews.

The remainder of this document is laid out as follows:

- Section 3 describes new service developments in the broadcast TV sector in the UK, namely:
  — an overview of services, devices and consumption habits (Section 3.1)
  — trends and development in 4K content (Section 3.2)
  — availability and take-up of managed IPTV and OTT content, including hybrid models (Section 3.3)
  — trends in consumption of TV and video services over mobile networks (Section 3.4)

- Section 4 considers the likely impact on broadcasting and broadband networks of these service developments. Within this we consider:
  — the networks and platforms used to deliver video content, and their coverage and quality (Section 4.1)
— the ability of traditional broadcasting networks to deliver increasingly HD content (Section 4.2)
— the ability of IP networks to deliver TV and video content, and the technologies that can support this (Section 4.3)
— hybrid models that can be used to meet new and emerging service developments (Section 4.4)
— delivery of content over mobile networks, including broadcast solutions (Section 4)

Within Section 3 we include a number of case studies illustrating wider international developments in the broadcast TV, IPTV and mobile TV sectors. The case studies are presented in the following format:

**Case study format**

At the end of each sub-section we also include a summary of the findings or conclusion in the following format:

**Sub-section conclusions**

The report includes a number of annexes containing supplementary material:

- Annex A provides a list of the main sources used as part of the literature review.
- Annex B includes a list of the industry stakeholders interviewed.
3 New service developments

In this section we first present the wider context for TV and video services in the UK, describing the services, consumer devices and consumption habits found in the broadcasting sector. We then consider new and emerging service developments within the sector. The three primary service developments identified are:

- a migration towards increasingly high-definition (and therefore high-capacity) content
- the emergence of managed IPTV and OTT as stand-alone services, and as part of a hybrid network delivery model
- increasing consumption of TV and video services over mobile networks and the emergence of LTE broadcast.

3.1 Overview of services, devices and consumption habits

In recent years, the UK broadcasting sector has grown in complexity and has become increasingly fragmented. Below, we discuss three major themes: the way in which content is consumed; the devices it is consumed on; and the service provider and payment models used.

*Linear consumption continues to dominate, but there is increasing consumption of on-demand content which is driving requirements for IP-connected devices*

Ofcom’s 2014 *Communications Market Report* (CMR) confirms that linear viewing remains the most popular way of consuming broadcast content in the UK: as shown in Figure 3.1 below, live TV still makes up 70% of the average daily consumption of video content. Feedback from stakeholders confirms that linear viewing is resilient, and is likely to remain so for at least the next few years.

![Figure 3.1: Average time per day spent on selected types of video content](Source: Figure 2.20, Communications Market Report, Ofcom, August 2014)
New service developments in the broadcast sector and their implications for network infrastructure

However, alongside linear content consumption, catch-up TV and VOD services are being used by an increasing proportion of consumers: according to the CMR, 50% of respondents stated that they had used VOD services within the past 12 months in H2 2013, and 38% had used BBC iPlayer in the last month alone in Q1 2014. Whilst previously this non-linear viewing was supplementary and used mostly for short-form content, it is now becoming increasingly common for long-form content as well. This behaviour is driving requirements for IP-connected devices.

*The number of connected devices per household on which to consume media is growing, and increasingly primary sets are connected to an IP network*

Considering now the consumer devices used to view content, there are two key trends: an increasing number of devices, and the prevalence of connected TVs and STBs.

TV and video content can now be consumed on an increasing number of connected devices, including laptops, tablets, e-readers and smartphones. This has enabled a much more personal viewing experience, meaning that within a single household there may be multiple video services being consumed simultaneously, in some cases by the same individual (e.g. viewing content on a tablet whilst also watching the main TV).

An increasing number of primary TV sets are being connected to IP networks, in some cases with the help of an STB or Wi-Fi device (e.g. Google Chromecast). This enables a wider range of content to be consumed on the primary TV set, not just the linear stream or services provided by a single TV broadcaster.

*The number of TV and video service providers has grown considerably, accompanied by an array of payment models, allowing the take-up of multiple services by consumers*

As a result of connected devices and TV or video applications, the barriers to entry for TV service provision have reduced considerably, and a large number of service providers have emerged. These service providers use a wide range of different payment models, including:

- subscription (linear channels)
- subscription (access to a VOD library)
- catch-up (free)
- VOD (free)
- pay per view (PPV)
- download to own (DTO)
- download to rent.

Furthermore, any individual or household may use several different services within a single month: they are no longer limited to a single service provider.

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21 Figures 2.18 and 2.19, Communications Market Report, Ofcom, August 2014
To a large extent, it is these trends that are driving the migration towards IPTV, which we explore in detail in Section 3.3. In this report, TV services delivered over IP networks are split between ‘managed IPTV’ and ‘OTT’. Managed IPTV refers to services delivered over broadband, offered by broadband service providers with end-to-end management of user-experience. OTT services refer to TV services provided ‘over-the-top’ of a third-party IP network, without end-to-end management of user-experience. Before that we consider the potential future requirements of TV and video delivery networks in terms of the definition of the content.

3.2 Ultra high definition (4K)

This subsection describes the demand-side trends in the TV industry in terms of the latest improvements in TV displays. One of the key components in the evolution of the quality of TV displays is the continuous increase in pixel resolution. In recent years, screens have evolved from standard definition (SD, 720x576 pixels), to high definition (HD, 1280x720 or 1920x1080 pixels). The latest generation that consumers are able to purchase is known as 4K (3840x2160 pixels), which is the first of the two UHD formats that have been defined so far. Commercial 3D TV services were launched in 2010 by Sky, but have failed to get significant traction, with the BBC terminating its 3D programming in 2013.

Whilst 4K TVs are commercially available in the UK, take-up is nascent, and there is a limited amount of 4K content available. The OTT provider Netflix launched a small selection of 4K programmes in June 2014, and the launch of 4K content on certain other platforms seems likely in the next couple of years as more consumers purchase compatible devices and there comes to be a viable business case. Take-up of 4K is likely to be driven by sports content, as broadcasters can take advantage of other benefits of 4K beyond screen resolution (for example, higher frame rates) – see below.

The transmission of a 4K channel requires around double bandwidth in the broadcasting or IP networks, though this effect can be counteracted to some extent through the use of more advanced compression technology known as HEVC (high efficiency video coding).

3.2.1 4K offers several improvements, not just in pixel count

As well as providing greater screen resolution, 4K has the potential to offer a number of other features that will improve the viewing experience. These include the following:

- **Frame rate** – the rate at which the image is refreshed, measured in frames per second or hertz (Hz). There are two techniques for managing the frame rate: interlace and progressive. For

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22 Different formats are frequently defined in terms of their pixel count, i.e. the number of horizontal and vertical pixels that comprise the image on the TV screen – e.g. HD typically has a pixel count of 1280x720. Sometimes the pixel count is abbreviated by just specifying the vertical count (i.e. the number of lines on the screen), so HD 1280x720 may be referred to as 720p.

23 The more advanced UHD format is called 8K (7680x4320 pixels), but this has yet to be implemented commercially.

interlace, only half of pixels (every other line) are updated at a time, so that a complete refresh requires two frame changes. In contrast, with progressive scan the entire image is updated at each frame change.

- **Dynamic range** – the maximum contrast ratio of the image, i.e. the range between the lightest and darkest image possible.

- **Colour gamut** – the range of colours that can be reproduced accurately, measured as a percentage of the full range (‘colour space’) that can be displayed.

- **Audio quality** – the quality of the sound transmitted alongside the video content.

Figure 3.2 compares HD and 4K TV systems in terms of these features, as defined by the ITU-R\(^{25}\) and EBU\(^{26}\) recommendations.\(^{27}\) Pixel count, frame rates and colour gamut have been standardised (though a range of frame rates is included), but dynamic range and audio quality have not.

*Figure 3.2: Specifications of HD and 4K TV systems [Source: Analysys Mason, 2014; EBU Policy Statement on Ultra High Definition Television, 2014; Recommendation ITU-R BT.2020-1,\(^{28}\) 2014; Recommendation ITU-R BT.709-5, 2002]*

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<tr>
<td>Dynamic range</td>
<td>There does not appear to be a standard for this set by the ITU, though it is expected that wider dynamic range will become a key feature of improved image quality on 4K TVs in the future</td>
<td></td>
</tr>
<tr>
<td>Colour gamut (% of colour space)</td>
<td>35.9%</td>
<td>75.8%</td>
</tr>
<tr>
<td>Audio quality</td>
<td>Whilst no audio standard is identified in the ITU recommendations, the EBU identifies ‘immersive audio’ as a means of improving the user experience</td>
<td></td>
</tr>
</tbody>
</table>

Although pixel count is the most widely marketed feature of 4K TVs, there is some doubt over whether under typical viewing conditions the human eye is able to perceive the improved pixel count compared to HD. An analysis of the separation between pixels and the maximum distance at which the eye is able to distinguish separate pixels is shown in Figure 3.3 below, and suggests that viewers would have to be seated very close to a large-screen TV in order to notice the difference in pixel resolution between HD and 4K. It is clear that there are diminishing returns in viewing experience as the pixel count increases beyond HD.

\(^{25}\) The part of the International Telecommunication Union that develops standards for the radiocommunication sector.

\(^{26}\) European Broadcasting Union.


\(^{28}\) Recommendation ITU-R BT.2020-1 also states the pixel count for 8K (7680×4320), though 8K technology is not considered in detail in this report.
If a viewer is watching 4K content on an 85 inch (2 metre)30 screen (the largest 4K TV commercially available in the UK), the maximum distance at which they can discriminate individual pixels is around 1.7m – much closer to the screen than most viewers would consider comfortable. At a more normal viewing distance of around 3m, viewers would only benefit from 4K resolution if the screen were around 150 inches (3.8m) in size, which is far beyond practical limits in terms of the size of the average living room, current commercial availability, and affordability. We note, however, that such huge screens may be used for other purposes, e.g. as advertising displays, or for special events.

However, 4K may be more beneficial for smaller, second-screen devices such as smartphones and tablets. For example, the maximum pixel viewing distance for an iPad Air showing 4K content is around 20cm which, while still very close, is more feasible than the TV viewing distances described above. Furthermore, this type of device has a shorter replacement cycle than TVs, which means we are likely to see more rapid adoption. Apple advertises its MacBook Pro as having ‘Retina display’ with a resolution of 2560×1600 pixels, around halfway between HD 1920×1080 and 4K. Apple attests that the resolution is so high that it is not possible to discern individual pixels at a normal viewing distance,31 and Figure 3.3 (above) confirms this.

29 Based on the ability of a human eye with 20/20 vision to distinguish objects a minimum of 1 arcminute (1/60 of a degree) apart. It is assumed that SD, HD and 4K displays have 1024, 1920 and 3840 pixels horizontally, and that these screens have an aspect ratio of 16:9.
30 Measured diagonally – the standard convention among TV manufacturers.
31 http://www.apple.com/uk/macbook-pro/features-retina/
Although the benefits of greater pixel resolution are not yet proven for the mass market, the higher frame rates included in the ITU’s standard for 4K can improve the viewing experience (as evidenced during the BBC’s trials at the Glasgow Commonwealth Games, where a frame rate of 100Hz was trialled, and positively received by viewers). The improvement is most noticeable for complex and fast-moving images, such as in sports programmes and action films.

The impact of increased colour gamut is also significant, though it appears that not all commercially available 4K TVs have incorporated this development yet. The DVB has approved the specification for Phase 1 of the DVB-UHD standard, which includes a frame rate of up to 60Hz and higher dynamic range as well as a higher pixel count. Phase 2 is expected to include even higher frame rates.

The view that frame rate, dynamic range and colour gamut are more significant aspects of 4K than pixel count is supported by content producers and industry bodies.

4K is about more than just the number of pixels – improvements in frame rate, dynamic range, colour gamut and audio quality are also key components. The higher pixel count of 4K will be imperceptible for most users, though mobile devices such as tablets held 20cm or less from the user may be an exception. In fact, the greater frame rate is likely to be the key differentiator, especially for sports content.

3.2.2 The availability of 4K content is relatively limited, but is set to increase

Overall, there is limited availability of 4K content at present – though there is some variation depending on the type of service provider (4K is already available from some OTT providers). In order for this situation to change, there needs to be development across the whole chain of production and distribution of content, from the recording and storage of content, through to its broadcast. At the most basic level, in order to produce 4K content, appropriate recording equipment is required. The degree to which 4K professional recording equipment is used varies depending on the type of content. Film production has been in 4K for quite a few years, but content has not always been transferred, screened or archived at this resolution, due to the high costs of post-production. TV production lags behind: some TV and sports producers have started recording in 4K (see below for examples), but in the wider industry equipment upgrades are likely to be required. Overall, recording equipment does not appear to be a major barrier to the development of the 4K market.

32 See http://www.bbc.co.uk/rd/blog/2014/08/higher-frame-rate-television-for-future-broadcasts-at-the-commonwealth-games-but-i-already-have-a-100hz-tv
33 See http://hometheaterreview.com/the-colors-the-thing-that-will-make-4k-so-amazing/
34 The Digital Video Broadcasting Project develops standards for
35 See http://www.hdtvtest.co.uk/news/dvb-4k-201407043842.htm
36 Based on our stakeholder interview process – see Annex B for details.
37 See http://www.ctvnews.ca/sci-tech/after-earth-among-1st-movies-to-be-shot-shown-in-4k-1.1305890
From a consumer perspective, the range of 4K content available is small, though some content producers and distributors offer more than others. Film studios and content aggregators are partnering with each other as well as manufacturers, and pay-TV platforms are undertaking trials, but only YouTube and Netflix have commercial 4K content for consumers in the UK.

Below, we consider 4K developments by film studios, content aggregators and broadcasters, and pay-TV platforms.

**Film studios**

- **Sony** launched a 4K video download service in 2013 which includes over 70 feature-length films from the company’s own studios and other production houses, though this is not yet available in the UK.\(^{38}\)
- **Warner Bros.** and **20th Century Fox** have entered into partnership with Amazon and Samsung to distribute 4K content via Amazon’s video download and streaming services.\(^{39}\)
- **Paramount Pictures** have partnered with Samsung.\(^{40}\)
- **Universal Pictures** have remastered 13 of their classic films in 4K, achieving improvements over the original negatives.\(^{41}\)
- **Walt Disney Studios** have emphasised the importance for the film industry of the higher dynamic range and wider colour gamut offered by 4K, not just the higher resolution.\(^{42}\)

**Content aggregators and broadcasters**

- **YouTube** has supported 4K since 2010.\(^{43}\)
- **Netflix** started offering *House of Cards* (original content) as well as *Breaking Bad* and some content from Sony Pictures in 4K in the UK in June 2014.\(^{44}\) In October 2014, the company announced price rises for access to 4K content in the USA, from USD8.99 per month (within its HD bundle) to USD11.99. This increase was explained as due to the “increased costs of

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41 See http://www.4kshooters.net/2014/07/12/4k-digital-restorations-bringing-classic-films-back-to-life/
44 See http://techblog.netflix.com/2014/06/delivering-netflix-in-ultra-hd-4k.html
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producing, acquiring, and distributing 4K content”. 45 4K content is also available in the UK on the Ultra HD package for GBP8.99 per month. 46

- **Amazon Prime Instant Video** will include original content in 4K on Samsung devices from October 2014. 47

- **Wuaki.TV** is developing a 4K app to be available on compatible smart TVs by the end of 2014. 48

- **BBC** has trialled 4K at Wimbledon 2013, the 2014 World Cup final and the 2014 Commonwealth Games (during which higher frame rates of 100Hz were used). 49

- **Formula 1** delivered a live feed in 4K from the Singapore Grand Prix to its technical headquarters in the UK. 50

**Pay-TV platforms**

- **Sky** trialled a live broadcast of the English Premier League in 2013, and is planning to introduce 4K-compatible STBs known as ‘Project Ethan’, which will also use cloud storage for personal video recording. 51

- **BT’s** media and broadcast unit is carrying out 4K trials for sport this year, and partnered with the BBC and Arqiva for the trial of the 2014 World Cup final. 52

- **Virgin Media** partnered with BBC during its trials at the Commonwealth Games, but has said that 4K is not a priority for it at present. 53

- **Outside of the UK** there have been other significant developments:
  
  — Japan launched a 4K test channel in July 2014, and Sky Perfect JSAT (a Japanese satellite broadcaster) has announced plans to launch two 4K channels in March 2015, to include sports, entertainment and factual content. 54 (For more details see Case study 1 below.)

  — A commercial 4K channel launched in South Korea in April 2014, as a partnership between major cable operators. (For more details see Case study 2 below.)

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45 See http://www.theverge.com/2014/10/12/6965087/netflix-subscription-price-increase-for-4k-streaming
46 Pricing as of 13 October 2014.
47 See http://www.wired.co.uk/news/archive/2014-08/28/amazon-4k-samsung
48 See http://www.engadget.com/2014/09/05/wuaki-tv-4k-streaming/
51 See http://www.staff.tv/sky/project-ethan-revamp-will-transform-sky-s-set-top-box-service/news
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Sky Deutschland has plans for a 4K service towards the end of 2015, and has emphasised the benefits of 4K beyond pixel count, though it has identified that the lack of devices compatible with HEVC compression is a bottleneck.55

In terms of home video, in 2015 the Blu-ray specification is to be upgraded to include 4K; compatible films and devices are scheduled to be commercially available in late 2015. In addition to 4K resolution, it has been announced that the new specification will include greater dynamic range, a wider colour gamut and HEVC compression.56

Currently the amount of 4K content available is relatively limited, but is set to increase as more trials take place and manufacturers partner with OTT service providers. In the UK, 4K content is available on YouTube and Netflix, and is due to launch on Amazon Prime Instant Video. The BBC and pay-TV platforms such as Sky, BT and Virgin have carried out 4K trials.

Case study 1: Japan – Driving UHD broadcasting in time for the 2020 Olympic Games

Underpinned by the interests of major consumer electronics companies, Japan has historically been at the forefront of research in higher resolution TV broadcasting. The 2020 Olympic Games in Tokyo will provide Japan with the opportunity to continue to innovate in this space. The Ministry of Internal Affairs and Communications has committed to the development and commercial deployment of UHD TV (both 4K and 8K formats) before the start of the games.57

To achieve this, the public service broadcaster NHK has partnered with manufacturers to pursue a holistic approach to the deployment of UHD technology, including displays, transmission and receiver systems and cameras. Panasonic has developed a 145 inch (3.68m) plasma display panel for demonstrations. Manufacturers are hoping that being at the forefront of this technology will help strengthen their position in the international TV set market.58

In June 2014, Japan completed a trial broadcast of a 4K channel (known as Channel 4K) via satellite, with a frame rate of 60Hz. However, given the low penetration of compatible devices in households, the service was most easily accessed in consumer electronics showrooms.59 Commercial services are expected to be launched from spring 2015.60

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56 See http://www.blu-ray.com/news/?id=14923
NHK also broadcast nine matches from the 2014 World Cup in 8K to four cities in Japan, and three screens in Rio de Janeiro, including a 330 inch (8.38m) display.\textsuperscript{61} Other testing by NHK has demonstrated that 8K can be transmitted in 85Mbit/s of bandwidth with HEVC.\textsuperscript{62} Experimental broadcasts of 8K are expected in 2016, with commercial services going live over satellite in time for the 2020 Olympic Games.\textsuperscript{63}

Whilst Japan appears to be at a more advanced stage in the development of UHD-TV services than the UK, the challenges faced are not that different. Despite the greater availability of 4K content in Japan, compatibility of devices is a global issue – particularly for 8K, for which devices are not yet commercially available.

**Case study 2: South Korea – First launch of a commercial 4K broadcast channel**

In April 2014, the South Korean content aggregator Homechoice launched the world’s first commercial linear 4K channel with a frame rate of 60Hz, known as UMAX. The channel is on air 20 hours per day and broadcasts 40 programmes, including films, documentaries and animations. There are plans to expand the range of content to include live sports by the end of the year.\textsuperscript{64}

The channel is jointly funded by, and available from, the country’s major cable operators (CJ Hellovision, C&M, T-Broad and HCN) at no additional cost. By partnering with each other, the cable operators have been able to share the costs of launching 4K and providing a range of content, removing some of the risk associated with launching individually.\textsuperscript{65}

The UMAX channel does not require an STB, but does require HEVC-compatible 4K TVs (some may require a software upgrade). A bandwidth of 32Mbit/s is used, which is higher than the rate used by Netflix for its 4K service.

No announcements have been made with regards to the launch of 8K in South Korea.

### 3.2.3 Take-up of 4K devices is likely to be slower than for HD

*Current take-up of HD and 4K*

HD services were launched in the UK in 2006 on Sky’s DTH platform, for GBP10 per month on top of the standard subscription fee. As seen in Figure 3.4 below, take-up of HD services rose steadily from 3% in 2007 to 48% in 2013.

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\textsuperscript{61} See http://www.studiodaily.com/2014/07/the-world-cup-was-the-biggest-experiment-yet-for-4k-and-8k-broadcast/


\textsuperscript{64} See http://www.cedmagazine.com/news/2014/04/4k-goes-live-in-south-korea

As Figure 3.4 shows, the take-up of HD TV sets actually preceded the availability of HD broadcast content, mainly due to the promotion of Blu-ray DVDs. Furthermore, once HD services had been launched (at first on Sky’s pay-TV platform), take-up of HD devices was probably accelerated by the fact that consumers had begun to replace their TVs in preparation for the digital switchover (DSO) in 2012.

Turning to 4K, compatible TV sets have only been available in the UK in the last couple of years, and their specifications have been improving throughout this period. There are now over 50 models available for purchase in the UK, manufactured by LG, Panasonic, Samsung and Sony, and with prices ranging from around GBP650 (42 inch / 1.07m) to GBP35 000 (85 inch / 2.16m). 4K TVs are projected to represent 5% of global TV shipments in 2014.66

Factors affecting the take-up of 4K devices

It seems inevitable that the major TV manufacturers will make 4K standard on an increasing number of their models in future so that, in a similar way to what is happening now with HD TV sets, device availability will improve. Consumers looking to replace TV sets are likely to opt for future-proof technology, and price reductions for 4K equipment will help to support this. Therefore, as for HD, 4K devices are likely to be adopted before 4K services.

4K offerings are available now in the UK on the OTT platform via Netflix. This makes them more accessible to consumers than was the case with the first HD services on Sky – satellite installation is not required, and there is no need for a long-term contract. In addition, Netflix’s 4K content is available for GBP3 more than its standard subscription (less than the GBP10 charged by Sky at the launch of HD, albeit for different content). This is complemented by the fact that tablets (which

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are likely to have shorter life cycles than TVs) are able to receive OTT content such as Netflix, and 4K tablets are starting to enter the market.67

Nevertheless, there are a number of factors that suggest that take-up of 4K devices will be slower than for HD. These are discussed below.

► Lack of perceived urgency in switching to 4K

Given that the replacement cycle for the primary TV in the home is around eight years,68 and that the future compatibility of HD TVs with a significant amount of TV content is almost guaranteed, consumers are unlikely to feel any urgency in replacing HD TVs with 4K TVs. However, it should be noted that 4K is a global trend, and TV manufacturers will actively market this technology. Furthermore, there are early adopters who have a much shorter replacement cycle.

► Wider compatibility issues

Compatibility issues are another barrier to take-up of 4K services. Since 4K has a high bandwidth requirement, it is likely to require advanced HEVC compression, which is more efficient than the current standards.69 But TVs and STBs that are compatible with HEVC are only just beginning to appear on the market. In addition, no 4K STBs have been rolled out yet, leaving OTT as the only platform that supports 4K services in the UK.

Another technical issue is that early 4K TV sets were fitted with HDMI1.4 ports (rather than HDMI2.0 ports)70 do not support the higher frame rates and dynamic range anticipated for some 4K content, due to the higher bandwidth required. For Netflix, compatibility with HEVC and HDMI2.0 alone do not guarantee that its service will be supported on a particular TV set. Netflix carries out its own analysis, which also tests picture quality and colour gamut, which means that not all HEVC TV sets can receive the service.71 Some sets simply require software upgrades, whilst for others new hardware is needed.

► Secondary TV sets

In the medium term, households will become increasingly 4K-ready as (a) the main TV set is replaced with a 4K- and HEVC-compatible one; (b) devices are able to receive transmissions using DVB-T2, S2 or C2;72 (c) average broadband speeds rise as superfast broadband take-up increases; and (d) more TVs become connected.

69 At present the most common video compression technology is MPEG-4 AVC, also called H.264. See Section 3.2.4 for more details.
70 HDMI – High-Definition Multimedia Interface – the usual port used for connecting high-definition video devices. These ports may implement one of several versions of the HDMI standard.
72 Technical broadcast standards for DTT, satellite and cable TV, which provide greater capacity within the same bandwidth. See Section 4.2 for more details.
However, there is an issue with the replacement of secondary TV sets in the home. Often, such sets are older models that have been superseded by a new primary set and moved to another room. The continued use of such aging devices presents a barrier to full migration to IP and the transition to DVB-T2, as is recognised by Digital UK.

One way to overcome this problem is to purchase a ‘second-set’ STB such as the YouView Extra Box, which has similar functionality to the main YouView box but allows multi-room use for BT subscribers. Users have access to Freeview, pay-IP channels, catch-up and PVR services for a one-off cost of GBP99 and a supplementary fee of GBP5 per month. Such STBs allow the longer-term use of TVs that lack the most recent technologies. Additionally, the increasing use of tablets (which have shorter replacement cycles) as secondary viewing devices can also alleviate this problem. For example, estimates suggest that tablets’ share of the long-form VOD market increased from 12% in H2 2012 to 20% in H2 2013.

Forecasts for take-up of 4K devices

Forecasts for 4K device shipments and consumer take-up vary widely. Global shipments of 4K TVs in 2013 were estimated to be between 780 000 and 2.2 million, and are forecast to reach 22–68 million by 2017. Projections by Strategy Analytics forecast that take-up of 4K TV sets will reach 10% in Western Europe by 2018. Based on these figures, and assuming a slightly delayed take-up profile of 4K compared to HD, if 4K services were launched on pay-TV platforms in 2015, take-up can be expected reach around 50% by 2024.

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3.2.4 4K requires higher bandwidth, which can be counteracted by better compression technology

As the quality of displays and content improves, content streams take up greater capacity in the underlying network (the capacity of different types of network is discussed further in Section 4.2). For this reason, video compression technology has been developed in tandem with improvements in resolution, and appears to halve the required bandwidth for a given resolution approximately every five years. Codec standards have evolved from MPEG-2 to MPEG-4 Part 2, to the current

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73 It is not available to TalkTalk subscribers.
74 See http://www.productsandservices.bt.com/consumerProducts/displayTopic.do?topicId=35039
77 See http://www.pcworld.com/article/2683192/just-upping-the-resolution-risks-turning-4k-into-a-dud.html
78 See http://stakeholders.ofcom.org.uk/binaries/research/technology-research/video.pdf
most common standard, MPEG-4 Part 10 AVC,\(^79\) (referred to as MPEG-4 AVC in the remainder of this report) also known as H.264.

The most advanced compression standard implemented so far is HEVC, which is expected to be a key feature of 4K streams. This is important for both linear and on-demand content. Figure 3.5 below shows the bandwidth requirement for different resolutions using MPEG-4 AVC and HEVC compression. The bandwidths lie within a fairly wide range because of variations in picture quality within each resolution and advances that are made within the same compression technology. The exact bandwidth consumption of 8K is unknown, but for the purposes of this figure we have assumed it will be approximately double that of 4K.\(^80\) The upper bound of bandwidths for 4K using HEVC are in line with data from an ISP for a drama programme, but sports content may require more bandwidth due to the more limited post-production processing which is typically applied.

*Figure 3.5: Bandwidth consumed by different pixel resolutions with MPEG-4 AVC and HEVC compression*  
[Source: BBC iPlayer, Netflix, Ericsson, Plum Consulting, Analysys Mason, 2014]

The chart shows that HEVC reduces the bandwidth requirement of 4K to similar levels to HD using MPEG-4 AVC. Therefore, a given amount of bandwidth can deliver the same number of 4K channels using HEVC as HD channels using MPEG-4 AVC. Alternatively, the same bandwidth could be used to deliver significantly more HD channels, as the bandwidth of each HD channel reduces by around two-thirds if MPEG-4 AVC compression is used.

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\(^79\) AVC – Advanced Video Coding.

\(^80\) A trial of 8K in Japan used 85Mbit/s with HEVC, see the case study in Section 3.2.2, and http://www.flatpanelshd.com/news.php?subaction=showfull&id=1394089255
As explained in Section 3.2.3, device compatibility is an issue: HEVC is now fully standardised, but whilst most 4K TVs are now HEVC-compatible, 4K STB specifications have yet to be implemented.

Realistically, HEVC is required to reduce the capacity requirements of 4K services and enable more economic delivery. The technology is already used in the UK by Netflix’s 4K service.

3.2.5 Development of 4K services will be driven by PSBs and pay-TV operators

Different market players will have different levels of interest in developing 4K services, depending on their position in the value chain. Public service broadcasters (PSBs) such as the BBC are likely to be at the forefront of adopting innovations in TV technology, as they have been with HD. Generating innovative content and improving quality is part of the BBC’s public-service remit, and it has also stated its goal of enhancing the experience of sports programmes. The BBC has already taken part in trials of 4K (see Section 3.2.2 above).

The picture for commercial service providers is more varied. We have analysed potential business models for monetising 4K content, and the results for different types of service providers are shown in Figure 3.6 below. The green shading represents the most feasible models, the red shading represents the least feasible, and yellow represents models between the two.

*Figure 3.6: Feasibility of potential business models for monetising 4K content [Source: Analysys Mason, 2014]*

<table>
<thead>
<tr>
<th></th>
<th>Increase ad revenues</th>
<th>Generate ancillary sales</th>
<th>Acquire / retain subscribers</th>
<th>Increase subscription fees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pay-TV</td>
<td>DTH</td>
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<td>Cable</td>
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<td></td>
<td>Managed IPTV (e.g. BT TV)</td>
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<td>FTA</td>
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<tr>
<td></td>
<td>OTT (e.g. iPlayer)</td>
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</table>

For pay-TV platforms, 4K content presents an opportunity to gain or maintain market share: early adopters of 4K may churn to the first mover in the market. This is particularly important as sports seems to be the main driver of 4K content, and the main sports content owners in the UK being Sky and BT.

The first 4K services may incur a supplementary fee, as was the case for HD. As mentioned in Section 3.2.3, Sky charged a premium of GBP10 per month at the launch of its HD service, and

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81 The standard has been defined by the Video Coding Experts Group and the ITU (Recommendation ITU-T H.265).
82 The BBC HD channel was one of the first HD channels to launch in the UK in May 2006.
83 See http://www.bbc.co.uk/aboutthebbc/insidethebbc/whoweare/publicpurposes/creativity.html
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Netflix is charging an additional GBP3 per month for its 4K content. However, in the longer term this mark-up is likely to be eroded as free-to-air (FTA) channels begin to offer 4K, and it becomes more standard.

Another important revenue source for TV channels is advertising. Advertisers are unlikely to pay more on a per-impression basis for 4K advertising slots compared to SD or HD, and for this reason the business case is less clear for 4K channels without premium content such as popular sports events, which can command higher advertising rates. However, if 4K channels are able to attract more viewers, they would increase their advertising revenues by virtue of achieving a higher number of impressions. This applies to channels on both free and paid-for platforms, but is unlikely to be relevant for most pay-OTT services, as they usually operate on a subscription model rather than an advertising model.

4K may also enable ancillary revenue sources, particularly in conjunction with the next generation of STBs, which allow purchases (such as the next episode, or merchandise) directly from the primary screen, and also enable the dynamic insertion of ads (a feature that is already available in the UK from Sky AdSmart). This is a relatively new and untested concept, but one stakeholder in our interviews identified this as a potential way to monetise 4K content. These solutions are most likely to be implemented for services over IP networks, as they require feedback which is not feasible on DTT and satellite platforms unless they are part of a hybrid solution (DTT-plus-IP or satellite-plus-IP).

4K service developments are likely to be driven by PSBs as part of their public service remit, or pay-TV platforms with premium content (particularly sports) that can use 4K to gain market share or generate supplementary revenues.

3.2.6 Summary: OTT, satellite and IP are likely to launch 4K first, focused on premium content and exclusives, while DTT will take much longer

Our projections of the timelines for the launch of 4K services on different platforms are shown in Figure 3.7 below. These timelines are based on publically available information and our own projections.

84 See http://www.skymedia.co.uk/sky-adsmart/
Following on Netflix’s launch of a small selection of 4K programmes in June 2014, Amazon Prime Instant Video has announced plans to include its original content in 4K from October 2014 (see Section 3.2.2). Whilst 4K OTT services still require a compatible TV, there is no need to replace an STB as the content is delivered over IP. Take-up of such services has been aided by growing on-demand viewing (see Section 3.1) and increased penetration of superfast broadband (see Section 4.1.1).

After the OTT providers, satellite and IP players have the next-greatest commercial incentive and technical capacity to launch 4K, and in our interviews stakeholders have expressed an interest in doing so. As described in Section 3.2.5, the business case for launching 4K for premium content such as sports on pay-TV platforms is relatively strong. However, an important barrier is device limitations in terms of consumers’ take-up of 4K TVs and the compatibility of STBs with HEVC.

The replacement cycle is around eight years for TVs, and two to five years for STBs, so it will take some time for the addressable market for 4K services to grow. As mentioned previously, the shorter replacement cycle for tablets, and the relative ease of delivering 4K content to such devices over IP (as already seen with Netflix), suggests that penetration of 4K-compatible tablets will outstrip the TV market, further driving IP-delivered 4K services.

In terms of capacity, Sky has enough satellite capacity to launch 4K even without HEVC (see Section 4.2.2), though reports suggest that the next generation of its STBs will be required in order to receive 4K services; these may be launched in 2016.\(^{86}\) Realistically on IP networks HEVC is

\(^{85}\) Netflix launched 4K services in June 2014. See http://techblog.netflix.com/2014/06/delivering-netflix-in-ultra-hd-4k.html

\(^{86}\) Reports also suggest that the next generation of STBs will store recorded programmes in a central data centre rather than a hard disk, and will develop multi-screen technology further.
required to reduce the bandwidth used by 4K, so that more households will have a fast enough broadband connection to be able to use the service. Further detail on the capacity of the different types of networks is provided in Section 4.2.

Cable is likely to follow satellite and IP, though Virgin Media has fewer incentives compared to providers on other platforms, as it does not hold premium sports rights (at least at present). Aside from the commercial aspect, there are the same limitations on consumer devices as for the other platforms. However, on the plus side, capacity does not appear to be an important constraint (see Section 4.2.3).

The launch of 4K on DTT faces a number of issues. Commercially, the business case is not clear as it is not feasible to charge significantly more for the higher capacity that 4K channels need on a multiplex (MUX), as the resulting increase in revenues will not be proportionate to the increased capacity (and cost) required. Technically, MUXs in the UK have limited capacity and DVB-T2 is required even for HD channels (see Section 4.2.1). According to Mediatique, the installed base of DVB-T2-compatible devices is relatively low – 25% of all TV sets and 44% of primary sets in 2014. This is forecast to increase, although Mediatique projects that without intervention near-universal penetration of DVB-T2 primary TV sets may not be achieved until 2030.87 The upcoming connected proposition from Freeview is expected to be DVB-T2-enabled, and this may help the migration. A managed migration could also accelerate the replacement of devices, as seen during the DSO, but this appears to be unlikely in the medium term.

Given the trials that the BBC has already undertaken and its commitment to innovation in this space, it is probable that it will make 4K content available. One channel, with limited content, could be launched (as was seen with the initial BBC HD channel), though it seems likely that such a 4K service would be available on IP rather than DTT, due to the issues explained above.

4K services have already launched on OTT, and are likely to expand. Satellite and IP platforms are the next most likely to launch services, followed by cable. There are some technical issues to overcome before 4K can be launched on DTT. The main drivers for 4K are sport on linear TV and film and TV on on-demand. Overall, device limitations affect potential take-up across all platforms.

The implication of the introduction of 4K services is that the higher bandwidth required will increase demand on networks used to deliver content. Section 4 explores the potential impact on networks, and how this can be mitigated.

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87 See http://www.telegraph.co.uk/finance/newsbysector/mediatechnologyandtelecoms/media/10789883/BSkyB-plans-major-overhaul-of-set-top-box-to-meet-Apple-threat.html

See http://stakeholders.ofcom.org.uk/binaries/consultations/700MHz/discussion/Mediatique.pdf
3.3 Managed IPTV and OTT services

3.3.1 A wide range of managed IPTV and OTT services are available in the UK

Another relatively new service development is the increasing availability and popularity of TV services delivered over IP networks. A wide range of these services are available in the UK, which can be split between operator-managed IPTV services which are offered by triple-play providers, and OTT services which are offered by a wide range of providers, including TV platforms, content aggregators and broadcasters. A list of these is shown in Figure 3.8 below, followed by a brief summary of each service.

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**Figure 3.8: Types of TV services delivered over IP networks available in the UK [Source: Service websites, Analysys Mason, 2014]**

<table>
<thead>
<tr>
<th>Operator managed IPTV</th>
<th>OTT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linear</strong></td>
<td></td>
</tr>
<tr>
<td>BT (YouView)</td>
<td>▪ TVCatchup</td>
</tr>
<tr>
<td>TalkTalk (YouView)</td>
<td>▪ TVPlayer</td>
</tr>
<tr>
<td>EE TV (pre-launch)</td>
<td>▪ VuTV</td>
</tr>
<tr>
<td><strong>Both</strong></td>
<td></td>
</tr>
<tr>
<td>▪ BT (YouView)</td>
<td>▪ NowTV</td>
</tr>
<tr>
<td>▪ TalkTalk (YouView)</td>
<td>▪ Sky Go</td>
</tr>
<tr>
<td>▪ EE TV (pre-launch)</td>
<td>▪ Sky+ / on-demand</td>
</tr>
<tr>
<td><strong>Non-linear (on-demand)</strong></td>
<td>▪ Virgin TV Anywhere</td>
</tr>
<tr>
<td>▪ Sky+ / on-demand</td>
<td>▪ BT Sport App / Online</td>
</tr>
<tr>
<td>▪ Virgin on-demand</td>
<td></td>
</tr>
</tbody>
</table>

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**BT (YouView)**  BT TV is a subscription hybrid DTT-and-IP service delivered via the YouView STB. As well as linear and on-demand TV, it also provides a pay-per-view (PPV) and download-to-own (DTO) service. On-demand bolt-ons are also available. As well as catch-up TV services from the main FTA broadcasters, users can also pay for OTT apps such as NowTV, and plans have been announced to include Netflix as well.

**TalkTalk (YouView)** TalkTalk is a subscription hybrid DTT-and-IP service delivered via the YouView STB. As well as linear and on-demand TV, it also provides a PPV service. In addition to catch-up TV services from the main FTA broadcasters, users can also pay for OTT apps such as NowTV, and plans have been announced to include Netflix. **88**

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88 See http://www.ft.com/cms/s/0/817d0758-47f6-11e4-ac9f-00144feab7de.html#axzz3FOA1pOJm
EE TV (pre-launch)\textsuperscript{89} EE TV is a subscription hybrid DTT-and-IP service delivered via a customised Netgem STB. As well as the linear Freeview channels, it will offer a range of catch-up TV and on-demand services. The STB will not offer access to NowTV or BT Sports at launch, but will offer access to Wuaki for films and TV programmes, and Box+ for music, as well as YouTube and BBC iPlayer.

Sky+ / on-demand Whilst Sky’s linear channels are provided over satellite, the catch-up and VOD service is delivered over IP through connected STBs. This service is part of the subscription fee.

TVCatchup TVCatchup is a live streaming service that retransmits FTA DTT channels over the Internet, and receives revenue from pre-roll advertising. It can be used on computers, tablets and smartphones, although fewer channels are available over a mobile connection.

TVPlayer TVPlayer is another live streaming service that retransmits FTA DTT channels over the Internet, and also receives revenue from advertising. It can be used on computers, tablets and smartphones, and is also available via an IP channel on connected Freeview HD.

VuTV VuTV is a subscription OTT service that retransmits 13 pay-TV channels over IP via connected Freeview HD. The service makes channels that would typically require a subscription from a pay-TV operator available on a monthly basis, with no contract.

NowTV NowTV is a platform for subscription and PPV OTT viewing provided by Sky, and allows users to use catch-up TV apps as well as other apps, and subscribe to packages of live streamed and on-demand Sky channels such as films or sports for a monthly fee. The service has its own branded STB, but can also be used with smart TVs, games consoles, computers, tablets and smartphones.

Sky Go Sky Go allows Sky subscribers to watch retransmitted linear channels over any IP connection (inside or outside the home). This service is part of the subscription fee, and is available on PCs, tablets and smartphones.

Virgin TV Anywhere Virgin TV Anywhere allows Virgin TV subscribers to watch both linear retransmitted and on-demand content that is included in their main TV package on other devices over an IP connection. The service can be used on PCs, tablets and smartphones, and is included in the subscription fee.

BT Sport App / This service allows subscribers to watch live content from BT Sport’s three channels (BT Sport 1, BT Sport 2 and ESPN) as well as on-demand content.

\textsuperscript{89} The planned launch was announced on 7 October 2014 (see http://www.telegraph.co.uk/finance/newspapersector/mediatechnologyandtelecoms/telecoms/11147319/EE-to-launch-TV-set-top-box.html); the EE website currently allows potential customers to register their interest (as of 13 October 2014) – see https://ee.co.uk/ee-and-me/ee-tv
The service also has exclusive content that is not available on the broadcast channels, includes event statistics and integrates with social media. It can be accessed on PCs, tablets and smartphones.

**BBC iPlayer**

BBC iPlayer is an online video and audio live streaming, catch-up and on-demand service, allowing users to stream and download programmes shown on BBC linear and online TV channels. The application is available via Internet browsers as well as many other devices (such as STBs, smart TVs, tablets, smartphones and games consoles). Content can be accessed for free.

**4OD, ITV Player Demand 5**

These services offer online video and audio live streaming, catch-up and on-demand, allowing users to stream and download programmes shown on Channel 4, ITV and Channel 5 linear TV channels. The application is available via Internet browsers as well as many other devices (such as STBs, smart TVs, tablets, smartphones and games consoles). Content can be accessed for free, with advertisements shown before the programme starts.

**Amazon Prime Instant Video**

Amazon Prime Instant Video (formerly Lovefilm) is an online video on-demand service which allows users to stream film and TV content for a subscription fee. The service can be used on many different devices.

**Netflix**

Netflix is an online VOD service which allows users to stream film and TV content for a monthly subscription fee. It is available on many different devices.

**iTunes Store**

The iTunes Store allows users of PCs and Apple devices to download films and TV programmes (plus other types of content). Films and TV programmes can be purchased on a PPV basis, and films can also be rented (to be viewed within 30 days).

**YouTube**

YouTube is a platform for users to upload and view videos on-demand or live for special events. Videos can be user-generated or owned by major commercial content producers, and show large variation in length, subject matter and resolution. YouTube operates an advertising business model, where revenue is shared with content owners.

**Blinkbox**

Blinkbox is a streaming VOD service which offers films and TV (as well as music) for purchase or rent on a PPV basis. The service can be used on STBs, smart TVs, iPads, games consoles, PCs and Macs. We note that Tesco recently announced that it was considering the sale of Blinkbox, which is reported to be heavily loss-making.³⁰

**Wuaki.TV**

Wuaki.TV is a PPV and subscription VOD service. It launched in the UK in June 2013. The service can be used on smart TVs, games consoles, PCs and Android and Apple devices.

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The features of managed IPTV and OTT services are compared below, in terms of the content available, pricing, device compatibility, user interface and screen resolutions.

Content

Most of the main OTT services offer on-demand, non-linear content. Some services such as TVPlayer, TVCatchup and VuTV provide linear (live) content, but there are significantly fewer of this type. YouTube also offers live streaming, though this is only for one-off events. Most OTT services, including those mentioned above, offer a mix of long-form content, feature-length films and TV series. YouTube includes a large number of short-form videos (for example user-generated clips and music videos), though other formats are also available.

Catch-up TV (as well as live streaming) services provided by PSBs, such as BBC iPlayer, Channel 4’s 4oD, ITV’s ITV Player and Channel 5’s Demand 5, include many different genres such as news, sports, children’s programmes, films (back-catalogue, rather than recent titles), documentaries, arts and lifestyle. Many of these genres form part of the PSBs’ public-service remit.

Other on-demand OTT services such as Amazon Prime Instant Video, Netflix, iTunes Store, Blinkbox, Wuaki.TV and Now TV specialise in catalogue films and TV series, which may include children’s, sports and documentary programmes.

Recent film titles tend to be offered by PPV OTT services including iTunes Store, Blinkbox and Wuaki.TV. Now TV’s subscription packs offer live streamed and on-demand film, sport and entertainment packs, leveraging the content available on Sky’s main channels.

Exclusive content is offered on Amazon Prime Instant Video, NowTV, Netflix, Blinkbox and iPlayer, often including TV series or live sports.

Pricing

In terms of pricing models, managed IPTV services require users to have a subscription with the provider, with a contract period of at least 12 months. For BT and TalkTalk’s IPTV services, users are required to take the respective operator’s broadband product as well.

Managed IPTV services are typically more expensive than subscription OTT services. BT TV costs GBP5 per month for Freeview channels, or GBP7.45 for pay channels, both with a 12-month minimum subscription. TalkTalk’s triple play product with Freeview channels costs GBP4.25 per month for the first six months, rising to GBP.50 thereafter, while EE charges GBP9.95 per month for the equivalent package, both on an 18 month contract. Netflix starts at GBP5.99 per month and VuTV costs GBP6.99 per month, with no long-term contract. It should be noted that each service provides different content; but overall subscription OTT services are usually more affordable than a managed IPTV service.

STBs and installation costs required for managed IPTV services are typically higher than for OTT services, though these costs are often subsidised or discounted by the provider to acquire subscribers. OTT services may not require any additional hardware if they are available via an app.
that can be used on a smart TV, PC, tablet or smartphone. For apps that are not available on smart TVs or users that do not own a smart TV, there are very affordable devices that can allow consumers to use the service on a TV set, such as NowTV from Sky (GBP10) or Chromecast from Google (GBP30). Chromecast allows users to ‘cast’ content from compatible apps and websites (such as BBC iPlayer, Netflix and YouTube) on smartphones, tablets and PCs to the TV in which the device is plugged in. Any website can be ‘cast’ using an extension to the Chrome browser on a PC.

There a number of free catch-up TV services, mostly operated by PSBs, which generate revenues from advertising (except for BBC iPlayer). User-generated and some professional content is available on YouTube for free.

Services such as iTunes Store, Amazon Instant Video, NowTV and Blinkbox offer PPV and DTO content. Prices vary depending on how recent and popular the programme or film is, whether it is PPV or DTO, and whether the user wants to watch it in SD or HD.

**Device compatibility**

Managed IPTV services require the proprietary STB of the provider, such as a BT or TalkTalk YouView box. A Sky+ box is required for Sky’s catch-up and on-demand services. These services can also be accessed on PCs, tablets and smartphones when consumers are in a different room or out of the home.

OTT services can generally be used on a wide range of devices such as PCs, laptops, tablets and smartphones, on both iOS and Android operating systems. Availability of OTT services on TV sets varies. Smart TVs and STBs have some OTT apps built in, but the range of apps varies from product to product. BBC iPlayer is one of the most readily available products across a wide range of devices.

The growth of relatively affordable streaming devices to use with TVs that are not Internet-enabled has helped to increase use of OTT services. Devices include NowTV, Chromecast and Roku. Amazon Fire TV is due to be launched in the UK on 23 October 2014, though it is relatively expensive. Freeview is also expected to launch a connected STB in the near future, which will provide access to IPTV channels as well as catch-up and on-demand OTT services via the main EPG (electronic programme guide).

**User interface**

The way that managed IPTV and OTT services are accessed varies. TV channels on hybrid managed IPTV services such as those delivered through a YouView box are often part of the EPG adjacent to the free DTT channels, so that users may not know what network is being used to deliver the channel. Catch-up and on-demand OTT TV may be accessed via a ‘backwards EPG’ (such as on YouView) or a separate app on an STB or smart TV.
OTT services used on PCs can be accessed either via a web browser (e.g. Netflix) or proprietary software (e.g. iTunes). Most OTT services have an app which is available on iOS or Android tablets and smartphones.

Arqiva also offers OTT broadcasters a number of ways to reach users via a connected Freeview HD box, via its Connect TV service. Arqiva can also add red button functionality, or allow channels to drop back from DTT to IP during periods when there are fewer viewers, to be more economical. This service can also enable subscription pay channels to be included on Freeview. This service gives channels with smaller audiences, such as Motors UK or Racing UK, the opportunity to reach the large number of users on the Freeview platform. As with the YouView box, users are not necessarily aware that the service is delivered over IP rather than DTT.

Resolution standards

Managed IPTV services include a mix of SD and HD channels. Most OTT services use adaptive bit rate systems that actively adjust the quality of a user’s stream depending on the capacity of their connection, and may also allow the user to select the resolution they wish to view. For PPV and DTO services, users can often choose between the SD and HD versions of the programmes, which are priced accordingly. Some 4K content is available in the UK on Netflix’s highest-tier package, while Amazon has announced its intention to launch 4K services in October.

Consumers in the UK have access to a wide range of managed IPTV and OTT services, which offer a range of content, with different pricing models and price points. OTT services are prevalent, primarily for catch-up and on-demand services.

3.3.2 OTT VOD services have significant subscriber numbers, and will occupy more and more IP network capacity as popularity increases

A large number of the services mentioned in Section 3.3.1 are OTT on-demand. Some of these have significant numbers of subscribers, as shown in Figure 3.9 below. BBC iPlayer is the most popular on-demand service for long-form content, with 4.6 million subscribers.

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92 See http://www.arqiva.com/overviews/tv/connect-tv
Other services are also popular:

- there are almost 800 million iTunes Store users worldwide\(^{94}\)
- there are over 19 million YouTube users in the UK (including short form viewing)\(^{95}\)
- the TVPlayer app was downloaded 250 000 times in its first month.\(^{96}\)

The rise in the number of screens in the home has helped to drive viewing over IP. A typical household may have multiple PCs, laptops, tablets and smartphones as well as the primary TV. Using IP services to get TV on multiple screens is also cheaper than using multi-screen over DTT, cable or satellite, which require additional hardware and, depending on the service, an additional subscription fee.

The growth of on-demand services has also led to an explosion in the choice of content, which has also stimulated multi-screen usage, as each member of a household can watch programmes according to their own individual preference. The rise in multi-screen usage and on-demand viewing will increase demand on networks.

Whilst non-linear and VOD viewing has been increasing (representing 13\% of viewing in 2013),\(^{97}\) it remains complementary to linear viewing rather than substitutive. This is the unanimous view of the stakeholders we talked to.

\(^{93}\) Sky+ on-demand users represents the number of connected STBs. BBC iPlayer subscribers are via PCs and laptops only.


\(^{95}\) See http://www.emarketer.com/Article/YouTube-Top-UK-Video-Site-with-BBC-iPlayer-Following-Behind/1010224

\(^{96}\) See http://www.dtg.org.uk/news/news.php?class=countries&subclass=0&id=5015
Case study 3: China – The rise of OTT TV

OTT services are popular in China: in 2013, there were 428 million subscribers of OTT services in the country, representing 69% of Internet subscribers. The rise in popularity of OTT services in China has been reliant on cooperation across the TV value chain. Whilst broadcasters have their own online TV platforms, most users use third-party OTT services, which compete with each other to purchase quality content from traditional TV broadcasters. These services include Youku Tudou, Sohu, Sina, QQ and iQIYI.

PPTV a live streaming service where users simultaneously download a video stream and upload the same stream to other users, has over 260 million users. This technology becomes more effective with scale and is accessible from PCs, mobile phones, tablets and TVs with STBs. Users have an average viewing time of 2.5 hours per day.

However, the model for the monetisation of OTT services is not yet clear. The main source of revenue is from device sales rather than on-going subscriptions, and in fact the popularity of OTT has caused OTT STBs to rise to a share of 15.1% of STBs shipped in China in Q3 2013.

The early expansion of the OTT market has contributed to the slow development of managed IPTV, which at the end of 2010 accounted for just 6.5 million subscribers (partly due to the dominance of China Unicom in northern China, and China Telecom in southern China), rising to 33 million in 2013. Take-up is expected to rise following the introduction of attractive tariff bundles with broadband.

Looking forward, the future of OTT and managed IPTV services looks promising. The new ‘Broadband China Strategy’ aims for 50% of households to be covered with broadband speeds of 100Mbit/s by 2020 and mobile operators are investing in 4G. The range and quality of online content is expected to increase now that GAPPRFT (General Administration of Press and Publication, Radio, Film and Television) has licensed more than 600 organisations for Internet programming. Also, higher penetration of handheld devices with larger screens will lead to increased demand for video services.

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99 PwC Global entertainment and media outlook 2014-2018, China
100 See http://www.pptv.com/aboutus/en/
102 PwC Global entertainment and media outlook 2014-2018, China
104 See https://www.digitaltvresearch.com/products/product?id=101
105 PwC: Global entertainment and media outlook 2014-2018, China
106 Ibid.
The growth of OTT VOD is set to continue as the number of services and the range of content increases. This will increase the demands placed on IP networks. Users with broadband data usage limits will need to be aware of their growing consumption, though many tariffs in the UK have unlimited data allowances.

3.3.3 Managed IPTV and OTT are complementary services to broadcast TV; IP is unlikely to substitute traditional broadcast over the next few years

The hybrid DTT-and-IP pay-TV platforms in the UK deliver content via the YouView STB. The box contains a DTT receiver and is also connected to the internet: the FTA channels are delivered over DTT (as with Freeview) while the paid-for channels are delivered over IP. Therefore, managed IPTV is complementary to broadcast TV for two of the main managed IPTV services.

Sky uses satellite for all its linear broadcasting to the main Sky STB (although we note that the Sky Go and Now TV services deliver linear content over IP networks). There is sufficient capacity on Sky’s satellite network to support all the linear channels it offers, and it is cost-effective to do so. As linear content is delivered over satellite its coverage is almost universal, while broadband – and therefore IP coverage – is not.

Virgin Media delivers linear TV over IP only through its TV Anywhere app. Its position is unique in that its platform is hybrid by definition, as all content is delivered through the same connection, just using different spectrum. A portion of spectrum is dedicated for VOD.

VOD services delivered over IP are offered across all managed IPTV platforms, and Sky, where users can access catch-up TV, OTT apps and PPV and DTO content on-demand. As mentioned in Section 3.1, consumption of these types of content is increasing, but linear viewing still dominates.

Therefore, IP is unlikely to substitute broadcast over the next few years. Other platforms are more efficient at delivering such content, and have better coverage. However, as the popularity of managed IPTV and OTT services increases, bandwidth requirements will rise.

**Case study 4 France – Leader in the take-up of managed IPTV**

Managed IPTV has been more successful in France than in any other European market. This is for both regulatory and commercial reasons: on the regulatory front, France’s support of local loop unbundling was a key enabler, and restrictions on the installation of satellite dishes in many areas (including Paris) have impeded the development of satellite TV as an alternative. Commercially, early launch of services and competitive pricing have driven take-up.

In France, all the major ISPs offer an entry-level TV package as a part of a triple-play tariff for around EUR33 per month. This presents an attractive commercial offering when compared to

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107 Although note previous comments on pay-TV services over DTT, see Section 3.3.1  
108 See http://www.analysysmason.com/Research/Content/Reports/payTV-OTT-WE-Aug2013-RDM0/  
109 Ibid.
similar cable offerings which start at EUR40 per month,\(^\text{110}\) or satellite offerings that start from EUR30 per month yet offer only limited broadband functionality (10GB monthly download limit).\(^\text{111}\) Managed IPTV providers, including Orange and SFR, have further consolidated their position by offering satellite coverage to subscribers unable to receive TV through DSL.\(^\text{112}\)

Managed IPTV is expected to be the fastest-growing platform, and its customer base is forecast to grow to 11.1 million by 2018 from an estimated 10.1 million in 2013,\(^\text{113}\) boosted by the deployment of VDSL in France (roll-out began at the end of 2013). As a result, managed IPTV’s share of households is expected to increase from 38% to 40%, confirming its position as the dominant pay-TV platform.

Important developments in line with this trend include Bouygues’ partnership with Google to develop a new Android TV box with DTT and IPTV compatibility.\(^\text{114}\) Also, Bouygues Telecom has partnered with Netflix to distribute its content in France from November 2014.\(^\text{115}\)

The most advanced managed IPTV offerings combine more than 400 channels, including HD, HD+ and 3D, catch-up TV, VOD and subscription VOD, multiscrreen functionality, and games. The transmission technology is either VDSL2 or FTTH\(^\text{116}\) depending on availability.\(^\text{117}\)

Whilst managed IPTV services in France have seen significant take-up, the strength of other platforms in the UK means that managed IPTV is unlikely to substitute other broadcast networks in the next few years.

Managed IPTV and OTT are complementary to broadcast viewing, but as their popularity increases, greater bandwidth will be required.

### 3.4 Mobile video

In the mobile sector, data traffic, specifically TV and video, is growing. A wide range of mobile video and TV services are currently available, while mobile broadcast is under development. In addition, more mobile users are consuming these services as penetration of compatible devices has risen, more services are available and services are becoming more affordable.

\(^\text{110}\) See http://offres.numericable.fr/television
\(^\text{112}\) See http://www.analysysmason.com/Research/Content/Reports/payTV-OTT-WE-Aug2013-RDMB0/
\(^\text{113}\) See http://www.analysysmason.com/Research/Content/Reports/payTV-OTT-WE-Aug2013-RDMB0/
\(^\text{116}\) Fibre to the home.
3.4.1 Consumption of TV and video content over mobile networks is likely to experience rapid growth over the next five years

The increasing penetration of smartphones and tablets is driving video consumption on mobile devices. In Q1 2014, smartphone penetration in the UK was 61% of adults, and 44% of households owned a tablet.\(^{118}\) This trend is projected to continue, with 94% population penetration of smartphones forecast by 2019.\(^{119}\)

To date, the majority of video consumption on mobile devices has been delivered over Wi-Fi networks (71% of data traffic consumed on mobile devices in 2013 was carried over Wi-Fi networks).\(^{120}\) However, as inclusive data allowances in mobile service bundles increase (supported by increasingly economic delivery of mobile data over LTE networks), video consumption over mobile networks is likely to grow.

**Mobile video and TV services currently available**

Video consumption over mobile networks is primarily based on on-demand content and catch-up TV services (71% of viewing on smartphones and 85% of viewing on tablets is non-linear).\(^{121}\) This is supported by mobile applications from the major PSBs and commercial service providers (e.g. BBC iPlayer, Netflix, YouTube). These services are offered OTT, and the service quality delivered will vary based on mobile network coverage and quality.

Mobile-operator-managed TV and video services have been relatively few to date, at least in part owing to concerns around capacity implications and quality management. With the advent of LTE, however, we are likely to see a greater number of TV and video services offered by mobile operators. In particular, Everything Everywhere (EE) has taken advantage of this additional capacity to offer mobile TV services. These are for smartphones only, not tablets or PCs, and cost GBP8.99 per month (in addition to the basic subscription).\(^{122}\) EE offers 16 linear TV channels (including ITV1, Channel 4, Cartoon Network and British Eurosport).

In comparison, the other UK mobile operators have made more limited moves to promote mobile TV. Vodafone includes access to Netflix, Sky Sports Mobile TV and Spotify as part of its 4G ‘Red’ packages; however, it appears that the usage is not separated from the standard data allowance.\(^{123}\) Three is promoting the use of on-demand applications over its mobile network (but not as part of a specific retail package), while O2 does not appear to offer any mobile TV services. However, all mobile operators (including O2) allow access to OTT mobile TV services based on standard data consumption charges.

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\(^{118}\) Communications Market Report, Ofcom, August 2014  
\(^{119}\) Analysys Mason Research, Western European telecoms market: trends and forecasts 2014–2019, August 2014  
\(^{120}\) Analysys Mason Research, Wireless network traffic worldwide: forecasts and analysis 2013–2018, October 2013  
\(^{121}\) Figure 2.33, The Communications Market Report, Ofcom, 7 August 2014  
\(^{122}\) Note: data used when watching mobile TV will be taken from your data allowance (http://ee.co.uk/help/add-ons-benefits-and-plans/entertainment-add-ons/entertainment-add-ons---music-games-tv)  
\(^{123}\) “Enjoy Sky Sports Mobile TV or Spotify Premium, included. And with double our standard UK data you can use it to your heart’s content.”; http://www.vodafone.co.uk/shop/pay-monthly/sim-only-deals/index.htm
In addition, almost all of the major pay-TV operators are now offering mobile apps to support their in-home offers. Again, these are offered OTT as an extension to fixed broadband services, rather than as part of an end-to-end managed service. These apps include Sky Go, Now TV (also powered by Sky Go), Virgin Anywhere and the BT Sports app, all of which provide access to linear TV services as well as on-demand and catch-up services.

All of these services are delivered over the mobile broadband network (using unicast or multicast), rather than as a mobile broadcast service provided over dedicated spectrum. The characteristics of service delivery will vary based on the coverage and speed available. Regarding its Sky Go service, Sky commented to us that 3G networks do not have the bandwidth to enable streaming quality, though this is possible over LTE and Wi-Fi.

**Mobile broadcast services**

Mobile broadcast services are not currently available in the UK, owing to the costs and quality concerns of delivering such a service over 3G networks. Mobile broadcast services may, however, be feasible over LTE networks.

In particular, mobile ‘stadium solutions’ (broadcasting in localised areas such as sports stadiums) are currently being evaluated. EE recently undertook an initiative with Qualcomm Technologies and Huawei to demonstrate eMBMS, a form of multicasting technology, with the BBC during the 2014 Commonwealth Games. We evaluate this further, including the technical solution behind the provision of mobile broadcast services over LTE (‘LTE broadcast’) in a later subsection (see Section 4.5.3).

Currently, commercial mobile broadcast services are not being proposed on a nationwide basis, although that may be achieved over the long term. National coverage has been implemented in South Korea (see case study below).

**Case study 5: South Korea makes mobile broadcast mainstream**

South Korea has a history of leading in the area of mobile broadcast. In 2005, it was the first country to introduce a mobile broadcast service, after having developed a new transmission technology called Digital Media Broadcasting (DMB). Since launch, this has evolved into Smart DMB which enables greater interactivity and video quality, including EPG updates and 480 pixel resolution. Services are now available to 80% of the population, and by September 2014, more than 62 million DMB-enabled devices had been sold, including smartphones, tablets and portable TVs.

One of the drivers for this trend is the presence of so-called ‘phablets’ (smartphones that are 5–7 inches in length), which account for 41% of all smartphone and tablets. These slightly larger mobile-connected devices provide a larger viewing screen for TV and video content, as well as gaming.

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124 Evolved Multimedia Broadcast and Multicast Service
125 See, https://www.worlddab.org/country-information/south-korea
126 http://www.androidauthority.com/southeast-asia-phablets-283826/
Furthermore, overall pay-TV penetration is very high, with almost all households (98.4% in 2013) taking some form of pay-TV.\footnote{PwC, PwC Global Entertainment and Media Outlook 2014-2018.}

More recently, the focus has switched to delivery of TV services over LTE networks. LTE now accounts for 65% of all subscriptions in South Korea\footnote{GSMA Intelligence, Q3 2014, extracted 15 October 2014.} and all three operators use LTE-A, including carrier aggregation. In January 2014, Korea Telecom launched an LTE broadcast service (another world first) based on eMBMS. The service is called ‘Olleh LTE Play’ and has been rolled out in partnership with Samsung (it was initially launched on Samsung Galaxy Note 3 devices).\footnote{http://webcache.googleusercontent.com/search?q=cache:yg2Hv3CD7e0J:www.totaltele.com/view.aspx%3FID%3D485128+&cd=1&hl=en&ct=clnk&gl=uk}

Importantly, the only action required by end users was a software update to enable the services.\footnote{https://event.on24.com/eventRegistration/EventLobbyServlet?target=registration.jsp&eventid=829736&sessionid=1&key=ACA3E562A8FA40C24AAE11C485E521C8&sourcepage=register}

With the increasing penetration of smartphones and tablets, take-up of LTE, and active trials of eMBMS, nationwide mobile broadcast services based on broadcast solutions could become a reality in South Korea towards the end of our five-year timeframe.

Video and TV consumption over mobile networks is likely to experience considerable growth, driven by the increasing availability of services and the falling costs of mobile data. The majority of this consumption will be on-demand or unicast based on OTT solutions. This will be the primary driver for traffic growth on mobile networks. Mobile broadcast services may start to become available from 2016-17, initially in localised areas such as sports stadiums.

### 3.4.2 Mobile data traffic is growing rapidly

As a result of the rising penetration of smartphones and tablets, the increasing affordability of mobile broadband, and the availability of TV and video content over mobile networks, mobile data traffic is growing rapidly. Forecasts suggest a four-fold increase in traffic carried over the mobile networks in the UK over the period 2013–2018 (36% CAGR), driven by data traffic on 3G and 4G handsets as well as mid-screen devices (tablets, e-readers).
Statistics from operators suggest that video over mobile networks currently represents 50% of data traffic. EE expects 70% of network traffic to be video by 2017, and anticipates carrying 4K video from 2020 onwards.

However, mobile networks in their current state will not be able to handle this level of traffic. In an effort to control traffic demand, mobile operators’ price plans for mobile data include data limits which are intended to prevent overload of the network by limiting video consumption (particularly at high quality). Nevertheless, it is clear that in the future improvements in mobile network capacity will be required in order to support the expected level of consumption.

Due to rising penetration of mobile devices, increasing affordability of mobile broadband and greater availability of mobile services, mobile data traffic is growing. Rising levels of consumption will require operators to improve mobile network capacity.

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131 Video over 4G: defining eMBMS gain, Three UK, June 2014
4 Network impacts

This section considers the network impact of the trends outlined in Section 1 above. The two primary service developments considered in that section were (a) the shift towards increasingly high-definition (and therefore high-capacity) content, and (b) the emergence of managed IPTV and OTT both as stand-alone services and as part of a hybrid network delivery model. In the following we examine the impact of these trends on the underlying network infrastructure in the UK. The key considerations are:

- The ability of each of the networks to scale up to meet the demand for additional capacity.
- The ability for IP networks to deliver comparable TV and video services to traditional broadcasting networks, and technology developments that can be used to manage this.
- The use of hybrid service models to support the increasing demands on networks to deliver increasingly high-definition TV and video services.

We conclude this section with a brief discussion of TV and video delivery over mobile networks.

4.1 Overview of networks and platforms used to deliver TV and video content

There are several networks and platforms that can be used for the transmission of video or TV content to different end user devices. Within this report, we consider the traditional model of DTT, satellite and cable broadcast networks delivering content to TV sets, as well as the more recent model of managed IPTV and OTT delivery to TV sets and other connected devices. This is illustrated in Figure 4.1 below.

By way of context for our analysis, within this subsection we provide an overview and comparison of the characteristics of each of these networks in terms of coverage and quality of service.
4.1.1 Next-generation IP network coverage will match that of DTT within five years, supporting the take-up of managed IPTV and OTT services

When comparing the ability of each of the TV and video distribution networks to support the new service developments we have discussed, it is important to consider the coverage of the network in question. One of the key strengths of the DTT and satellite networks is their virtually ubiquitous coverage. In comparison, cable and IP networks (ADSL, VDSL and FTTH) have a more limited footprint. Furthermore, in relation to IP networks, coverage must be considered in terms of the minimum speed delivered, which will impact both quality and capacity. In the table below, we compare the network coverage of each network type.
**New service developments in the broadcast sector and their implications for network infrastructure**

<table>
<thead>
<tr>
<th>Network</th>
<th>Coverage (% of households)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTT</td>
<td>98.5%&lt;sup&gt;133&lt;/sup&gt;</td>
</tr>
<tr>
<td>Satellite</td>
<td>98%&lt;sup&gt;134&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cable</td>
<td>48%&lt;sup&gt;135&lt;/sup&gt;</td>
</tr>
<tr>
<td>Superfast broadband&lt;sup&gt;136&lt;/sup&gt;</td>
<td>67%&lt;sup&gt;137&lt;/sup&gt; (rising to 95% in 2017&lt;sup&gt;138&lt;/sup&gt; and 99% in 2018&lt;sup&gt;139&lt;/sup&gt;)</td>
</tr>
<tr>
<td>ADSL – over 2Mbit/s&lt;sup&gt;*&lt;/sup&gt;</td>
<td>92%&lt;sup&gt;140&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

* At speeds below 2Mbit/s, we do not consider that an ADSL network is capable of delivering TV or video services.

Cable coverage is unlikely to increase significantly in the medium term, but within a five-year timeframe, the coverage of IP networks delivering a minimum of 24Mbit/s will approach that of DTT, thereby supporting the take-up of managed IPTV and OTT. In May 2014, 28% of residential broadband connections offered headline speeds of 30Mbit/s or higher, having grown by 8 percentage points year-on-year<sup>141</sup>. We note, however, that actual take-up of high-speed broadband services by consumers will lag behind the coverage available.

Roll-out of next-generation IP networks to 99% of households will enable more widespread adoption of TV and video services delivered over IP networks, either as a complementary or substitutional service to traditional broadcasting.

### 4.1.2 Delivering reliable ‘broadcast-level’ quality remains a challenge for IP networks

Alongside coverage, quality – and in particular, reliability – is an important component to consider when comparing networks and examining the impact of the observed trends in broadcasting services. Quality covers a wide range of components that affect the user experience, including reliable service delivery (uptime or availability), interference, jitter, latency and the user interface (i.e. the EPG). In addition, IP broadcast services require a noticeable time to change channels (‘zap time’) and, for live

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<sup>133</sup> Coverage of 98.5% of households is for public service broadcaster multiplexes only; the three main commercial multiplexes reach 90%, whilst COM7 reaches 70%, http://www.digitaluk.co.uk/industry/Multiplexes

<sup>134</sup> Satellite signals cover the whole of the UK, however, a clear line of site is required between the dish and the satellite, and as such some households in built-up areas and valleys are unable to install a dish in such a way as to achieve this, http://www.radioandtelly.co.uk/freesatfaq.html

<sup>135</sup> *Infrastructure Report, 2013 Update (Ofcom, 24 October 2013)*

<sup>136</sup> Defined in the *Infrastructure Report, 2013 Update (Ofcom, 24 October 2013)* as “The next generation of faster broadband services, which delivers headline download speeds of greater than 30Mbit/s.”

<sup>137</sup> Figure 5.6, *The Communications Market Report (Ofcom, 7 August 2014)*, figure quoted is for Q1 2014

<sup>138</sup> 95% household coverage committed for the end of 2017, extending household coverage of next-generation broadband services to 99% is being explored by Government, quoted in the *Infrastructure Report, 2013 Update (Ofcom, 24 October 2013)*

<sup>139</sup> Speech by Chief Secretary to the Treasury, Danny Alexander, ‘Investing in Britain’s future’ (27 June 2013); we note that this speech leaves the possibility of using “fixed, wireless or 4G” networks to meet this target

<sup>140</sup> *Infrastructure Report, 2013 Update (Ofcom, 24 October 2013)*

<sup>141</sup> Figure 1.3, UK fixed-line broadband performance, May 2014, Ofcom
content; and there may also be a delay in reception amounting of several minutes compared to traditional broadcast – this delay can be a significant issue for users, particularly for sports events. The topic of end-to-end quality of service (or quality of experience, from the user’s perspective) is one that regulators are becoming increasingly interested in, as reliance on the Internet increases. However, there are no independent, reliable statistics which provide a cross-platform comparison of these measures of quality.

All networks experience challenges from outages due to equipment failure, network damage, vandalism interference from the weather or – in the case of IP networks – network congestion. None of the broadcasting or IP network providers guarantee service availability as part of their consumer contracts: these kinds of guarantees are only offered to business customers, through service level agreements (SLAs) – and which incur additional costs. Generally, the DTT network is very reliable: there are a very small number of single points of failure within the network, and those that exist (transmitters and repeaters) are highly resilient. In comparison, IP networks have a large number of single points of failure in the form of street cabinets (which may be vandalised) or underground or overhead cables (which may be damaged during civil works).

Historically, consumers have accepted the lower quality of service of TV content over IP networks. This acceptance is linked to the fact that TV content delivered over IP networks is commonly used as a complementary service to broadcast and is often consumed on second screen devices such as laptops, tablets and smartphones, which have different associated content consumption and viewing behaviours compared to primary TV screens (e.g. on-demand consumption of short-form content). But the emergence of IPTV and hybrid models means that customers are now consuming TV over IP on their primary TV set – indeed, in the case of hybrid models, customers may not even be aware that a particular channel is being broadcast over IP rather than DTT, for example. Accordingly, there is an increasing expectation of a like-for-like equivalence in quality between traditional broadcast platforms (DTT, satellite, CATV) and IP platforms. This creates challenges for IP networks in ensuring a consistent, high-quality user experience.

In response, IP network operators are adding increased redundancy to their broadband networks to remove single points of failure within the core network. However, this may not be economically feasible for the access network in the foreseeable future, due to the large number of network elements (e.g. cabinets) involved.

Backhaul and access network capacity increases and migration to next-generation broadband services will alleviate congestion. In addition, adaptive bitrate streaming can also be used to ensure service delivery on IP networks when access speeds are lower.\[^{142}\] This technology enables operators to select the level of screen resolution that will be provided, based on the access speed available. The speed of the user’s connection is tested in the first few seconds of the content delivery, and the content will usually be delivered first in lower definition before it is adjusted upwards.

\[^{142}\] Both BT and Sky make use of adaptive bitrates in order to maintain good quality of service when IP networks are being used to deliver content (Source: http://www.ispreview.co.uk/index.php/2013/06/bt-vision-warns-no-sky-sports-tv-unless-you-take-superfast-broadband.html; http://www.techradar.com/reviews/audio-visual/av-accessories/now-tv-1192011/review).
Furthermore, IP networks can use a number of techniques to reduce zap time. For example, the first 5–20 seconds of each channel can be cached so that when a user changes channel it is possible to start showing content before that change has been fully executed. Over time, zap time is likely to reduce as network enhancements are made, and improvements in EPG software and STB processing power will undoubtedly emerge over time as well.

As consumption habits converge, IP networks will face challenges in delivering like-for-like quality of service compared to traditional broadcasting networks.

4.1.3 Poor in-home connectivity exacerbates the challenges of maintaining quality over IP networks

There are three main technologies used to provide in-home connectivity for IP networks: coaxial cabling, Ethernet, powerline and Wi-Fi. The table below summarises these:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coaxial cabling</td>
<td>Wired data connection using coaxial cabling, e.g. from the terrestrial TV aerial or satellite dish to the TV socket in the living room.</td>
</tr>
<tr>
<td>Ethernet</td>
<td>Wired data connection commonly using CAT5 cabling directly from the broadband router to the TV or STB.</td>
</tr>
<tr>
<td>Powerline</td>
<td>Wired data connection that uses the home electrical wiring, based on a pair of adapters plugged into power sockets, with Ethernet cables between the first adapter and the router, and between the second adapter and the TV or STB.</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>Wireless data connection based on IEEE 802.11 standards from the broadband router to a wireless receiver in the TV or STB</td>
</tr>
</tbody>
</table>

A significant challenge for ensuring IP network quality is in-home connectivity, and, in particular, the use of Wi-Fi to access services. Wi-Fi is a popular means to connect to IP networks owing to its ease of set-up, the ubiquity of Wi-Fi receivers within connected devices, and the mobility that Wi-Fi makes possible. However, Wi-Fi networks pose challenges for providers offering TV over IP, in terms of (a) propagation (the signal will be significantly weaker in rooms situated a long way from the router and will not penetrate dense materials such as concrete), (b) interference, and (c) contention – operators are not able to prioritise traffic over Wi-Fi, and applications that are less quality-dependent (e.g. file downloads) may negatively affect a voice or video stream. Wi-Fi networks also raise security concerns, though this is not an area we consider in this report.

Traditional broadcasting networks use coaxial cables for in-home connectivity and so the issues facing Wi-Fi have not been relevant. Sky and Virgin Media include in-home wiring in their installation services, and provide a direct cabled connection into the STB. In the case of DTT, coaxial cabling down from the aerial is included when the aerial is installed, and the majority of UK households already have suitable cabling in place. In comparison, connecting TV sets to an Ethernet cable is a relatively new development, and often requires the installation of new in-home cabling.
To avoid the quality problems associated with Wi-Fi, BT and TalkTalk both require customers to either connect directly via Ethernet or, where this is too far away, via powerline. Indeed, the YouView box does not include Wi-Fi, and a separate device must be used if a Wi-Fi connection is desired. Similarly to other operators offering TV services over IP networks, Sky prefers to connect its STBs to Ethernet cables in the first instance. However, where this is not possible, it offers customers the option of connecting via Wi-Fi. However, we note that Sky only offers VOD (and not linear TV channels) over IP – VOD content is more tolerant of lower-quality signals, as a slower load time is usually acceptable to users (who are unlikely to be channel-hopping), and the content is largely downloaded rather than streamed in real time.

Some quality concerns remain around powerline connectivity, but in interviews the two largest managed IPTV providers (TalkTalk and BT) deemed it to be fit for purpose (and preferable to Wi-Fi). BT highlighted the developments in this area, stating that initially it did not support the use of powerline for linear channels, but improved powerline solutions are now capable of delivering sufficient quality for linear channels. In-home connectivity will remain a challenge for ensuring quality in the delivery of TV and video services over IP networks over the next five years. Extension of in-home Ethernet cabling and improvements in powerline technology and Wi-Fi equipment will go some way towards resolving these issues.

4.2 The ability of broadcasting networks to deliver large volumes of linear content

In this subsection we consider the ability of each of the types of broadcasting network (DTT, satellite and cable) to scale up to meet the demand for additional capacity being driven by developments in higher-definition services. The migration towards 4K will place increasing pressure on networks, and in order to provide the same number of channels in increasingly high definition, further capacity will be needed.

The number of channels that can be simultaneously broadcast over a network is dictated by (a) the capacity (Mbit/s) occupied by each channel, and (b) the capacity available. The capacity occupied by each channel is the same across all platforms and is itself dictated by the screen resolution being provided (SD, HD, 4K) and the compression technology being (MPEG-2, MPEG-4 AVC, HVEC). A further factor is that providers must support legacy end-user equipment, and therefore need to simultaneously broadcast at least some of the channels using two different technical or compression standards (for example DVB-T and DVB-T2 for DTT, and MPEG-2 and MPEG-4 for cable and satellite).

The network capacity available varies by platform, but is broadly dictated by the technical standard used and the spectrum available. We consider the capacity available on each of the three types of broadcasting networks in turn below.

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143 Source: stakeholder interview
144 Source: stakeholder interview
4.2.1 The DTT platform is unlikely to be able to support further take-up of HD or 4K without migration to DVB-T2 and HEVC

Terrestrial TV services in the UK have been fully digitalised since October 2012. This significantly increased the capacity available owing to the increased spectral efficiency of digital transmission, making it possible for the number of channels to increase to around 140. DTT network capacity is determined by the number of MUXs being used and the transmission standard adopted. The number of MUXs depends on the spectrum available. There are seven DTT MUXs operational in the UK today, with a further MUX planned for 2015.

Two different standards are used for DTT in the UK. The initial standard was DVB-T, and subsequently an evolution of this standard, DVB-T2 was developed which provides a higher bitrate than DVB-T (40Mbit/s compared to 24Mbit/s). Two MUXs have migrated onto the DVB-T2 standard to date.

Three of the UK’s MUXs are dedicated to PSBs, and the remainder are commercial MUXs. The PSB MUXs provide coverage to 98.5% of the population, whilst the commercial MUXs cover 90%. The commercial MUXs using DVB-T have a slightly higher bitrate than the PSB MUXs (27Mbit/s compared to 24Mbit/s) owing to the use of different coding rates for error correction. Details of all the UK’s DTT MUXs are given in Figure 4.4 below.

![Figure 4.4: Summary of multiplexes in the UK today [Source: Analysys Mason, 2014]](image)

<table>
<thead>
<tr>
<th>MUX</th>
<th>Standard</th>
<th>Capacity</th>
<th>Compression</th>
<th>Channels (concurrent streams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSB1</td>
<td>DVB-T</td>
<td>24Mbit/s</td>
<td>MPEG-2</td>
<td>7 SD</td>
</tr>
<tr>
<td>PSB2</td>
<td>DVB-T</td>
<td>24Mbit/s</td>
<td>MPEG-2</td>
<td>9 SD</td>
</tr>
<tr>
<td>COM4</td>
<td>DVB-T</td>
<td>24Mbit/s</td>
<td>MPEG-2</td>
<td>14 SD</td>
</tr>
<tr>
<td>PSB3</td>
<td>DVB-T2</td>
<td>40Mbit/s</td>
<td>MPEG-4</td>
<td>5 HD</td>
</tr>
<tr>
<td>COM5</td>
<td>DVB-T</td>
<td>27Mbit/s</td>
<td>MPEG-2</td>
<td>14 SD</td>
</tr>
<tr>
<td>COM6</td>
<td>DVB-T</td>
<td>27Mbit/s</td>
<td>MPEG-2</td>
<td>14 SD</td>
</tr>
<tr>
<td>COM7</td>
<td>DVB-T2</td>
<td>40Mbit/s</td>
<td>MPEG-4</td>
<td>8 (6 HD + 2 SD)</td>
</tr>
<tr>
<td>COM8*</td>
<td>DVB-T2</td>
<td>40Mbit/s</td>
<td>MPEG-4</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>246Mbit/s</td>
<td></td>
<td>71 (60 SD + 11 HD)</td>
</tr>
</tbody>
</table>

*COM8 is likely to come into operation in 2015.

Should the 700MHz band be re-farmed as is currently proposed, COM7 and COM8 will no longer be available and the total DTT capacity will drop to 166Mbit/s. This could be increased to 240Mbit/s (slightly less than the capacity today) by migrating all MUXs to DVB-T2. However, all

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133 The commercial MUXs using DVB-T have a slightly higher bitrate than the PSB MUXs (27Mbit/s compared to 24Mbit/s) owing to the use of different coding rates for error correction.

145 The PSB MUXs use 2/3 coding, whereas the commercial MUXs use 3/4 coding. This can have a negative impact on the ruggedness of the signal, resulting in lower coverage for the commercial MUXs.
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consumer equipment would need to be DVB-T2 compatible to do this, which presents a major barrier to migration.

Whilst the network costs of migrating to DVB-T2 are not insignificant, the real cost and disruption will be for consumers. Nevertheless, Arqiva stated in interviews that it believes the decision to switch to DVB-T2 will need to happen in the next two or three years. The Digital TV Group commented that even though the UK had been the first to launch DVB-T2, other countries such as Germany, Sweden and Austria are leading the market to a DVB-T2 switchover. Furthermore, its view is that market intervention, either through regulation or by platform mandate, is the only way to ensure a migration to more efficient technology.

The two MUXs transmitting using DVB-T2 broadcast some HD channels, whilst the remaining MUXs broadcast SD channels only. HD content is compressed using MPEG-4 AVC, whereas SD uses MPEG-2.

Without either a wider migration to DVB-T2 or a move to HVEC compression (both of which require changes in the end user equipment), the addition of any further HD channels will reduce the total number of channels. Over time, compression is likely to improve sufficiently to allow the same number of HD channels to be transmitted as SD channels today. 4K is unlikely to be available on DTT in a five-year timeframe.

The DTT platform is capacity constrained. More extensive broadcasting of HD channels will require migration to DVB-T2 and MPEG-4 compression, which presents significant equipment compatibility challenges. 4K over DTT is unlikely in the next five years, even if HEVC compression is adopted. However, hybrid models can be used to deliver 4K content to DTT viewers (see Section 4.4).

4.2.2 The satellite network is likely to be the first to offer linear 4K services

Satellite has the highest capacity of all of the types of broadcasting networks. Capacity is determined by the number of satellites, the number of transponders on each satellite (itself limited by the amount of spectrum available), and the technical standard used.

The geostationary satellites covering the UK are positioned at 28.2–28.5 degrees East and all use Ku-band spectrum (13.78-14.5GHz). There are four satellites currently active: Eutelsat 28A, Astra 2A, Astra 2E and Astra 2F. These satellites have a total of 80 transponders, and of these, 23 use the DVB-S2 standard (with a capacity of circa 44Mbit/s), whilst the remainder use the older DVB-S standard (capacity circa 34Mbit/s). The total capacity of the satellite network is therefore 2886Mbit/s.146 A summary of the satellites and their capacity is provided in Figure 4.5 below.

146 Calculated based on individual transponder capacity, using data provided by KingofSat extracted in September 2014.
New service developments in the broadcast sector and their implications for network infrastructure

**Figure 4.5: UK satellite broadcast TV capacity based on current transponders [Source: KingOfSat, Lyngsat, Analysys Mason, 2014]**

<table>
<thead>
<tr>
<th></th>
<th>Eutelsat 28A</th>
<th>Astra 2E</th>
<th>Astra 2F</th>
<th>Astra 2A</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total transponders used</td>
<td>14</td>
<td>29</td>
<td>17</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>for TV today</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DVB-S2 transponders</td>
<td>1</td>
<td>12</td>
<td>5</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>Total Mbit/s today</td>
<td>483</td>
<td>1069</td>
<td>607</td>
<td>727</td>
<td>2886</td>
</tr>
<tr>
<td>Total SD channels</td>
<td>201</td>
<td>199</td>
<td>141</td>
<td>155</td>
<td>696</td>
</tr>
<tr>
<td>Total HD channels</td>
<td>6</td>
<td>50</td>
<td>14</td>
<td>24</td>
<td>94</td>
</tr>
<tr>
<td>Total Mbit/s with all</td>
<td>615</td>
<td>1246</td>
<td>757</td>
<td>878</td>
<td>3495</td>
</tr>
<tr>
<td>active transponders on</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DVB-S2*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total potential SD</td>
<td>246</td>
<td>498</td>
<td>303</td>
<td>351</td>
<td>1398</td>
</tr>
<tr>
<td>channels (MPEG-2) –</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5Mbit/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total potential HD</td>
<td>123</td>
<td>249</td>
<td>151</td>
<td>176</td>
<td>699</td>
</tr>
<tr>
<td>channels (720 using</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPEG-4) – 5Mbit/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total potential 4K</td>
<td>31</td>
<td>62</td>
<td>38</td>
<td>44</td>
<td>175</td>
</tr>
<tr>
<td>channels (using MPEG-4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– 20Mbit/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: we have used mid-points for figures on the capacity per channel for each level of screen resolution and type of compression.

The satellite network currently broadcasts 696 SD channels and 94 HD channels, the highest number of any broadcasting platform in the UK. Based on the existing active transponders, the network would be capable of delivering 175 4K channels, assuming that all transponders transmitted using DVB-S2 and MPEG-4 AVC compression. Since 83% of homes taking a Sky TV subscription already have DVB-S2 boxes (as of June 2014), full migration to DVB-S2 in three to five years appears feasible. Beyond this, migration to HEVC compression would add further capacity.

It therefore appears that the satellite network is future-proof in terms of having enough capacity to deliver 4K services, and in fact it is likely to be the first linear broadcasting network to offer such services. In the unlikely event that further satellite capacity is required, existing Ka-band spectrum could be used, which has a greater capacity than the Ku-band spectrum currently used – this would, however, require replacement of consumers’ receivers.

Satellite networks have the highest capacity of all of the traditional broadcast TV networks. Fully commercial delivery of linear 4K content is feasible in three to five years without significant investment in infrastructure or STBs.

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147 BSkyB financial results presentation, 30 June 2014.
4.2.3 The cable network will be able to offer 4K linear TV services once MPEG-2 transmission is ended, and can offer 4K over VOD before this

The capacity of cable networks for the broadcast of TV services is determined by the amount of spectrum that is allocated to transmit such services over the coaxial cable. An illustrative split of spectrum for a fully-digital cable operator is shown in Figure 4.6 below (note that this does not necessarily correspond to Virgin Media’s actual spectrum allocation, which is confidential). In addition to the allocation for digital TV, some cable operators also allocate separate spectrum for VOD services, as shown here. Note that the use of the upper range of the spectrum (up to 862MHz) is an artefact from the analogue TV world.

In the case of Virgin, we understand that separate spectrum is indeed allocated for its VOD service. Furthermore, a dedicated 10Mbit/s line using the DOCSIS3.0 standard is provided to the TiVo STB to support third-party OTT applications.

MPEG-4 compression is roughly twice as spectrally efficient as MPEG-2, allowing twice as many channels to be broadcast in the same spectrum. However, many cable operators simultaneously broadcast (at different frequencies) using both MPEG-2 and MPEG-4 compression due to the need to support legacy STBs. Roughly one third of Virgin’s TV customers are using old V+ STBs which are only compatible with MPEG-2. We understand from stakeholder interviews that Virgin’s linear broadcast uses MPEG-2, and MPEG-4 is only used for VOD. Further, Virgin stated that it has no immediate plans to turn off MPEG–2 transmissions. Should Virgin choose to switch to MPEG-4 only for linear broadcast at a future date, it could offer double the number of channels within the same spectrum (at present a total of 187 SD and 43 HD channels are available in the largest Virgin Media TV bundle).

Given the limited information available on the spectrum use within Virgin Media’s network, we have estimated its capacity based on the number of channels broadcast, the screen resolution, and the compression standard. Our indicative calculation is shown in Figure 4.7 below.

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150 Virgin Media 2013 annual report
Based on our estimates, Virgin Media has around 898Mbit/s of capacity for linear TV services, which would allow 37 4K channels using MPEG-4 AVC compression. This is lower than satellite, but many times the capacity of DTT. However, in order to achieve this, Virgin would need to switch off its MPEG-2 transmission, which would require STB replacement for a third of its subscribers.

Should further capacity be required beyond that gained by switching off MPEG-2 transmission, it is technically possible to use a wider range of spectrum on coaxial cables, but the migration would need to be done in a concerted way, with defined standards, and will likely require replacement of active equipment (e.g. RF transmitters, CMTS, modems, MUX, etc.) and possibly also some passive equipment (e.g. amplifiers or cables). There are current discussions in the cable industry of using frequencies up to around 1.7GHz (i.e. double the amount of spectrum today).

The cable network will be able to support 4K linear programming once MPEG-2 transmission is switched off. This is likely to require some subsidisation of new STBs for those customers using legacy STBs.

4.2.4 Summary: 4K fits with the natural evolution of satellite and cable networks, but is unlikely to be available on DTT within a five-year timeframe

Our analysis shows that whilst satellite and cable networks will be able to manage the growing demand for UHD content based on a continued evolution of their current strategies, the DTT network will struggle to support 4K at any significant scale within the next five years (it is possible that a single channel could be launched occupying one of the DTT MUX). The reasons for this are evident when comparing the underlying capacity of the networks and the current availability of content, as illustrated in Figure 4.8 below. Furthermore, in the case of DTT,
replacing consumers’ STBs would be considerably more challenging and would require a government initiative akin to the DSO.

![Figure 4.8: Indicative comparison of network capacity for linear TV and channels by platform](source: DTT channel list and MUX capacity, Digital UK; Virgin and Sky websites, KingofSat for satellite transponder capacities; estimated split of bandwidth for cable capacity, 2014)

4.3 Next-generation IP networks are capable of delivering comparable TV and video services to traditional broadband networks

One of the key service developments within the broadcast TV sector in the UK is the availability and take-up of managed IPTV and OTT services. It is therefore important to understand the ability of IP networks to deliver TV and video services that are comparable to traditional broadcast networks, and the technology developments that can be used to achieve this.

There are a number of different IP networks that can be considered here, including ADSL, VDSL, cable broadband and mobile broadband. We will primarily focus on VDSL, given that this will be the primary technology used to reach the target of 95% coverage of the population with next-generation broadband (speeds of at least 24Mbit/s) within the next two or three years. We also consider delivery of TV and video services over ADSL, which will continue to be used by a significant proportion of households within a five-year timeframe. Mobile broadband networks are considered separately in Section 4. Coverage and quality considerations have already been discussed in Sections 4.1.1 and 4.1.2 above, and therefore we will focus here on capacity.

An important distinction between IP and broadcasting networks is that the latter broadcast all channels at all times, whereas IP networks only deliver linear TV streams (e.g. a channel) or selected VOD content when they are requested. As such, the measure for any IP network is not the

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153 Please note, these calculations are indicative. Virgin Media capacity is representative of the capacity used for traditional broadcast only (based on 187 SD and 43 HD channels, 2.5Mbit/s per SD channel, and 10Mbit/s per HD channel), overall capacity of the cable network is around 3-4Gbit/s
number of channels available, but rather the number of channels or VOD requests that can be simultaneously requested across each part of the network (e.g. between the house and the cabinet, and between the cabinet and the exchange).

An added complexity for IP networks is that video content needs to be repurposed or ‘transcoded’ to enable it to be consumed via a range of different devices (TVs, tablets, laptops, smartphones), screen resolutions (SD, HD, UHD.) and compression standards (MPEG-2, MPEG-4 AVC, HEVC). This increases the processing time and caching capacity required for each individual content stream. The repurposing itself is done by the content aggregator, though the IP network may hold a cache of the different content formats. For linear TV, content repurposing needs to happen live, and can therefore cause delays in the delivery of the programme.

4.3.1 VDSL networks are capable of supporting 80Mbit/s per household today, which is more than sufficient to stream 4K services

In Openreach’s VDSL network, the line between the cabinet and the home is capable of 80Mbit/s today, with the potential to reach 120Mbit/s through the use of bonding and vectoring technologies. This would enable streaming of 4-5 simultaneous 4K programmes to a single household (assuming HVEC compression). Any bottleneck is therefore more likely to be in the backhaul network between the cabinet and exchange, rather than in the final drop. It is likely that at present there will be a 1Gbit/s fibre connection between the cabinet and the exchange; this could be upgraded at relatively low cost in the future. A single 1Gbit/s connection could support over 60 simultaneous 4K streams. To support all 200-300 lines per cabinet with simultaneous 4K streams, 4-5 1Gbit/s fibre lines would be needed, which represents a feasible upgrade.

The minimum capacity that is guaranteed on a VDSL line is 15Mbit/s (after this point Openreach’s systems will register a network fault). Given that a 4K stream occupies around 16Mbit/s of capacity, there is some potential for quality issues during peak times. However, bottom-up calculations suggest a lower backhaul requirement than the capacity guaranteed by Openreach, suggesting that providing the required capacity to deliver managed IPTV and OTT services is feasible based on the current architecture (see Figure 4.9 below).
New service developments in the broadcast sector and their implications for network infrastructure

Figure 4.9: Illustration of the capacity required to deliver linear TV on VDSL [Source: Analysys Mason, 2014]

Ultimately, VDSL can be upgraded to fibre to the premise (currently marketed as ‘fibre on demand’), which would take the speeds up 330Mbit/s. However this would be very costly, and does not appear to be necessary within a five-year timeframe to meet the demand from most households.

Based on the VDSL network specifications, IP networks will be able to deliver the required capacity for managed IPTV and OTT services, including 4K. Should peak simultaneous usage exceed forecasts, capacity upgrades between the cabinet and exchange would be relatively inexpensive to implement.

4.3.2 ADSL networks can support SD and even HD today, but are likely to get congested and cannot deliver 4K services

A significant proportion of households are likely to remain on the ADSL network in a five-year timeframe, and as such, it is necessary to consider the impact of the trends in TV and video services on this network. Speeds delivered by ADSL networks vary considerably. In May 2014, 10% of broadband subscribers in the UK received a service of ‘up to’ 8Mbit/s or ‘up to’ 10Mbit/s and received on average 3.3Mbit/s, which would be insufficient to support HD streams assuming MPEG-4 AVC compression.154

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154 UK fixed-line broadband performance, May 2014, Ofcom.
The speed delivered on ADSL reduces with the length of the copper line between the exchange and the home. Reducing the length of this line amounts, in effect, to migrating to VDSL (i.e. the copper line is then only between the cabinet and the home; the connection from the cabinet to the exchange uses fibre).

Both TalkTalk and BT deliver managed IPTV services, including linear programming, over ADSL and use multicasting technology (see next section) to alleviate the capacity demand. However, these operators are unlikely to attempt to offer 4K services over ADSL, instead reserving this for customers on VDSL connections.

ADSL networks can be used to deliver SD and HD services, but to receive 4K customers are likely to require a VDSL connection.

### 4.3.3 Technologies to manage capacity requirements will further support delivery of TV and video services over IP networks

IP networks are dimensioned in such a way that they should be able to manage the required capacity for TV services. However, they experience very high variability in traffic load, and can struggle to manage the capacity at peak times. In order to minimise the risk of network congestion and performance issues during peak hours, operators use various technologies to reduce the loading. The technologies that we will consider within this section are as follows:

- **Multicasting** can ease congestion for linear content from the ISP’s core network to the FTTC cabinet, as only one stream is required per channel.

- **Caching** reduces the repeat transmission of the same content, or enables transmission at off-peak times, and is traditionally applied at the core network and in the home.

- **Content delivery networks** – Commercial and in-house CDNs bring the content closer to the end user by caching it at multiple locations.

These technologies focus on managing traffic in different parts of the network, as illustrated in Figure 4.10 below.
Multicasting

Multicasting is a technology used to reduce the capacity used by one-to-many applications (primarily linear IPTV today). Ordinarily, an IP network will separately deliver each individual request for data (or content). This allows all users on the network to choose when and what they watch. In the case of programmed linear TV content delivered over an IP network, individual requests for the same channel can be combined and a single stream delivered. In the case illustrated in Figure 4.11 below, this means that instead of delivering 18 streams from the exchange, only 6 need to be delivered. This saves considerable capacity in the backhaul from the exchange to the cabinet.
Openreach’s GEA\textsuperscript{155} multicast product was introduced in November 2013, and functions for both VDSL and FTTH. The availability of this at a wholesale level has made multicasting more feasible for ISPs without incurring significant capex investment. From our interviews we understand that both BT and TalkTalk make use of this product to multicast over VDSL.

Sky does not use multicasting at all today, although it may consider this in the future. For customers using STBs, all linear content is delivered over satellite and therefore multicasting is not required. However, for customers using Sky Go and Now TV, linear content is being delivered over IP networks. Nevertheless, we understand that the current requirement does not justify the investment in multicasting.\textsuperscript{156} Furthermore, caching reduces the load on the core network (see following subsection). Similarly, Virgin Media uses unicasting for its Anywhere application.

ADSL multicasting has been implemented independently by both TalkTalk and BT, using different approaches.

Multicasting significantly eases capacity constraints for the delivery of linear content over IP networks, and can be used to reduce the additional capacity required to support UHD services.

\textsuperscript{155} Generic Ethernet Access.

\textsuperscript{156} Stakeholder interview.
Caching

For delivery of VOD content, caching is an effective way to reduce the capacity load on the network. Caching involves the temporary storage of content at different points in the network, and is used to avoid retransmitting popular content from the data servers of the content aggregator. Compared to rolling out more network capacity, adding storage to different points in a network is relatively low-cost. Content can be cached at any point in the network, as illustrated in Figure 4.12, but today caching mostly occurs either in the core network or in the home. In addition, distributed CDNs are a form of caching (see the following sub-section).

Figure 4.12: Points in an IP network where content can be cached [Source: Analysys Mason, 2014]

The economics of caching in the exchange or even the cabinet are not clear today, and none of the stakeholders interviewed stated any plans to cache at this level, though it is possible that this will be implemented by some operators in the future. We understand from our interviews that Virgin Media caches DVB-C VOD content at the regional head-end/node and, similarly, Sky caches at the edge of its network in high-traffic locations.

With the growing penetration of STBs, caching in the home is becoming an increasingly attractive strategy, especially since the storage capacity of new STBs is commonly 1TB or more (see Figure 4.13 below).

<table>
<thead>
<tr>
<th>Name</th>
<th>Model</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>YouView box</td>
<td>Humax DTR-T1000</td>
<td>500GB or 1TB</td>
</tr>
<tr>
<td>YouView+ box</td>
<td>Humax DTR-T1010</td>
<td>500GB or 1TB</td>
</tr>
<tr>
<td>V HD</td>
<td>Cisco 4585DVB</td>
<td>N/A</td>
</tr>
<tr>
<td>TiVo box</td>
<td>Cisco, CT8620</td>
<td>500GB or 1TB</td>
</tr>
<tr>
<td>Sky+ HD box</td>
<td>Amstrad DXR890</td>
<td>250GB</td>
</tr>
<tr>
<td>Sky+ HD 2TB box</td>
<td>Amstrad DRX895 (PVR6)</td>
<td>1.5TB</td>
</tr>
<tr>
<td>EE TV box</td>
<td>Netgem (model unknown)</td>
<td>1TB</td>
</tr>
</tbody>
</table>

In-home caching can take three main forms:

- Recording of content being viewed, to enable pause and rewind functionality as well as a retrospective record option.
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- Recording of broadcast content for catch-up TV (this may be stored for example for seven days and can completely avoid use of the IP network for catch-up TV services).

- Drip-feeding (e.g. overnight download) of VOD content that is anticipated will be popular, either across the entire customer base, or (in the future) to targeted subscribers identified by analysis of their viewing behaviour.

Sky, Virgin, BT and TalkTalk all offer versions of the first form of in-home caching. According to stakeholder interviews, Sky is caching targeted advertisements through its AdSmart application, but does not cache IP content on the STB. However, it appears from the ‘Best of On Demand’ service that some satellite broadcast content is cached on the STB, to make this service possible for non-broadband customers (“If you don't have broadband at home, you can still access the pick of the week's TV. Just click on the Best of On Demand on your Sky+ Homepage”157). There appears to be some reticence amongst stakeholders to use capacity on the customer’s STB to auto-cache content, but this reluctance is likely to lessen as STB capacity increases.

EE’s planned TV service (currently in a pre-launch phase in which consumers can register interest) will auto-cache up to six TV channels that are selected by the customer as their favourites. This will be a 24-hour cache of the content, enabling catch-up and restarting at the beginning of programmes.158

Increasing network efficiencies can be gained by caching content closer to the end user. In particular, in-home caching of content could considerably reduce the amount of content actively streamed over IP networks.

**CDNs**

CDNs provide dynamic caching and optimise the routing of traffic by using a network of servers, distributed geographically, together with a series of routing options. CDNs may be international (i.e. caching and routing content into a country) or national (i.e. caching and routing in different cities or regional hubs).

One of the benefits of CDNs is that they cache content in the UK (often in several regional hubs), rather than transporting it across from, for example the USA when a user requests it. This helps to improve quality of experience by reducing latency. In addition, the use of intelligent routing platforms ensures that traffic is more evenly spread across the network, avoiding excessive loading of popular routes.

Content from a content aggregator is usually delivered to a central point in the network (for example, in London), and distributed from there, as illustrated in Figure 4.14 below.

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158 See https://ee.co.uk/ee-and-me/ee-tv
New service developments in the broadcast sector and their implications for network infrastructure

Operators can implement their own CDNs, but commercial solutions are also available – in particular, Akamai, Google and others have large CDN networks. According to stakeholders, TalkTalk makes use of Akamai and Google, while Sky uses Akamai and Level 3. The key reasons cited by stakeholders for their use of CDNs are to ensure quality of experience, provide redundancy and allow operators to switch between caches. It should be noted that in addition to the network investments of local service providers, international content providers are also investing heavily in infrastructure to improve the quality of the content delivered. This includes distributed datacentres, direct links and CDNs.

CDN solutions have moved beyond pure delivery to analytics, device detection and optimisation, but in the context of this study we are primarily interested in the caching and routing elements.

CDNs are effectively geographically distributed caches of content together with alternative traffic routing systems, which together ease the load on the fibre backbone.

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159 Akamai’s Intelligent Platform has more than 150,000 globally distributed servers (see http://www.akamai.com/html/solutions/media-delivery.html)
160 TalkTalk uses Akamai’s Accelerated Network Partner Program. This is not a traditional CDN service but allows content to be served closer to the end user.
161 YouTube does not store video content on third-party CDNs due to major concerns by the rights owners regarding breach of copyright.
162 For more details on these investments, see the following report: Investment in networks, facilities and equipment by content and application providers (Analysys Mason, 30 September 2014).
4.4 Hybrid models can be used to leverage the benefits of both traditional broadcasting and IP networks

It is clear that there is not one single distribution platform or network technology that provides all of the desired qualities within a workable economic model. In particular, the ability to deliver large volumes of linear and on-demand content varies significantly by network. Traditional broadcasting networks can support high-quality, and in some cases high-capacity, linear TV services but are unable to offer on-demand functionality. IP networks are ideally suited for on-demand content and are increasingly able to support linear content as well, but face challenges around quality and capacity (at least on ADSL connections).

However, hybrid models can be used to better manage this, and can meet requirements for content consumption in the short-to-mid-term. Cable networks are already, in effect, hybrid, since they operate using separate spectrum for broadcast and IP content. When an IP network such as VDSL is added to a DTT or satellite proposition, the capacity for content delivery quickly becomes comparable with cable. Indeed, it is significant that to date, the major linear IPTV service providers (namely BT and TalkTalk) use a hybrid network approach. The Freeview Connect initiative will further promote the use of hybrid services. The benefits of hybrid network are illustrated in Figure 4.15 below.

*Note: FTTH networks are included for the sake of completeness, but we note that there will be very limited FTTH coverage within a five-year timeframe, and whilst FTTH effectively provides sufficient capacity to deliver both linear and on-demand services over IP, it is unlikely to be affordable for the majority of households.*
In reality, all the major pay-TV providers have adopted hybrid solutions, as illustrated in the diagrams below.

* However, it appears that Sky does cache some satellite broadcast content on the STB (see Section 4.3.3 above).

Over a five-year timeframe, hybrid models are likely to be the most economic means to meet the requirements for content consumption in the UK, including high-capacity linear and on-demand services.

### 4.5 Mobile networks

The continuing growth in mobile traffic is partly being fuelled by increasing consumption of mobile video and TV services. This section considers the options available to mobile network operators to increase the capacity of their networks, as well as the technologies that can be used to alleviate capacity. Specifically, we consider developments in mobile broadcasting technology and how this can be used to deliver TV services in a spectrally efficient manner.
4.5.1 Growth in mobile network capacity

Mobile operators can increase the capacity of their networks in a number of ways, including (a) adopting more efficient technical standards such as LTE, (b) network densification (adding small cells in areas of high demand), and (c) acquisition of additional spectrum. In reality, a combination of all of these approaches will be required to manage the forecast traffic growth and to meet the demand for TV and video services over mobile networks. We consider each of these options in turn below.

**LTE**

LTE standards provide a more efficient way of delivering data traffic over the same amount of spectrum. LTE services were first launched in the UK in October 2012 by EE, and the three other operators have followed suit. EE maintains the highest coverage levels at 75% of the population. LTE coverage will reach 98% by 2017 in line with licence obligations.

LTE device penetration remains relatively low in the UK today (8%) but by 2019 is expected to reach 65%. Over time, the mobile operators are likely to re-farm their remaining spectrum to LTE, leaving a small amount for legacy 2G and 3G usage.

Increasing the size of the LTE carrier increases the speed and capacity of the services that can be delivered. In July 2013, EE increased its LTE carrier in the 1800MHz band from 10MHz to 20MHz in selected locations, enabling it to offer average speeds of over 20Mbit/s for 4G customers. Enhancements to the LTE standard such as carrier aggregation and small-cell integration will further increase the capacity that can be carried in the same amount of spectrum (see below).

Carrier aggregation (part of the LTE-A standard) enables operators to aggregate multiple, non-contiguous channels to deliver a single stream of content to an end-user. EE trialled carrier aggregation in November 2013 using 20MHz of 1800MHz spectrum and 20MHz of 2600MHz spectrum. This provided an uplift of 250% in headline speeds, from 80Mbit/s to 300Mbit/s. However, we understand that in the UK there are currently no plans to launch commercial services using carrier aggregation.

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163 We note that UK Broadband launched wholesale TDD LTE services in March 2012. However, commercial services were not available until October 2012.


165 Analysys Mason Research, Western European telecoms market: trends and forecasts 2014–2019, 4 August 2014; based on total connections excluding M2M.

166 Current LTE deployments in the UK use 2G or 3G for voice services (circuit-switched fall-back); Voice over LTE (VoLTE) will be introduced from 2015.

167 2G and 3G networks will also need to be maintained for inbound roaming services, to support visitors from countries with a lower LTE device penetration.

168 The portion of the operator’s spectrum which carries the LTE signal, usually at least 10MHz wide.

169 See http://www.ispreview.co.uk/index.php/2014/06/ee-delay-uk-launch-300mbps-4g-mobile-broadband-service-2015.html
**Additional spectrum**

A further means to increase the capacity of mobile networks is to increase the spectrum available to them. Ideally, a combination of low frequency (sub-1GHz) and high-frequency spectrum is required to provide coverage and capacity, owing to their different propagation characteristics. The 900MHz, 1800MHz and 2100MHz bands have been allocated to mobile services for some time, and in March 2013 the 800MHz and 2.6GHz bands were auctioned for mobile broadband services, providing an additional 250MHz of spectrum.

In addition, Ofcom is currently undertaking a consultation on the 700MHz band (694–790MHz), which it proposes to allocate to mobile services. However, should the decision be taken to do so, migration of DTT (the incumbent user of this spectrum) into the 470–694MHz band would take several years, so this spectrum is unlikely to be available before 2018 or 2019.\(^\text{170}\) Beyond this, Ofcom plans to auction 150MHz in the 3.4GHz band, and 40MHz in the 2.3GHz band. The earliest date that this auction would take place would be the financial year 2015–16.\(^\text{171}\)

**Network densification and small cells**

To date, mobile spectrum has been allocated on a nationwide basis. However, the traffic demand on mobile networks varies greatly by area, so some solution is needed to meet this localised demand. Small-cell solutions may be used to achieve this. Small cells are low-powered (and therefore low-range) mobile sites capable of servicing up to 128 users. By deploying small cells in carefully chosen locations, operators can remove up to 32% of the traffic from the macrocell network.\(^\text{172}\) Furthermore, a small-cell deployment could cost up to five times less than expanding the macrocell network.\(^\text{173}\)

A range of different types of small cells are available, as shown in Figure 4.20 below.

*Figure 4.20: Types of small cells and their characteristics [Source: Analysys Mason, 2014\(^\text{174}\)]*

<table>
<thead>
<tr>
<th>Type of small cell</th>
<th>Location</th>
<th>Number of simultaneous users supported</th>
<th>Range (metres)</th>
<th>Radio power output</th>
<th>Size of small cell equipment (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femto</td>
<td>Indoors</td>
<td>4–16</td>
<td>20–50</td>
<td>&lt;100mW</td>
<td>0.5</td>
</tr>
<tr>
<td>Pico</td>
<td>Indoors/outdoors</td>
<td>16–32</td>
<td>50–100</td>
<td>&lt;250mW</td>
<td>1</td>
</tr>
<tr>
<td>Metro</td>
<td>Indoors/outdoors</td>
<td>32–64</td>
<td>100–200</td>
<td>250mW–3W</td>
<td>3–5</td>
</tr>
<tr>
<td>Micro</td>
<td>Mostly outdoors</td>
<td>64–128</td>
<td>200–1000</td>
<td>5W–10W</td>
<td>10–15</td>
</tr>
</tbody>
</table>

\(^\text{170}\) Ofcom, Consultation on future use of the 700 MHz band, May 2014.

\(^\text{171}\) Ofcom, 2.3 and 3.4 GHz spectrum award: Consultation on a 3.4 GHz band plan, varying UK Broadband Limited’s licence and a call for inputs on other aspects of the award, October 2013.

\(^\text{172}\) http://www.analysysmason.com/Research/Content/Reports/Small-cells-deployment-June2014/

\(^\text{173}\) Ibid.

\(^\text{174}\) Figure 1 in Analysys Mason white paper entitled, ‘Small cells: How do operators and vendors overcome deployment challenges?’, June 2014. See http://www.analysysmason.com/Research/Content/Reports/Small-cells-deployment-June2014/#1%120June%202014
Even though small cells require considerably less space and power than macrocells, there remain challenges, including finding suitable locations, providing backhaul connections and power, network and traffic planning, and the complexity of managing a large network of small cells. Backhaul can be challenging in some locations, and fixed or wireless solutions may be used. Furthermore, careful network and traffic planning is required to minimise interference problems between macrocells and small cells, and to ensure seamless handover between cells. For these reasons, the benefits of small cell deployment need to be carefully weighed against the costs. Nevertheless, solutions are being developed to resolve some of these difficulties.

LTE Release 12\(^\text{175}\) includes enhanced support for HetNets\(^\text{176}\) to mitigate interference problems between macrocells and small cells. Problems are lessened when different bands are used for the macrocell network and the small-cell network within a particular area. In most cases, the small cells will use a higher frequency and larger channel size to maximise the capacity provided, whereas a macrocell will provide wider area coverage using lower-frequency spectrum.

Moving forward, operators may also choose to use managed Wi-Fi networks to offload traffic from their macrocell networks. Initial standards for LTE and Wi-Fi interworking were included in LTE Release 12.

Mobile network capacity will be significantly increased over the next five years, primarily by improving spectral efficiency through the use of LTE and LTE-A (including carrier aggregation) and through the deployment of small cells. Some additional spectrum may become available towards the end of our five-year timeframe. Small-cell deployment in particular will help to support TV and video consumption over mobile networks in areas of high traffic.

### 4.5.2 Approaches to alleviate capacity

Caching, CDNs and adaptive bitrates – techniques which were discussed earlier in this report in the context of fixed broadband networks – can also be used in mobile networks. Caching at the eNodeB\(^\text{177}\) has also been discussed as a means of reducing demand on the network, in particular to reduce backhaul costs. Caching will also provide benefits in terms of improved latency (and therefore improved quality). However, we understand that caching is not yet used by mobile operators in the UK.

As regards CDNs, Akamai has just announced a base station CDN for mobile broadband, which may help the business case for mobile CDNs.\(^\text{178}\)

\(^{175}\) 3GPP standard released in September 2014.

\(^{176}\) A HetNet or heterogeneous network is a network which combines different kinds of cell sites, this includes small cells using the same or different spectrum from the macrocell network, as well as combinations of cellular and Wi-Fi sites.

\(^{177}\) The equipment in LTE networks that communicates directly with user handsets; this corresponds to the base station in GSM networks.

Mobile networks make extensive use of adaptive bitrates to deliver TV and video services, since the speeds available to subscribers on such networks are highly variable. Operators also exchange data on network performance with content providers in order to understand where improvements are needed.

All of these solutions will become increasingly important as TV and video consumption over mobile networks increases.

In a similar way to fixed IP networks, mobile broadband networks can alleviate the capacity requirements of delivering video and TV content through technologies such as caching and CDNs. The recent launch of a base station CDN product may drive take-up amongst mobile operators as video consumption increases. In the meantime, adaptive bitrates are commonly used to manage the quality of video delivered on mobile networks.

4.5.3 Mobile broadcasting

Despite all of the techniques outlined above, as mobile video traffic increases, demand is likely to exceed capacity, at least in certain high-density locations. This could lead to poor video quality or other aspects of the user’s experience being negatively impacted. One of the ways in which this issue can be addressed is through use of mobile broadcast to offload some of the mobile video traffic and deliver the service in a spectrally-efficient manner.

We provide more detail on the standard for mobile broadcast on LTE networks, eMBMS, below considering the potential application, before evaluating the challenges around device compatibility and content availability.

*eMBMS*

The recently developed eMBMS standard is a solution that could significantly reduce the strain on the network when a localised group of users are watching the same content simultaneously. eMBMS reduces traffic demand by broadcasting the same content to multiple users at once, instead of unicasting an individual stream to each user. Furthermore, the solution enables dynamic switching between broadcast and unicast, such that it can be actively only when needed. EE undertook trials of eMBMS using 2.6GHz spectrum during the Commonwealth Games in July 2014, in partnership with the BBC, Huawei and Qualcomm. Trials have also been undertaken by Telstra (Australia), Verizon (USA) and Korea Telecom (South Korea).

The primary application of eMBMS in the near term is stadium solutions, i.e. providing live video streams of, for example, different playing angles or players. EE has undertaken research showing that live video streams of the sports event are the largest consumer of bandwidth within a stadium. An example quoted is from the USA, where the NFL had to block the streaming of the game from within the stadium hosting the Superbowl XLVIII is order to alleviate the load this was

causing on the network. eMBMS is designed to alleviate the strain on the main network, thereby enabling voice, messaging and basic browsing services to continue to be used, whilst ensuring that fans are still able to stream the game.

The primary business motivation for this solution is to reduce the capacity provisioning required for such events. However, other benefits include guaranteed quality of service all the way to the cell edge (interference issues are removed) and increased interactivity with the event, which includes an attractive opportunity for targeted advertising.

Other potential uses of mobile broadcasting technology include mass downloads at off-peak times (for example iOS or Android updates) and local or national warnings and alerts.

The downside of using the eMBMS solution for mobile broadcasting is that it will reduce the capacity of the mobile network for other uses (i.e. other than the linear streams being broadcast). Furthermore, some network updates are required, including on-site alterations, which can be expensive.

**Content and device compatibility**

Challenges for the widespread deployment of mobile broadcasting services such as eMBMS include the development and packaging of content, and device compatibility.

Mobile operators will need to partner with content producers to develop the apps and package the content for mobile broadcasting services. Due to the time and effort required to do so, content development is likely to only be undertaken for very large, high-profile events. An industry body, the Mobile Video Alliance, has been established to enable this coordination between mobile operators and content producers.

Device compatibility also remains a challenge. All Qualcomm chipsets are now eMBMS-compatible, but it will take some time for the installed base of mobile devices to be replaced to those with the new chipsets. Given the replacement cycle of smartphones, it will be two or three years before there is a reasonably-sized installed base. Nevertheless, vendors are seeing interest in trials of eMBMS-compatible smartphones and tablets. More trials are set to take place, particularly stadium trials in 2015. Any demonstrations are likely to take place in partnership with a device manufacturer, given the relative newness of the technology. There may be commercial launches from 2016 onwards. We expect these to be focused on live sports owing to the large addressable market and higher willingness to pay.

Delivery of 4K via mobile broadcasting is possible, towards the end of the five-year term, following the launch of services on traditional broadcasting and fixed IP networks. Furthermore,
the range of content will eventually expand, but it will be complementary to traditional ways to watch TV. However, we do not see LTE broadcast being a substitute for DTT.

Commercial mobile broadcasting solutions are likely to be launched from 2016 based on stadium solutions. Device compatibility will be an issue in the short term, but chipsets are already becoming available. Content availability is likely to be limited in the near term, and will initially focus on major sports events. Nationwide mobile broadcast services based on broadcast solutions may start to become available towards the end of the five-year time horizon.
Annex A  Literature review: sources

At the start of this study, we undertook a review of a number of reports and data sources, which are listed below. These were supplemented by a number of other sources (referenced in the main body of this report).

- Analysys Mason Research, *OTT video services tracker 2Q 2014*, 1 May 2014
- Analysys Mason Research, *NGA tracker 3Q 2014*, 28 August 2014
- Analysys Mason Research, *Pay-TV and OTT video services in Western Europe: forecasts and analysis 2013–2018*, 13 August 2013
- Analysys Mason Research, *Small cells: how do operators and vendors overcome deployment challenges*, 11 June 2014
- Analysys Mason Research, *Now TV – BskyB’s OTT video strategy*, 23 May 2014
- Analysys Mason Research, *Connected TV: the future for European audiovisual content*, 17 April 2014
- Analysys Mason Research, *IPTV and OTT video services to account for most pay-TV growth in Western Europe between 2013 and 2018*, 27 August 2013
- Analysys Mason Research, *Connected TV: Access and prominence are key issues for policymakers and industry*, 10 June 2013
- Analysys Mason Research, *Traditional pay-TV operators need to adopt elements of the OTT video business model to defend their position*, 10 April 2013
- Analysys Mason Research, *Freeview Connect may help UK broadcasters to regain the initiative in connected TV*, 13 June 2014
- Analysys Mason Research, *BSkyB launches low-cost set-top box in a bid to establish itself in the UK’s OTT video market*, 26 July 2013
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- Analysys Mason Research, *Pay TV operators start to move into OTT services: A logical extension to multi-screen services*, 18 May 2012
- Analysys Mason, *Presentation for Circom’s 31st Annual conference, Scenarios for a convergent world: Non-linear TV and the online challenge – Where is the European TV industry heading?*, 10 May 2013
- Analysys Mason, *Report for Ofcom, Opportunity cost of the spectrum used by digital terrestrial TV and digital audio broadcasting*, 12 March 2013
- Ofcom, *The availability of communications services in the UK*, May 2013
- Ofcom, *UK fixed-line broadband performance*, November 2013
- Ofcom, *Consumer research into the transparency of traffic management information provided by ISPs*, 4 September 2013
- Kantar Media, *Transparency in internet traffic management*, 4 September 2013
- Ofcom, *Consumer segmentation*, July 2013
- Ofcom, *On-demand services: understanding consumer choices*, October 2012
- Ofcom, *UK audience attitudes to the broadcast media*, 7 May 2013
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- Ofcom, *Consultation on future use of the 700 MHz band*, 28 May 2014
- Ofcom, *The future of free to view TV - a discussion document*, 28 May 2014
- Technologia, *Assessing the impact of second screen*, 4 March 2014
- Mediatique, *The development of free-to-view television in the UK by 2024*, May 2014
- Netflix, *Content Delivery Summit Keynote*, May 2013
- Three, *Video over 4G: defining eMBMS gain*, June 2014
- Orange, *eMBMS: technical and business challenges*, 4 July 2014
- European Broadcasting Union, *EBU to demo on demand UHD through HEVC*, 11 September 2014
- European Broadcasting Union, *EBU policy statement on ultra high definition television*, July 2014
- Broadband Stakeholder Group, *Domestic demand for bandwidth: an approach to forecasting requirements for the period 2013-2023*, 5 November 2013
- Qualcomm, *LTE Broadcast - Evolving and going beyond mobile*, 7 August 2014
Annex B  List of stakeholders interviewed

Over the course of this study, we conducted interviews with a number of stakeholders in the industry in order to inform and sense-check our analysis. These are listed below:

- Arqiva
- BBC
- BT
- Digital TV Group
- Digital UK
- EE
- Google
- Huawei
- Qualcomm
- Sky
- TalkTalk
- Virgin Media.