Entertainment in the UK in 2028

A report for Ofcom

Executive Summary and Main Report

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Executive summary

I The scope and objectives of the study

The UK entertainment sector is, and will remain, a major user of spectrum. In this study we assess the spectrum requirements for both the distribution and production of entertainment by 2028. We then compare spectrum demand with likely supply, identify problems of increased scarcity, and suggest possible ways of dealing with them.

In doing this it is impossible to predict with any certainty what the UK entertainment sector will look like in 20 years time - technology is rapidly changing the types of entertainment services which are possible and expanding the ways in which they might be delivered. To deal with this uncertainty we have produced a small number of scenarios for the likely state of UK entertainment in 2028. Our aim is to bring together economic, social, technology, regulatory and business drivers in a coherent way so as to span the space of possible states of the sector 20 years from now.

Such an exercise is important. Few studies look more than 10 years ahead. But a longer timeframe allows us to consider radical ways in which technology developments and basic end user needs, rather than the current state of the sector, shape the changes which occur. And the resulting scenarios provide a long-term vision which Ofcom can use to initiate and cross-check nearer term policy developments.

II Entertainment in 2008 - market trends and end user preferences

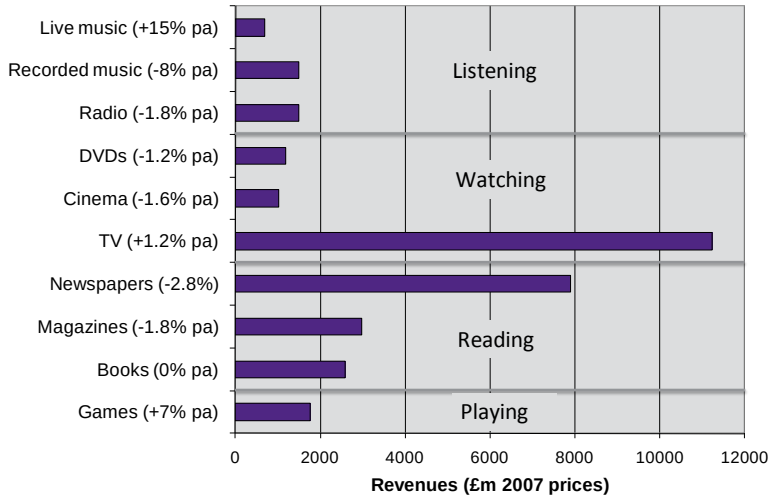
Entertainment, as we define it in this study, is made up of a wide range of activities which we group under four main headings - watching, listening, reading and playing. Figure S1 illustrates and shows that, in revenue terms, the UK entertainment sector is dominated by television and newspapers.

The main trends which shape our scenarios for 2028 include the following:

- There is an enduring consumer need for entertainment. The average consumer spends 4.5 hours per day consuming various entertainment services, a figure which is likely to grow slightly as the UK population ages and becomes more sedentary
- The revenues generated by entertainment are in decline. Revenues shrank by 0.7% per annum over the last five years[1] while UK GDP grew at 2.2% per annum. The decline reflects a shift in advertising spend, away from entertainment-based and toward search-based Internet advertising. Public funding and end user spend, the other two components of entertainment revenues, have remained roughly constant over the past five years.

[1] When measured at constant prices. There is some uncertainty over this estimate which is based on revenue reported by Ofcom and various industry bodies. Household Expenditure Survey data suggest that revenue might be growing slightly

Figure S1: The revenues generated by the UK entertainment sector in 2007[2]



- Consumers' willingness to pay for entertainment has changed with the growth of Internet-based entertainment. Large amounts of what was premium video content are now available free of charge on the Internet, albeit often in low quality formats. So the basis on which consumers are willing to pay for entertainment is shifting towards a high-quality viewing experience and physical ownership.
- Entertainment on the move is increasingly important to consumers as ownership of personal devices like the MP3 players, net books and iPhone-like personal devices grows. But most consumers prefer to read or to listen rather than to watch on the move. Those who own mobile devices with Internet capability are more likely to use them to check e-mails or browse the web than to watch streaming videos.

Additional trends within each of the individual activities which make up entertainment are summarised in Figure S2. In combination these trends suggest that we might see radical changes to the business models used to deliver entertainment over the next 20 years. For example we might reasonably expect that:

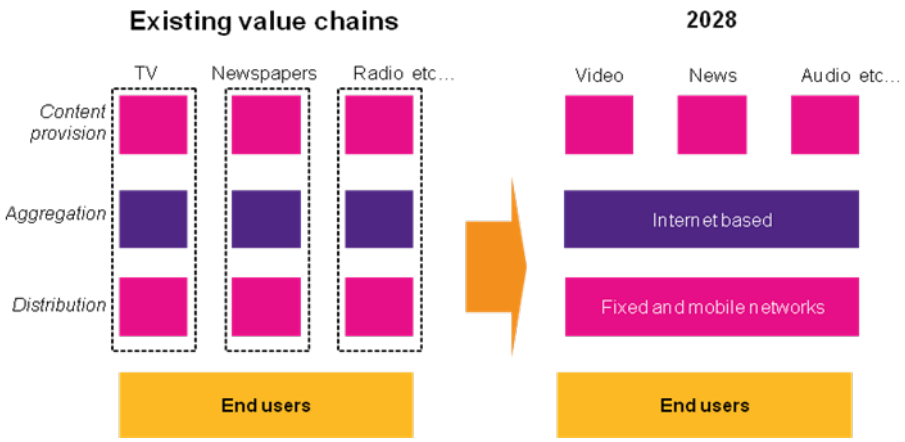
- Internet-based entertainment will lead to disruptive new value chains as illustrated in Figure S3.
- Targeted advertising will help shape future value chains. In particular the organisations which are best able to collect information on entertainment consumption patterns are likely to exert strong control over the entertainment value chains.
- There will be a move from value chains based on vertical integration and bundling to value chains based around horizontal specialists.
- Mobile personal devices will play an important, but uncertain, role in the delivery of entertainment services in future.
- We will see a growing diversity of business models for entertainment services in the UK. Any Internet-based models for delivering video entertainment and news will run in parallel with, rather than totally replace, traditional models.

[2] Revenues include advertising revenues, end user spend and public funding of broadcasting. They exclude entertainment equipment sales. Growth rates are measured at constant prices over the last five years.

Figure S2: Trends by entertainment activity[3]

Entertainment activity	Trend
Watching	TV revenue growth of 1.2% pa driven almost entirely by subscriptions to cable and satellite. Strong migration from scheduled to time shifted viewing based on PVRs, iPlayer and VoD. Rapid growth in watching video over the Internet e.g. YouTube, user generated content, VOD services The number of channels has grown from 3 to 500 in the last 30 years. The number of TV viewing hours per person is constant.
Listening	Revenues from recorded music have declined at 8% pa because of illegal copying and distribution. Live music revenues are growing at 15% pa. Radio listening hours are constant but revenues are declining at nearly 2% pa.
Reading	Revenues from books is stable, but revenue from consumer magazines and newspapers is in decline. Newspaper advertising revenues are falling by 4% pa as advertisers switch to the Internet. News publishers are putting increasing efforts into on-line news.
Playing	Games revenues are growing at 7% pa. On-line games revenues are growing at 30% pa.

Figure S3: A possible change in the value chains for the delivery of entertainment services



[3] Growth rates over a 5 year period at constant prices

III The capability of platforms and devices by 2028

We can expect dramatic improvements in the price performance of the platforms used to distribute, and the devices used to consume, entertainment over the next 20 years. If the improvements in price performance of the last 20 years for electronic components are repeated in the next 20 then this implies:

- A 1000 fold increase in storage and processing power.
- A 250 fold increase in the capacity of wireless networks.
- A home server which is capable of storing more than 20,000 hours of high-definition[4] 3-D format video and personal devices capable of storing more than 1000 hours of such video.

In terms of the platforms used to distribute entertainment we expect that:

- Satellite TV broadcasts will have sufficient capacity to meet the expected demand for multichannel, broadcast, high-definition video over the next 20 years.
- Terrestrial TV broadcast platforms will not have sufficient capacity to support multi-channel HD services.
- The wireline network should have sufficient capacity in its core switching and transmission components to meet all anticipated demands. Whether the same is true for the access network is less certain and varies across our scenarios.
- Cellular mobile and public wireless hotspots networks are likely to complement rather than compete with each other. Whether they have enough capacity, with planned spectrum assignments, to meet demand varies across our scenarios.

IV Three scenarios for 2028

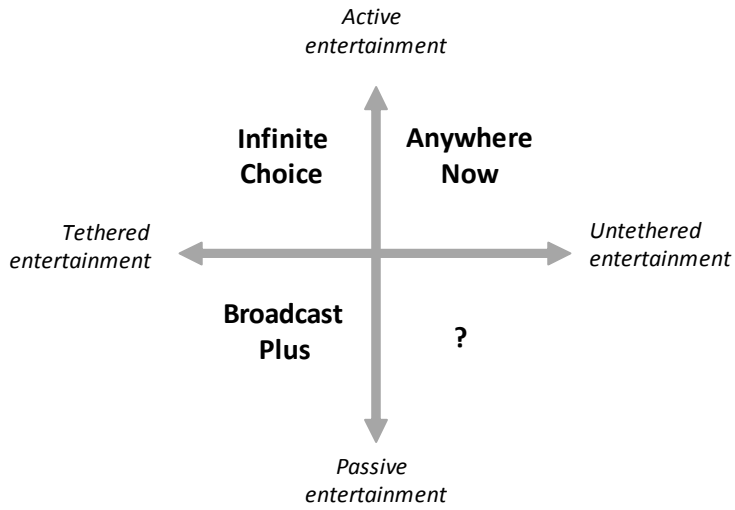
Using standard scenario development techniques, we have analysed key drivers in terms of end user needs, changes in technology, business models, economic and regulatory drivers to identify the three scenarios shown in Figure S4. The focus is on the distribution and consumption of video services which are especially spectrum hungry.

We chose as our primary dimensions for scenario creation two measures which reflect the greatest uncertainty over future end user demand for entertainment:

- The extent to which consumers seek ***active*** rather than ***passive*** entertainment, in which they search out content for themselves, recommend it to others, engage in immersive entertainment such as games, and/or create content for others.
- The extent to which consumers want entertainment services which are ***untethered*** rather than ***tethered*** to a location. Tethered use might involve consumption in the home or consumption while stationary in an office or public place.

[4] We refer to both HD (1080 x 920 pixels) and Ultra HD (7680 x 4320 pixels) in this report. We assume that the bulk of video will be distributed using HD formats up to 2028 but that some production will move to Ultra HD by then.

Figure S4: The three scenarios selected



The three scenarios share some common features. We assume that by 2028, regardless of scenario:

- Home servers and networks are readily available, affordable and easy to operate. Such home equipment automatically connects wirelessly to each new electronic device as it is introduced into the home.
- Personal devices with storage for over 1000 hours of high-definition video, and interfaces to both cellular and WiFi networks are used by virtually everyone.
- HD/3-D video formats are standard for most video content.
- Substantial public funding of UK originated entertainment content remains for a mix of social cohesion and industrial policy reasons.
- Fixed and mobile operators focus on selling their access products to consumers and on selling other services[5] wholesale to retail service providers.
- Only a minority of people turn to printed newspapers for their news. Most get news online.
- Radio remains popular - largely as a complement to other activities such as housework, driving and many forms of paid work.
- Local radio and newspapers have largely been replaced by Internet-based community services offered over global platforms.

The *Broadcast Plus* scenario for 2028

Under the *Broadcast Plus* scenario, illustrated in Figure S5, the majority of the population prefer scheduled video delivered through a mix of subscription and advertising funded services. They are attracted by live coverage of major events, the high quality viewing experience, the convenience and ease of use of schedules and the opportunity to chat about last night's TV with friends.

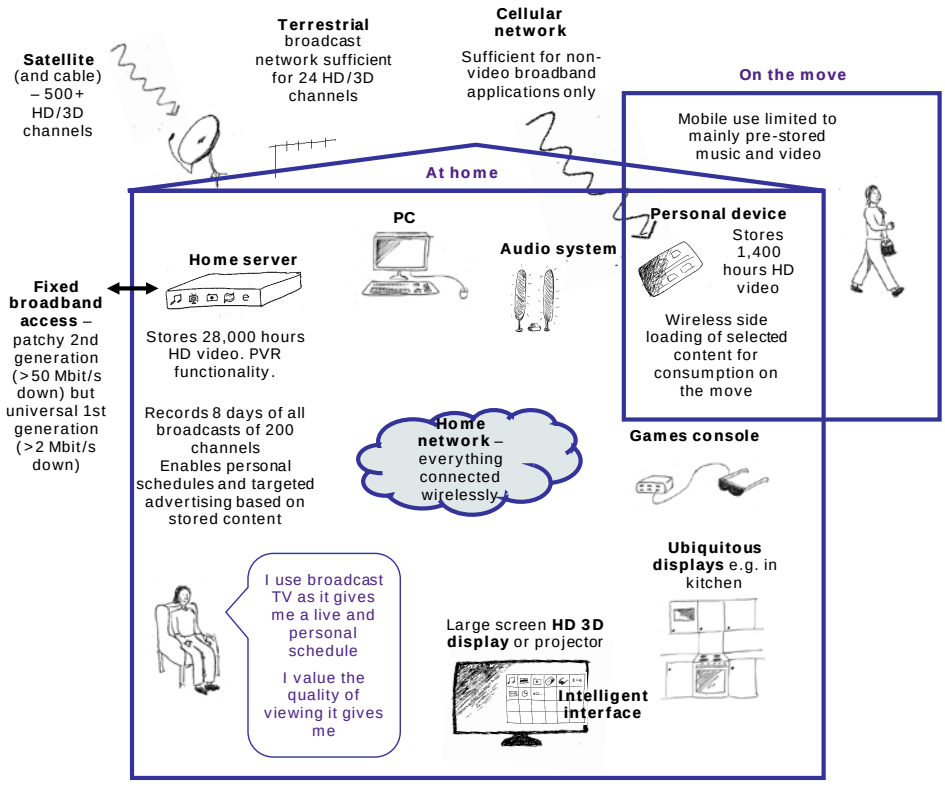
[5] Such as guaranteed quality of service, storage and caching, and content recognition services.

The home server now stores all of last month's broadcast TV for 200 selected channels. Service providers assemble personal channels, embedded with targeted advertising, from the stored content, which end users also access to catch up on programmes they have missed.

Mobile broadband now generates most of the revenue of the mobile operators. But the price premium for video over the cellular mobile network is substantial. So the consumption of video on personal devices is restricted largely to the reception of mobile TV and viewing of pre-stored content.

Business models have changed modestly under the *Broadcast Plus* scenario. Broadcasters remain strong in their traditional roles. But a handful of broadcasters now dominate in the new markets of targeted advertising and the supply of personalised channels. It is these broadcasters who, with the biggest profit streams available to fund content, are the most successful in the supply of traditional scheduled television.

Figure S5: The *Broadcast Plus* scenario - key features



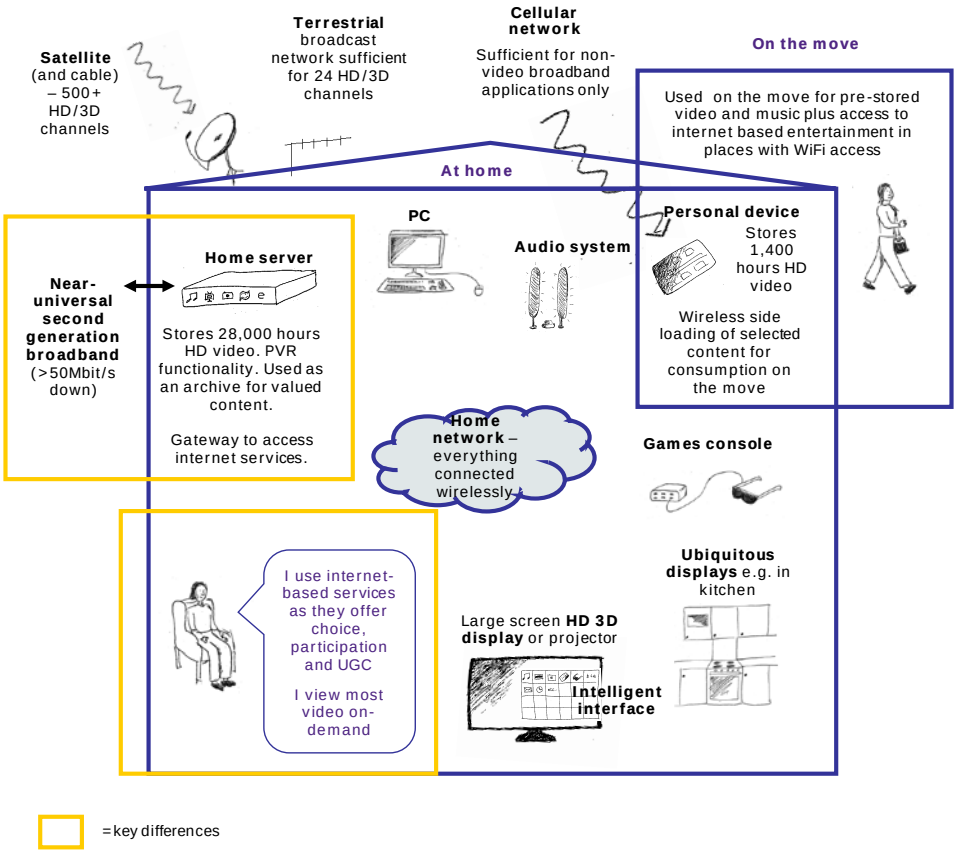
The *Infinite Choice* scenario for 2028

By the early 2020s consumers of virtually all ages have embraced the participative and immersive experiences of entertainment which the Internet can offer over second-generation broadband networks. As a result the bulk of entertainment content and services are now delivered over the Internet, although a minority of the population still watches broadcast television. Figure S6 illustrates.

Consumers are attracted to Internet-based entertainment by the almost infinite variety of content which is available, the immersive nature of the experience, the innovative combinations of content and the relevance and immediacy of content. Users find the entertainment they want through a variety of

means. Some use active video search. Others rely on recommendations from social networking with friends or buy from entertainment stores. Yet others subscribe to personalised schedules.

Figure S6: The *Infinite Choice* scenario - key features



Under the *Infinite Choice* scenario:

- Only a few UK broadcasters survive and the entertainment sector is dominated by global service providers.
- Local UK based service providers struggle to compete with these global service providers.
- Content producers have switched channels of distribution, away from the broadcast aggregator. Now they sell their content primarily through Web stores and directly from their own websites.
- The move from broadcast to Internet-based entertainment has led to new forms of content discovery. In particular social networking sites now play a central role.

The *Anywhere Now* scenario for 2028

Most people now use their mobile personal devices as the primary means of controlling the consumption of entertainment, making it a more personal experience. Services are available anywhere, and at any time, by using the personal device to access services via a mix of WiFi and cellular network connections. Driven by strong end-user demand for Internet-based entertainment on

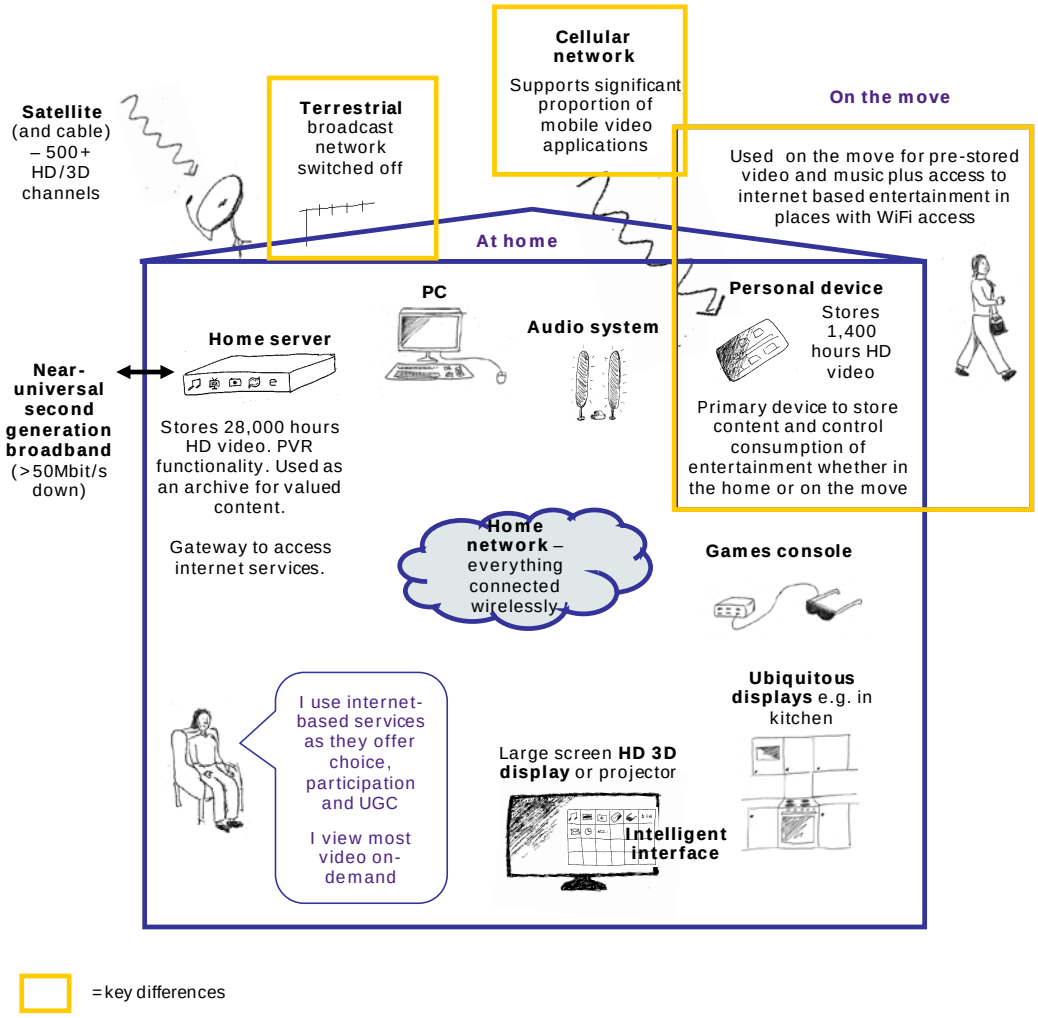
an “anywhere any time” basis, the mobile operators formed two rival consortia in 2022 to build high density radio access networks across the UK.

Internet-based entertainment dominates. But in the *Anywhere Now* scenario it is the personal device rather than the home network server which is the key to consumption of entertainment. Consumers use their personal device directly to download or stream content from the Internet rather than side-loading it via the home network server. If they want a “sofa cinema” experience they link their personal device to a large high-definition screen to view in the living room or bedroom - either alone or as a shared experience. Figure S7 illustrates.

The terrestrial TV broadcast platform was switched off in 2026, following migration to satellite platforms for high-definition multichannel broadcasting and to Internet-based entertainment. A significant proportion of the UHF spectrum released as a result is now assigned to cellular mobile use.

The business models and value chains of the *Anywhere Now* scenario, and the regulatory issues which they generate, are similar to those of the *Infinite Choice* scenario.

Figure S7: The *Anywhere Now* scenario – key features



V Spectrum for the distribution of entertainment in 2028

Figure S8 shows the role which the different wireless distribution platforms play under the three scenarios. What, if any, increases in spectrum scarcity do these demands create by 2028? Our assessment is as follows:

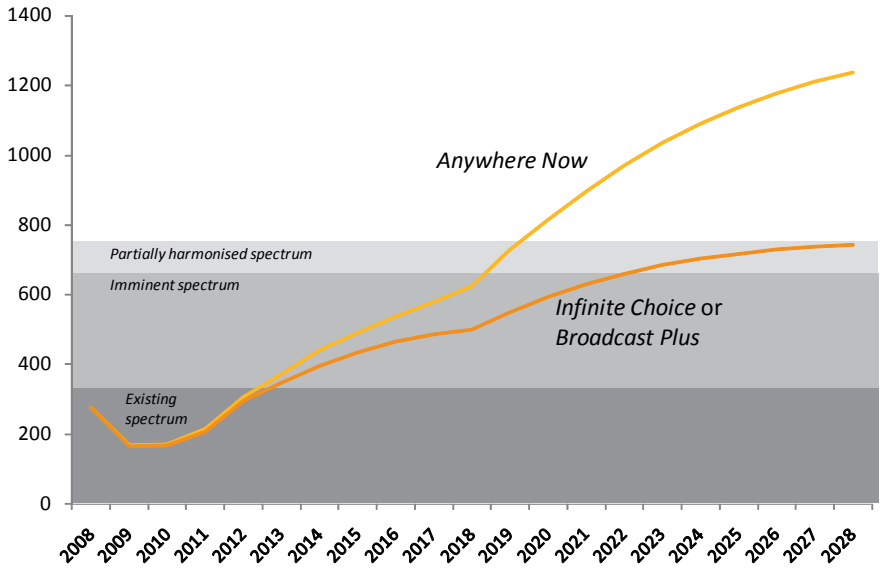
- The existing spectrum at 2.4GHz and 5GHz should be sufficient to meet requirements for the distribution of entertainment content around the home and in public wireless hotspots.
- The UHF spectrum available for terrestrial TV broadcast will not be enough to meet demand for multichannel high-definition and 3-D video formats. The bulk of TV broadcasting will switch to satellite platforms where no significant spectrum problems are expected.
- As Figure S9 illustrates, demand for spectrum from cellular services is likely to exceed supply[6] by 2019 under the *Anywhere Now* scenario and by 2022 under the *Infinite Choice* or *Broadcast Plus* scenarios. This increased scarcity is generated at least as much by other mobile broadband applications as by entertainment.

Figure S8: Demand for distribution of entertainment by wireless platform

Platform	Baseline – 2008 - current use of platforms	Broadcast Plus - broadcast oriented entertainment	Infinite Choice - tethered Internet based entertainment	Anywhere Now - untethered Internet based entertainment
Home entertainment network and server	Limited	Near ubiquitous	Near ubiquitous	Home network but no central home server
Terrestrial broadcast	500 channels of SD	Capacity for HD limited	Capacity for HD limited	Terrestrial switch off
Satellite broadcast	Sky + Freesat	Major platform – 500+ HD channels	Big on HD but in decline	Big on HD but in decline
Wide area wireless access eg public wireless hotspots	Widespread but limited bandwidth	Limited demand for entertainment	Substantial demand for entertainment	Substantial demand for entertainment
Cellular network access	Very limited for entertainment	Limited importance	Limited importance	Major demands

[6] As represented by the *Imminent spectrum* line of Figure S9.

Figure S9: Spectrum requirements for cellular mobile use - MHz



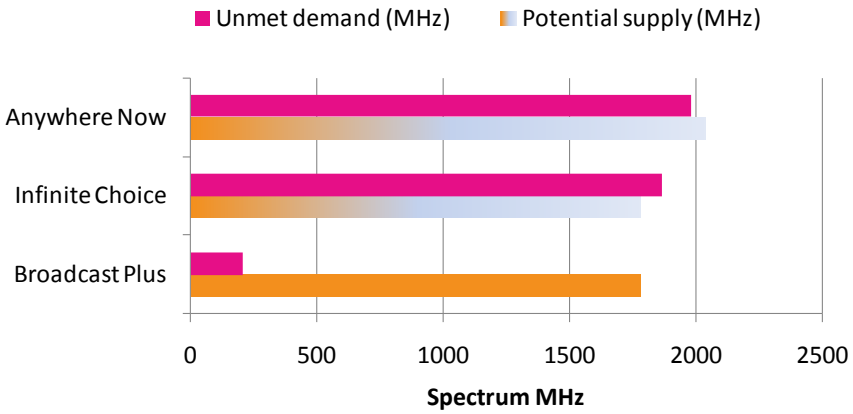
VI The production of entertainment

Technology developments will enable major changes, not just in the distribution and consumption of entertainment, but also in its production. Many of the future production devices will use cabled, and especially fibre, connections. We do not consider these any further. But the production of entertainment will also create additional demand for spectrum in three key areas:

- The widespread adoption of new high-definition and 3-D video formats, alongside existing production formats, will create additional demand for the spectrum used by wireless cameras.
- Enhancements to the viewing experience for outside broadcasting events, particularly sports events, for both spectators and TV viewers will increase spectrum requirements for wireless cameras and video links.
- New genre formats for concerts, theatre or TV shows will require greater use of radio microphones and other wireless devices.

Under all three of our scenarios we expect that these developments will generate demand for spectrum in excess of that identified by Ofcom for transfer to a new band manager as Figure S10 illustrates. Under the *Broadcast Plus* scenario this excess demand is modest when compared to the potential supply, most of which may be generated by release of Ministry of Defence (MoD) spectrum over the next several years. Under the *Infinite Choice* or *Anywhere Now* scenarios the excess demand is roughly equal to potential supply. Given that programme making and special events companies may have to compete with others to use this potential supply, increasing spectrum scarcity might constrain production of entertainment if there are higher value competing uses of the spectrum.

Figure S10: Unmet demand vs potential supply for production of entertainment



VII Conclusions

The UK's entertainment sector is entering a period of radical change. Broadcasting has dominated the entertainment sector over the last 20 years. Now it is challenged by Internet-based entertainment. The struggle between the business models best suited to these two very different platforms will generate major change, whatever the outcome.

We have identified three possible scenarios for the state of the UK entertainment sector in 2028 – the *Broadcast Plus*, *Infinite Choice* and *Anywhere Now* scenarios. These reflect differing views on the extent to which consumers will prefer:

- Passive to active entertainment.
- Tethered to untethered entertainment.

Policy issues

The sector's evolution towards one of these three scenarios raises a number of long-term policy issues for Ofcom:

- Should universal service obligations for broadcasting be expressed in a more technology neutral way? The current specification assumes terrestrial broadcast will continue which makes terrestrial switch off less likely under the *Anywhere Now* scenario.
- Should regulation of different content types be made more consistent? Current regulation of video broadcasts, press content and Internet content is very different. But under the *Infinite Choice* and *Anywhere Now* scenarios they will increasingly be delivered on a single platform.
- What rights should consumers have over how data on their consumption patterns are used by advertisers or their agents? Such data are important for targeted advertising to fund future entertainment services under all three scenarios, but user permission mechanisms may be needed to make this form of advertising acceptable.
- Will Ofcom need to intervene to keep end user switching costs to acceptable levels? Some end users are now making a large investment in their entertainment profiles and our three scenarios

suggest that this will increase rapidly. Yet there are no incentives for service providers to offer profile transfer services.

- How can the supply of UK content be safeguarded? Two of our scenarios envisaged dominance of supply chains by US aggregators. This could limit funding to UK production companies.

Spectrum requirements

Depending upon which scenario is realised, we can expect increased spectrum scarcity before 2028:

- We envisage spectrum demand to exceed expected allocations of spectrum to cellular mobile services under the *Anywhere Now* scenario by 2019. These are less likely under the *Infinite Choice* or *Broadcast Plus* scenarios
- A move to ultra high-definition 3-D video formats is likely to lead to the spectrum available for wireless cameras and video links under either the *Infinite Choice* or *Anywhere Now* scenarios falling short of expected demand. However, this is a highly speculative development.
- There should be sufficient spectrum available for radio microphones unless terrestrial switch off occurs as is assumed under the *Anywhere Now* scenario. In this situation these services may need to move to other frequencies bands.

Three main sources of spectrum might be used to overcome this increasing scarcity:

- Release of additional UHF spectrum currently used for TV broadcasting. It might make economic sense to clear more spectrum in the range from 600 to 790 MHz[7], in addition to the 72 MHz of UHF spectrum that is potentially available for cellular mobile services. This would leave the lower UHF frequencies[8] for use by the main public service broadcast TV channels and for production purposes.
- Release of MoD spectrum in the 3 to 4 GHz range that might be used by future mobile services. This will depend on the extent to which relevant frequency bands become harmonised.
- Release of MoD spectrum in ranges between 3 and 10 GHz that could meet demand from wireless cameras and video links. Some of this spectrum will be offered on a shared basis where programme making and special events use is ideal.

Monitoring

It is impossible to say with certainty whether the spectrum problems identified above will occur. To deal with this uncertainty we suggest that Ofcom should monitor key parameters so as to provide early warning of potential spectrum problems and give itself as long as possible to take remedial action. This might include monitoring of:

- The growth of mobile data traffic, whether for entertainment or other applications, carried over the UK's cellular networks.

[7] Mobile operators AT&T and Verizon recently paid $16 billion for spectrum in the 700 to 800 MHz range.

[8] Which are of less value to mobile operators because of the large antennas required in mobile handsets.

- The progress of new TV broadcast standards, particularly 3D TV and Ultra HD. This will provide an early indication of increased demand for spectrum.
- The rate at which end users take up satellite-based high definition TV broadcast services such as those offered by Freesat and Sky. This should help determine whether and when some form of terrestrial switch off might be possible.
- The level of applications by the new band manager to Ofcom to "borrow" spectrum. This would provide early warning of increasing spectrum scarcity for the production of entertainment
- The pace and size of proposed releases and/or sharing by the MoD.

1 Introduction

1.1 The objectives of the study

In 2007 Ofcom commissioned two parallel studies to consider how the UK's health and transport sectors might function in 20 years time and what new demands for spectrum these sectors might generate. Following the successful completion of these studies Ofcom commissioned Plum Consulting, ?What*If!*, aegis and Quotient, to carry out a similar study of the UK entertainment sector. The study has two main objectives:

- To develop a small number of scenarios for the likely state of the UK entertainment sector in 2028. The scenarios should provide coherent and compelling descriptions which span the space of possible states of the sector 20 years from now.
- To assess the spectrum requirements of each of these scenarios.

The study team should consider both the ***production*** of entertainment content and its ***distribution and consumption*** by end users so as to inform Ofcom's thinking on communications sector and spectrum policy.

1.2 A definition of entertainment

Entertain: verb transitive, amuse, occupy agreeably (OED)

We need a more precise definition of entertainment for the study than that given by the Oxford English Dictionary. So we have defined entertainment in terms of the activities which are included and excluded. We include watching, listening, playing and reading for pleasure and exclude other activities. When we apply these principles we get the definition shown in Figure 1.1.

Figure 1.1: A working definition of entertainment

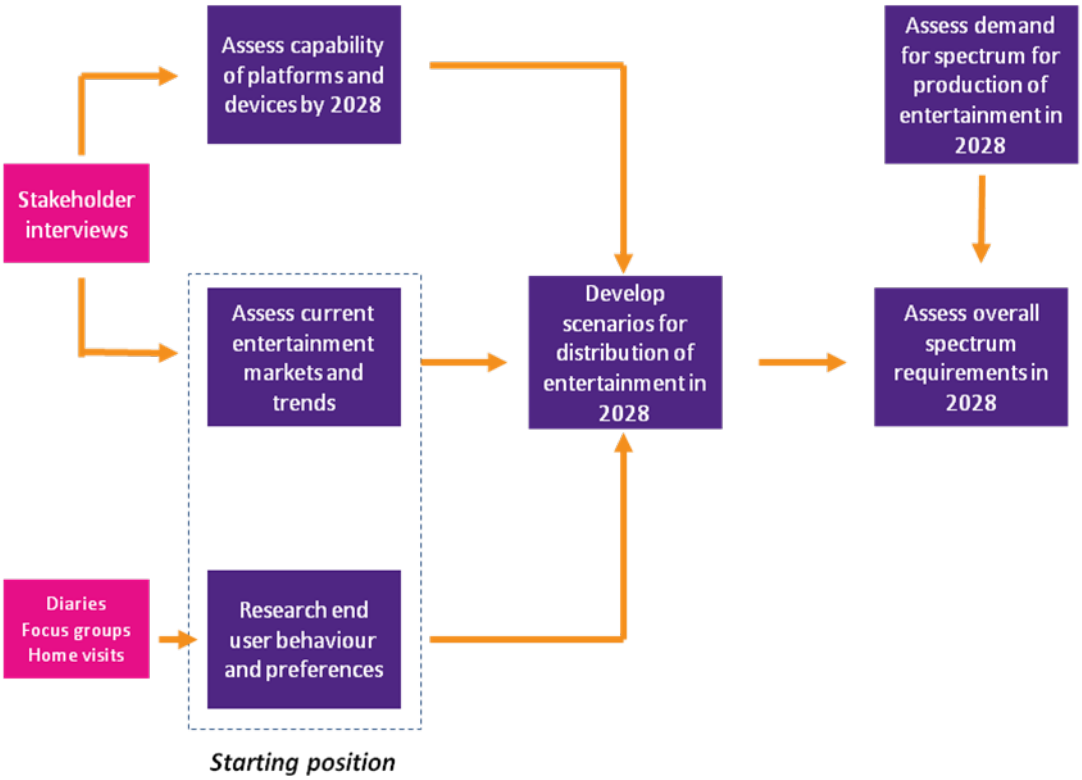
Within the definition	Outside the definition
Watching TV and films	Working
Attending live events	Learning or active recreation
Reading for pleasure	Sleeping, eating, shopping and cooking
Playing games (but not sports)	Personal and child care
Listening to music or radio	Civic or religious activities
	Gardening and other hobbies
	Socialisation

This working definition is far from perfect. For example the boundary between entertainment and socialisation is already blurring as consumers multi-task between the two activities and combine them on social networking sites. At the same time using leisure time for creative activities now forms a small but growing part of entertainment production as consumers produce user generated content. These trends are likely to grow stronger over the next 20 years. So it is important to recognise that, whilst the definition of Figure 1.1 may be satisfactory now, it is unlikely to work well 20 years hence.

1.3 The study methodology

Our approach to the study is set out in Figure 1.2.

Figure 1.2: The study approach



To establish a starting point for the development of the scenarios we:

- Held a series of stakeholder interviews to discuss the current state of the entertainment market in the UK, the business models on which service delivery is based, and key trends within the UK entertainment market. We summarise our findings in Chapter 2.
- Studied end user behaviour and preferences for entertainment through diaries, focus groups and home visits involving a sample of over 60 consumers. Chapter 3 summarises the findings from this work.

In parallel we used additional stakeholder interviews and desk research to project the likely capability of the devices and platforms used for the distribution and consumption of entertainment by 2028. Chapter 4 presents these projections.

Using the findings of Chapters 2 to 4 as a starting point, we then applied standard scenario development techniques to create three scenarios for the way in which entertainment is distributed and consumed in 2028. The study team developed initial scenarios which were then modified in following discussions with two separate panels of experts and major stakeholders. Chapter 5 presents the resulting scenarios and Chapter 6 then assesses each scenario's demand for spectrum.

In parallel with the work on distribution and consumption we also considered the production of entertainment content. Here we focussed more on those forms of production which generate substantial requirements for spectrum - notably outside broadcasting and news gathering. This assessment is presented in Chapter 7.

Finally Chapter 8 presents our conclusions. We consider the policy issues which arise from the scenarios and from the spectrum assessment and suggest parameters which Ofcom might monitor so as to get the earliest possible warning of potential increases in spectrum scarcity.

The report is based on a series of working papers which were produced throughout the eight months of the study and which provide more detailed analysis than the main report. These are provided in a separate volume in Annexes A to G.

1.4 Our thanks

We would like to thank the representatives of the many stakeholders who gave their time and views to the study team, and especially those who participated in the scenario validation workshops. The participating organisations are listed in Figure 1.3.

Figure 1.3: The stakeholders involved in the study

Organisation	Areas of contribution to the study
BBC News	Content production
BBC Strategy	Business models and long-term trends
BBC Research	General views on the development of entertainment
BERR	Key issues for the study
Blinx	Search for video content
Blue Tuna	Content production
BSkyB	Future business models entertainment and capability of platforms
BT	Future capability of devices and platforms
CoreMedia	Digital rights management
Cisco	Capability of IP platforms to carry entertainment
DCMS	Key issues for the study and development of radio platforms
Electronic Arts	Future of games

Organisation	Areas of contribution to the study
Five	Views on future of TV entertainment
Guardian Media Group	Future of the newspaper industry
IMG Sports Media	Role of sport and entertainment
Intel	Future capability of devices and platforms
Intellect	Future role of satellites
Kangaroo	Future of video
Last Mile	Content production
MBlox	Development of mobile entertainment services
Media Edge	Role of advertising in entertainment
Microsoft	Impact of future technologies on entertainment
Ministry of Defence	Content production
Mobile Virtual Centre of Excellence	Future role of mobile and home networks
Nokia	Development of mobile devices and role of mobile entertainment
Philips Research	Future capability of video display devices
Polymer Vision	Prospects for roll-up displays
The Publishers Association	Statistics on revenues from books
RIM	Future capability of devices and platforms
Robin Foster	Views of industry expert on development of entertainment
Sennheiser	Content production
Shelly Palmer	Views of US industry expert on development of entertainment
Society of London Theatres	Content production
Sony	Developments in consumer electronics and entertainment
Stephen Temple	Views of industry expert on spectrum requirements for entertainment
Telefonica	Future role of mobiles in entertainment
University of Bristol	Content production
University of Essex	Behaviour of cohorts towards entertainment
Vodafone	Future role of mobile entertainment

2 Markets and business models - current position and trends

2.1 Introduction

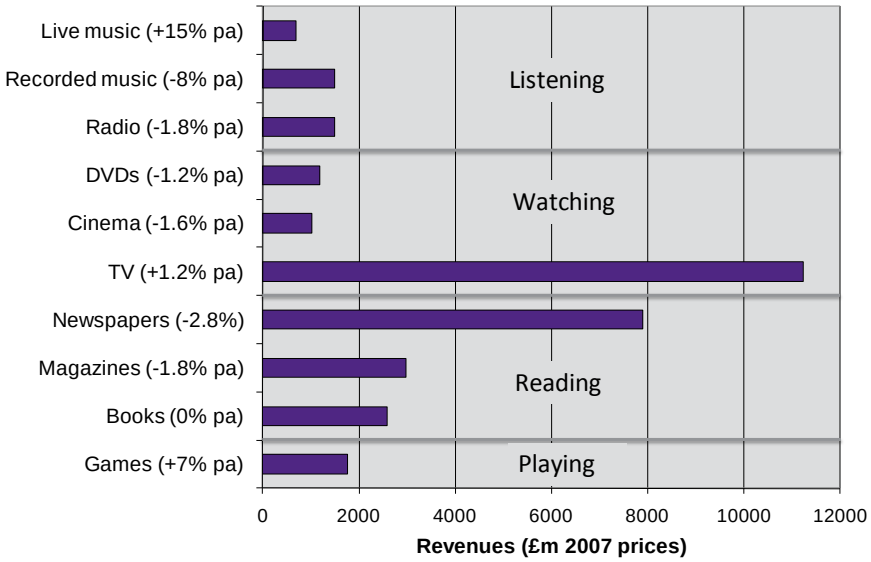
This chapter provides a brief overview of current UK entertainment markets, the main trends within these markets and their implications for future business models[9]. The current position and current trends provide one of the inputs which shape the development of entertainment scenarios in 2028.

Revenues in this chapter are quoted at 2007 prices, and annual growth rates refer to average annual growth at constant prices over the period 2002 to 2007 unless stated otherwise.

2.2 Revenues for the UK entertainment sector as a whole

Figure 2.1 shows that the UK entertainment industry is dominated in revenue terms by television and newspapers. According to industry statistics, entertainment sector revenues shrank over the past five years, when measured in constant prices, at 0.7% per annum in a period when GDP as a whole grew at over 2% per annum. But this statistic should be treated with some caution. If we exclude advertising from the industry statistics used to compile Figure 2.1, we get a compound revenue growth rate of 0% per annum. In contrast, the UK Household Expenditure Survey statistics suggest that end user spend on entertainment services actually grew by nearly 2% per annum over the same period. We have been unable to narrow this uncertainty. So we conclude that end user spend on, and public funding of, the UK entertainment sector is growing at somewhere between 0% and 2% per annum at constant prices.

Figure 2.1: The revenues generated by the UK entertainment sector in 2007[10]



Source: See Figures 2.2 to 2.6

[9] We provide more detail in Annex A.

[10] Revenues include advertising revenues, end user spend and public funding of broadcasting. They exclude entertainment equipment sales.

Within the entertainment sector as a whole:

- The biggest gainers are live music (+15% pa) and games (+7% pa).
- The biggest losers are newspapers (-2.8% pa) and recorded music (-8% pa).

It is interesting to note that the two segments of the entertainment sector which grew strongly, games and live music, are two segments which involve a high level of end user participation.

2.3 Watching

Figure 2.2 shows the revenues which are generated from entertainment activities which involve watching. These activities are dominated by television, which continues to generate growing revenues driven by strong sales of subscription services. In contrast sales of DVDs and cinema revenues are in decline.

Figure 2.2: Revenues from watching entertainment services

Item	Revenues in 2007 (£m)	Annual rate of change
Revenue from television of which:	11222	+1.2%
advertising	3544	+0.6%
public funding	2615	-0.2%
subscription	4288	+4.6%
other	775	0%
DVDs	2913	-1.2%
Cinema	1028	-1.6%

Source: UK Film Council, Ofcom

Key trends in the TV market include the following:

- There is a general move from analogue to digital platforms for the broadcast delivery of TV programmes as shown in Figure 2.3. Terrestrial digital switchover should be complete by the end of 2012.
- End users are moving from scheduled TV to time-shifted TV - partly through the use of personal video recorders, partly through take-up of video-on-demand services, and partly through use of the BBC's iPlayer and similar catch-up services.
- The Internet is increasingly being used to watch video content for entertainment purposes – for example through iPlayer, YouTube and various video-on-demand services.
- We have seen a substantial rise in the viewing of user generated content (UGC) which, to a limited extent, is now beginning to displace professionally generated content.
- There is a long-term trend to individual rather than communal viewing of television. Over the past 30 years the number of TV sets per household has doubled while the size of the average household has shrunk by 15%.

- The number of TV channels has proliferated - growing from three 30 years ago, to over 200 in 2002, and to over 500 by the end of 2008. This growth in the number of channels has led to a fragmentation of audiences. In 2002 the five main TV channels accounted for 78% of TV viewing. By 2007 this had shrunk to 65%.

Annex A provides details and sources.

Figure 2.3: The move from analogue to digital TV platforms

Platform type	Households served in 2007 (m)	Year when more than 90% digital
Satellite	8	2001
Cable TV	4	2006
Terrestrial only	13	2010[11]
Overall	**25**	**2008**

Source: Ofcom Communications Market Report 2008

2.4 Listening

As Figure 2.4 shows, radio revenues have declined steadily over the past five years, largely because of a reduction in advertising revenues for the commercial sector. Over the same period, time spent listening to the radio has hardly changed.

Figure 2.4: Trends in listening

Item	Position in 2007	Annual rate of change
Radio revenues (£m)	1179	-1.8%
Recorded music:		
total revenues (£m)	1488	-8%
physical singles sold (m)	21	-21%
physical albums sold (m)	246	+2%
paid downloads (m of tracks)	78	+47%
Live music concert revenues (£m)	699	+15%
Revenues from listening overall (£m)	3366	-1.0%

Source: Ofcom, IFPI, ?WhatIf!

Revenues from other forms of listening have changed dramatically. Sales of recorded music have shrunk rapidly, partly because sales of physical singles have declined rapidly, and partly because the price per physical album has dropped in the face of fierce competition. Illegal copying and distribution

[11] Plum estimate

of recorded music over the Internet have propelled these changes[12]. Sales of music downloaded over the Internet are growing strongly but do not compensate for the explosion in illegal copying and distribution.

In contrast revenue from live music is growing strongly. Some in the industry project that these revenues could overtake recorded music sales by 2012. Traditionally live music was used to promote record sales. Today many musicians see these roles reversed.

2.5 Reading

Revenue from the sale of books[13] is relatively stable. But sales of consumer magazines are now slowly shrinking, as shown in Figure 2.5, while the UK newspaper industry appears to be in long-term decline. Readership has shrunk steadily since the 1970s[14] and today many young people get their news exclusively from TV and the Internet[15]. Now advertising, which generates the bulk of newspaper revenues, is shrinking at 4% pa real terms as advertisers switch to the Internet. To compensate for this decline, newspaper publishers are putting significant effort into developing and promoting their on-line offerings while steadily raising the cover price of newspapers. But this creates a vicious circle. Higher cover prices reduce sales, which reduce advertising revenues, which in turn lead to higher cover prices. The switch to Internet advertising is now exacerbating this problem.

Figure 2.5: Key statistics on reading markets

Item	Position in 2007	Annual rate of change
Sales of consumer books (£m)	2578	0%
Sales of consumer magazines (£m)	2972	-1.8%
Newspapers:		
total revenues (£m)	7884	-2.8%
advertising revenues (£m)	4675	-4%
paid for newspapers pa (m)	7000	-1.5%
cover price (£)	0.70	+4%
Revenues from reading overall (£m)	13434	-2.1%

Source: The Advertising Statistics Yearbook 2008; The Publishers Association

[12] In the US 55% of recorded music is now acquired without payment according to an NPD Group survey of US Internet users 13+.

[13] We include consumer book sales but exclude business book sales.

[14] National Readership Survey, www.nrs.co.uk

[15] Between 2003 and 2006 reported use of the Internet for news rose from 15% to 27% while frequent reading of newspapers fell from 43% to 36%. See *New News, Future News*, Ofcom June 2007.

2.6 Playing

The revenue from games software[16] is growing strongly - especially the revenue for online games and games played on mobile terminals. Figure 2.6 illustrates. In addition the nature of the games market is changing rapidly. Current major trends are as follows:

- The appeal of games has spread from its traditional base of young males to the general population with the introduction of games like Nintendo Brain Training and Nintendo Wii.
- There is growing use of the Internet for the distribution of games, for example to mobile devices and to support new pricing models for console-based games.
- Demand for games involving virtual reality worlds and massively multiplayer online games (MMOG) is growing strongly. These games offer opportunities for new revenue streams from advertising.
- Console games are becoming more immersive, using the Internet to provide communal experiences within the games.

Figure 2.6: Key statistics on games markets

Item	Position in 2007	Annual rate of change
Revenue from games software:		
total revenues (£m)	1754	+7%
online game's revenues (£m)	100	+30%
games played on mobile phones (£m)	217	+10%
Percentage of UK population active in second life virtual world in 11/08	0.1%	Na
Growth in subscriptions to virtual reality games	Na	+25%

Source: Screen Digest

2.7 Funding of entertainment in the UK

The different sources of funding

Entertainment activities are currently funded from three main sources:

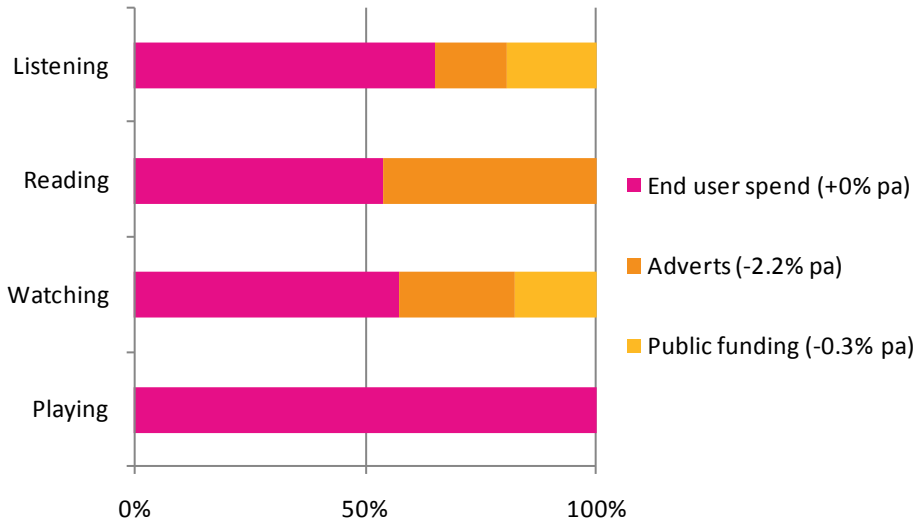
- Advertising.
- Public funding through the BBC licence fee.
- End users' spend.

In future we might add a fourth source - commissions on e-commerce transactions which are stimulated when users consume entertainment services.

[16] We exclude the sales of game consoles and other hardware from our analysis.

Figure 2.7 shows how the mix of funding varies by entertainment activity and how the overall revenues from each source of funding are changing. We can see that, while end user spend and public funding of entertainment is static in real terms, advertising spend has declined at more than 2% pa over the last five years.

Figure 2.7: Source of funding for entertainment activities

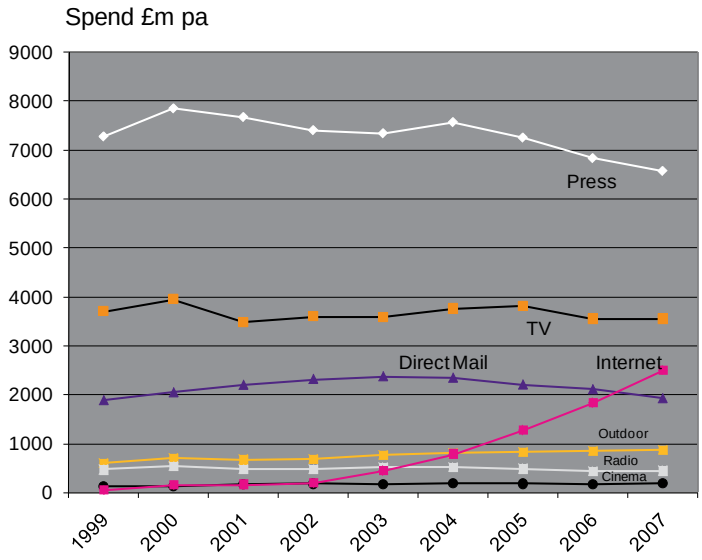


Source: See Figures 2.2 to 2.6

Funding through advertising

Figure 2.8 shows why advertising is currently declining as a source of funding for entertainment. Firms are turning to the Internet to spend an increasing share of the available advertising budget - mainly by diverting funds from direct marketing expenditure and newspaper advertisements. At the moment a high proportion of Internet advertising revenues come from paid search, with a small proportion generated by display advertising associated with entertainment content or applications.

Figure 2.8: Advertising revenues by source



Source: The Advertising Statistics Yearbook 2008

We are also starting to see the development of targeted advertising - in which adverts are accurately focused on those most interested in them, responses are accurately measured, and the targeted population can respond easily to the advertisement. The Internet offers an ideal platform for such advertising. Whether this targeted advertising further diverts advertising revenues away from entertainment will depend upon the extent to which there is a shift away from broadcast-based entertainment to Internet-based entertainment, and upon the level of participation of content producers and aggregators in the new value chains.

Public funding of entertainment

The Government currently raises £3.3 billion each year via the TV licence fee to subsidise entertainment content. This source of funding is assured up to 2013 through the current licence fee settlement agreement. We are likely to see continuing funding on a similar scale beyond 2013 for two main reasons:

- Such funding helps ensure mass audience consumption of content which reflects UK cultural values. This helps preserve social cohesion in an increasingly multi-ethnic UK society.
- Such funding is increasingly seen as providing a critical mass of UK produced content which forms the basis for UK success in the creative industry markets of the world.

End user spend

It is unclear how end user spend on entertainment will change in future, especially if there is a shift towards Internet-based entertainment where funding models are less certain. The future use of digital rights management (DRM) to protect this revenue stream is especially uncertain. DRM has not helped

the music industry protect its revenues from recorded music over the past few years. But, if it can be made good enough to protect video content from illegal copying and distribution, then we might see pay per use models for the distribution of video content over the Internet emerge, with direct distribution from the content producer to the end user. If not, then we are likely to see continued strong growth for subscription revenues and a resurgence in advertising revenues.

2.8 The role of mobile services

There is now growing evidence that the personal mobile device will play a much more substantial role in the delivery of entertainment services over the next 20 years. For example:

- The respected Pew Institute in the US recently published a report[17] in which it concluded that *"The mobile device will be the primary connection to the Internet for most people in the world in 2020."*
- The introduction of the i-Phone has led to a massive jump in the mobile Internet traffic generated by its owners, both in the US and in the UK. Much of the activity involves users in downloading music, software and videos from the Apple store
- Recent Nokia research[18], involving 9,000 16 to 35 year olds, claims that the consumption of entertainment is moving rapidly from the home to the mobile device amongst this age group.

On the other hand it is by no means clear that personal mobile devices will play a significant future role in ***video-based*** entertainment services:

- The user research of Chapter 3 suggests that there is strong resistance to watching video on the move.
- Video streaming and downloads use substantial radio access network capacity on the cellular network, and cellular video services are likely to attract substantial price premiums as a result.
- For those who do want to watch video entertainment on their personal devices there are much cheaper alternatives to unicast cellular in the form of mobile broadcast TV and/or pre-stored video content.

2.9 Implications for business models

What are the implications of the trends in entertainment markets, identified above, for the future of entertainment business models? We have identified five main implications, set out below, which we will consider again when we develop entertainment scenarios for 2028 in Chapter 5.

Implication 1: *Internet-based entertainment could lead to disruptive new value chains.* Traditionally different types of entertainment services are delivered to end users (largely) through separate and independent value chains as shown on the left hand side of Figure 2.9. But now the Internet is beginning to shape the characteristics, methods of distribution, and sources of funds all for entertainment activities. This opens up the possibility of innovative and disruptive business models in

[17] *The future of the Internet III*, Andersen and Rainie, Pew Institute, December 2008

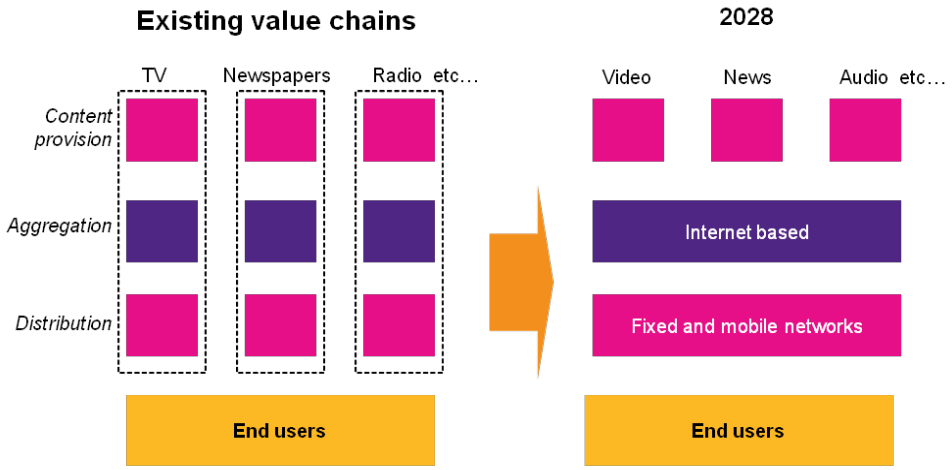
[18] *In the next episode… entertainment will be circular*, Nokia, December 2007

which global Internet service providers play a key role. This is illustrated on the right-hand side of Figure 2.9.

***Implication 2**: targeted advertising could help shape future value chains.* It is likely that targeted advertising will be an important source of funding for entertainment services in the future. If it is, then the organisations which are best able to collect information on entertainment consumption patterns are likely to exert strong control over the value chains of entertainment.

***Implication 3:** we could see a move from value chains based on vertical integration and bundling to value chains based around horizontal specialists.* Over the past few years fixed, mobile, satellite and cable TV operators have all tried to sell bundles of communications and entertainment services to end users. There is growing evidence that such strategies might fail and that end users, once they have broadband access, assemble their own bundles of entertainment and communication services sourced largely from Internet-based global specialists at low cost. Global suppliers of personal devices, such as Apple, Google and Nokia are now promoting this approach. If this trend continues then UK entertainment might in future be based on the horizontal value chain model on the right-hand side, rather than the silo model on the left-hand side, of Figure 2.9.

Figure 2.9: A possible change in the value chains for the delivery of entertainment services



Implication 4:** mobile personal devices will play an important, but uncertain, role in the delivery of entertainment services in future.* There is a strong trend towards the use of personal devices which are increasingly multifunctional and in which the mobile phone is just one of many functions. These devices now play a major and growing role in ***playing, ***listening*** and ***reading***[19] activities. But, as we discuss in the next chapter, it is not clear whether and how personal devices will be used for ***watching*** entertainment.

***Implication 5:** we will see a growing diversity of business models for entertainment services in the UK*. Our research suggests that new business models for delivering entertainment will coexist with, rather than fully replace, existing models over the next 20 years. There is general agreement that any Internet-based models for delivering video entertainment and news will run in parallel with traditional models, which will continue to exist in 2028 under all likely scenarios.

[19] As many young people switch from newspapers to the mobile Internet as the primary source of news.

3 End user behaviour and preferences

3.1 Introduction

To develop realistic scenarios for 2028 it is important to understand the current constraints provided by consumer behaviour and preferences for entertainment. It would be naive to try to get consumers to predict how they might consume entertainment in 20 years time. But it is possible to explore the extent to which current entertainment services meet basic needs which are unlikely to change over time. With this in mind we carried out a review of existing research on consumer use of entertainment and supplemented it with original, qualitative, consumer research. This involved just over 60 end users, selected to reflect the age, income, ethnicity and geographic characteristics of the total population. The research was conducted in three stages:

- Diary keeping – consumers kept diaries over the course of a week, noting their entertainment consumption and the reasons for it.
- Focus groups – consumers took part in structured sessions which probed key areas of consumer behaviour in the consumption of entertainment.
- Home visits – in-depth interviews with consumers in their homes.

We summarise the findings of this work below and provide more details in Annex B. The findings in Sections 3.2 to 3.4 and 3.11 are based primarily on desk research; the findings in the remaining sections are based primarily on our original consumer research.

3.2 Time spent on the entertainment

There is a strong and enduring consumer need for entertainment services. According to Figure 3.1 the average UK consumer spends over seven hours per day consuming entertainment - both as passive leisure in the home[20] and as a complement to other activities such as cooking and travelling. But there is considerable double counting of time because of overlaps between entertainment activities - with many people reading while watching or listening at the same time.

There is little evidence to suggest that the time spent on entertainment is changing. Time spent on passive leisure overall, and on individual components such as TV watching, and radio listening, has remained roughly constant over the past 15 years. If anything we expect an increase in time spent on entertainment in the future, given that:

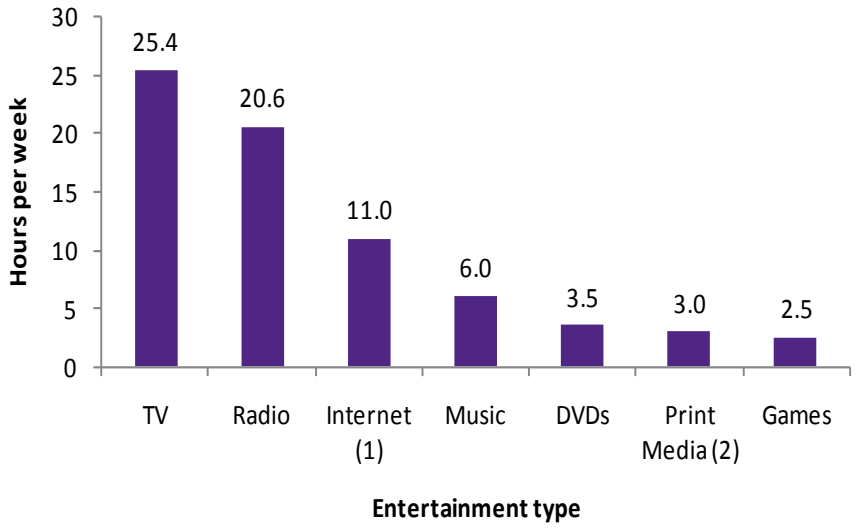
- The proportion of old people to the total population will grow significantly. The UK population of over 65 is predicted to grow by 46% - from 9.7 million to 14.2 million - over the study period. This population has lots of leisure time, much of which is likely to be spent on entertainment[21].
- There is a significant and steady growth of obesity in the UK population which could increase the demand for passive entertainment services.

[20] An average 4.5 hours per day.

[21] The over 65 year old currently watch 5 hours of TV per day compared with an average of 3.6 hours for the population as a whole .

- The development of entertainment services for mobile devices could expand the time available to consumers for entertainment services like TV to include time on the move and time while waiting.

Figure 3.1: The average time spent per person on entertainment services in hours per week



(1) Time spent using the Internet excludes school and work use (which accounts for an additional 7 hours per week) as this is mainly not entertainment activity. Home use is likely to include non-entertainment activities e.g. communication, shopping and banking. (2) 'Print media' includes newspapers and magazines. **Sources**: Ofcom, OxIS, ONS, Onepoll

Within this overall picture the time spent on use of the Internet is growing fast - from three hours per week per person in 2005 to 11 hours per week per person in 2007[22]. But it is not clear what other activities use of the Internet is displacing. For example time spent on TV viewing and radio listening have remained almost unchanged.

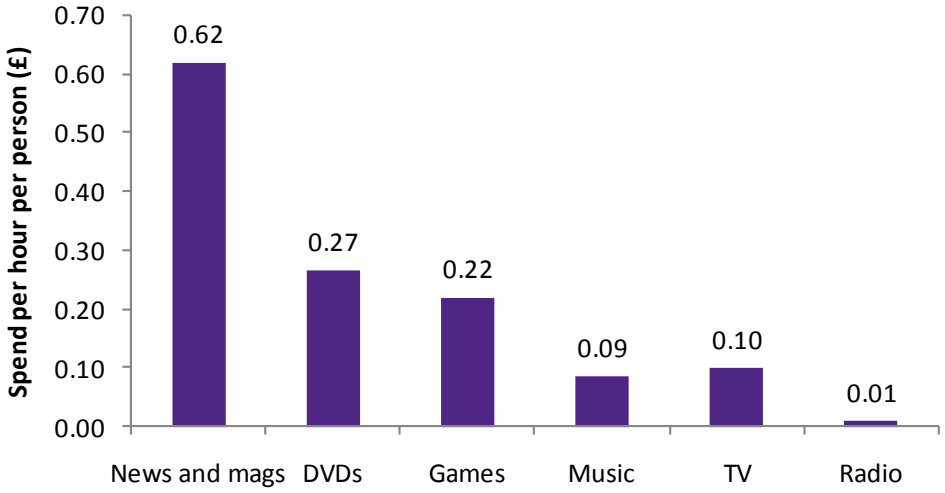
3.3 Money spent on entertainment

The average household spends £60 per week, or 5%, of its disposable income on entertainment. The way this spend is distributed in terms of spend per hour[23] by entertainment service varies considerably. Figure 3.2 illustrates.

[22] And US figures suggest that around 35% of this time is spent on entertainment.

[23] We include both direct end user spend and expenditure on the licence fee here.

Figure 3.2: Spend per hour on use of entertainment services



3.4 Take-up of new technologies

The pace of take-up of new technologies for entertainment and other applications appears to be accelerating[24]. Today well over half the population has access to digital TVs, DVD players, fixed broadband access and mobile phones and we can expect to add MP3 players, PVRs, and TV enabled computers to this list within the next decade.

There are however significant segments of the population which do not have access to these digital technologies, especially the over 75's. Less than half this age group own mobile phones or have access to the Internet. This lack of digital take up is expected to decline substantially over the next 20 years as today's 55-year-olds become 2028's 75-year-olds and technology becomes easier to use.

3.5 Willingness to pay for entertainment

A consumer's willingness to pay for entertainment is shaped largely by what is available to him or her through existing charging models. Consumers are willing to pay for live sports and films, for high definition or advertisement-light viewing of certain programmes, and for ownership of physical copies of content. But the Internet is eroding willingness to pay to some extent. Large amounts of what was premium content are now available free of charge on the Internet, albeit often in low quality formats. So the basis on which consumers are willing to pay for entertainment is shifting to a high-quality viewing experience and physical ownership. Some consumers, perhaps encouraged by their experience of the iTunes store, have expressed a preference for unbundled, pay per use, charging models rather than large subscription bundles.

[24] It took Apple 18 months to sell its first million iPods but only 5 years 5 months to sell 100 million; 74 days to sell its first million iPhones and 3 days to sell its first million 3G iPhones.

3.6 Entertainment on the move

People appear to have an innate desire to travel. On average individuals have spent 60 minutes per day on travelling since records began[25]. Traditionally people might have read a newspaper or listened to the radio whilst travelling. Today the mobile phone and MP3 player have substantially expanded options on what to do whilst travelling.

Our research indicates that most consumers continue to listen to music (on an MP3 player or car radio) or to read a book or newspaper while on the move. There is strong resistance to the idea of watching video on the move - partly because of the difficulty of watching video while walking or driving, partly because of the small screen size, and partly because of an aversion to watching in public arising from privacy concerns or fear of crime. Those that do have mobile phones with Internet capability often use them to browse the Internet or review e-mails rather than for watching video.

3.7 Scheduled versus on-demand viewing

Many consumers, and especially those with busy lives, are now moving from viewing scheduled television to viewing time shifted television by using PVRs, video-on-demand services or the BBC's iPlayer. People like to watch some programmes at a time of their choosing, instead of planning their lives around the television schedule. On the PVR this means recording for later viewing, while on the Internet it usually means 'catch up' TV - watching missed programmes. This on-demand functionality gives consumers more choice and flexibility. As a result consumers are watching more of what they judge to be high quality programmes and spending less time watching other programmes.

Video viewing on the Internet is growing rapidly. 21% of consumers viewed video content on the Internet in Q1 2007. This proportion had risen to 32% by Q1 2008. This form of viewing has led to the emergence of more active and engaged kinds of viewing behaviour, including:

- Getting ahead of the schedule by using file sharing or other services to watch episodes of series that have not yet been screened on broadcast television.
- Discovery and exploration by using services such as YouTube to browse nostalgic or other archived content and following links and connections to find new programmes.
- Quality checking. One consumer might use the Internet to watch the overseas version of a formatted shows which has not yet launched in the UK, to check whether it is any good. Other consumers use online recommendations for this purpose.
- "Snacking" in which consumers view short-form programming, whether user-generated (e.g. YouTube material) or professionally produced.

Yet our research also suggests that scheduled TV continues to address real needs. It meets needs among consumers for a structured daily life, as an event to look forward to, as something to talk about afterwards with others, and as a companion. These needs were mentioned by people of all ages. But the young and time poor are generally less attached to the schedule.

[25] Department for Trade and Industry. *Intelligent infrastructure futures: Project overview*. January 2006

3.8 The viewing experience

Consumers prefer to watch video content on a big screen in the comfort of their home. They value quality viewing. However they sometimes sacrifice this quality for:

- Free content.
- The opportunity to watch on the move or at a convenient time.
- Private individual viewing, e.g. on a TV set in the bedroom.

Two groups, the young and the time poor, are most likely to make this trade off and watch on a PC monitor, laptop or mobile screen.

3.9 User generated content

User-generated content (UGC) has achieved a high level of usage, but most users are ***consuming*** UGC rather than ***creating*** and uploading it. It is uncertain how this imbalance will evolve over time. At the moment large volumes of professionally produced content are being consumed on UGC sites, suggesting that users value quality as well as UGC.

3.10 Differences by age

We found three key drivers of entertainment behaviour:

- Skills and education (e.g. the young have been taught to use digital technology in school).
- Family circumstances (e.g. people in their 30s often have children and consequently have limited leisure time).
- Work situation (e.g. people in their 30s, 40s and 50s are likely to be in full-time employment, limiting their free time but giving them more disposable income).

These drivers are all correlated with age. Of course age is not the only factor affecting entertainment consumption behaviour. But it is useful to divide the population into three broad groups when considering entertainment requirements and behaviour:

Young people are most familiar with digital technology, having been brought up with PCs, the Internet and games consoles. They make the heaviest use of the Internet and games and there is some evidence of substitution for traditional media. For example young people are more likely to use a mobile phone or the Internet for video consumption; 45% of 15-24 year-olds had watched video clips online in Q1 2008. Their online video consumption includes some innovative behaviour such as looking at overseas sites for new programmes. We found that young people are the most likely to use multiple media simultaneously (media stacking) and to blur the boundary between communication and entertainment (e.g. multiplayer games, Facebook). Young people, who have relatively large amounts of free time and low income, are also the most likely group to seek out free content on the Internet.

People of ***working age*** typically have less time for entertainment due to work and child care commitments. This causes them to make more efficient use of their entertainment time: for example, by watching television programmes on demand or time shifted. 'PVR bingeing' behaviour (saving up programmes on a PVR and watching them all at once) was most prevalent among this age group.

There is widespread use of the Internet among people of working age: 38% of 35-44 year-olds watched video clips online Q1 2008. However, we found that online video was often used for 'catch-up', rather than for the more exploratory forms of online video consumption seen in younger people. Similarly, the gaming behaviour of this group differs from younger users, being weighted towards casual gaming as opposed to hard core console games. 37% of casual gamers are in the 35-49 year-old age group[26].

Older people's entertainment consumption tends to be more traditional. In part this reflects the lower uptake of digital technology among this age group. Older people are most likely to be digitally excluded, with less than 40% of 65-74 year-olds having access to the Internet[27]. But behaviour is mixed. We found examples of older people who are keen users of digital technology. Such people often used new technologies in an organised way, for example by carefully planning the week's viewing using a PVR. Retired people have large amounts of free time. So, not surprisingly, they are the heaviest consumers of entertainment, particularly television. The over 65s spend an average of 5 hours daily watching television compared to 3.6 hours for the population as a whole[28]. We found that older people often plan their entertainment consumption in advance and give media their full attention rather than multi-tasking.

3.11 Cohort effects

To what extent will the highly developed Internet usage behaviours observed among young people continue as they age? Will today's 20 year-old students, who spend a lot of time using Facebook, still use social networking sites at 40 when they have families and work commitments or will their behaviour more closely resemble that of today's 40-year olds? Cohort studies show that television viewing increases with age regardless of cohort. The more active and younger people watch the least television, and these viewing hours increase as people age and become less active. Given that these studies are conducted over long periods of time, the cohort effects of Internet usage have yet to be measured. However, the limited evidence which is available from time use and consumer behaviour studies suggests a model in which:

- People establish behaviour towards entertainment when they are young (16 to 25 years old).
- This behaviour is modified as life circumstances change (e.g. first job, having children, retirement).
- Skills have a strong effect on people's adoption of new technology (e.g. ICT skills learning in the workplace helps people to understand the Internet).

Under this model today's young people will retain their Internet skills and basic online behaviour as they age. However, the way that they use the Internet will change based on their life stage. For example, as these people have children they may look for more efficient ways to plan and consume their online entertainment, and find online entertainment experiences that they can share with their children.

[26] Casual Gaming Association, 2006

[27] Ofcom Communications Market Report, 2008

[28] Ofcom Communications Market Report, 2008

4 The likely capability of devices and platforms by 2028

4.1 Introduction

Over the last decade we have seen spectacular improvements in the price-performance of electronic components of all kinds[29]. This has led observers to formulate empirical "laws" which describe observed improvements. Figure 4.1 provides a summary.

Figure 4.1: Changes in price performance of technology components and communications networks

Label for empirical observation	Rule	Comment	Potential improvement over next 20 years
Moore's Law	Processing power doubles every 2 years	May reach quantum limits around 2018	10^3
Gilder's Law	Network bandwidth trebles every 12 months	Will persist for next 25 years	3×10^9
Hard disc storage capacity	10 Mbytes in 1980 has grown to 100,000 Mbytes by 2006	Magnetic domains will reach limits within next 20 years	10^3
Flash storage capacity	Doubling in capacity every 12 months	Quantum limitations at some point	10^6
Nielsen's Law	High speed bandwidth available to end users doubles every 15 months	Based on empirical observations since 1990	3×10^4
Coopers Law	Traffic carried over radio spectrum doubles every 2.5 years	Empirical evidence says valid since 1981	2.5×10^2
Edholm's Law	Capacity of fixed, nomadic and mobile networks all double every 2 to 3 years,	Based on empirical observations since 1990	2.5×10^2

Figure 4.1 also shows (in the final column) the potential improvements in price performance from 2009 to 2028 on the assumption that these laws continue to hold over the next 20 years. In practice this may not happen if technologies reach their quantum limits[30] within this period. But this does not mean that improvements in price performance of networks and devices will cease. Already equipment suppliers are beginning to move from electronic to optical switching. So, even if Moore's Law reaches its limits, the price performance of network switches will continue to improve substantially.

The potential improvements of Figure 4.1 are substantial - varying from a 250 fold improvement for cellular mobile networks to a potential 3 billion fold improvement for core network transmission. Figure 4.2 illustrates the scale of these potential improvements for the storage available in personal and home devices between 2008 and 2028.

[29] Strictly speaking our comments relate to the performance of components. But since the price of components has remained stable while annual investment in networks has not changed substantially, we can consider these improvements as relating to price performance rather than just performance.

[30] As electronic components become so small that it is increasingly difficult to control the electronic behaviour of the component.

Figure 4.2: A visual illustration of the scale of potential price performance improvements over the next 20 years

In this chapter we present our assumptions about how the price performance improvements described above will change the capability of the devices and platforms used for entertainment by 2028. Annex C provides discussion, justification and detail.

4.2 Compression and new video formats

We expect to see only a four to six fold improvement in compression technologies over the next 20 years. It is possible that vector representation techniques will lead to much greater gains. But this is speculative and we do not assume such developments in our scenarios.

In parallel with these modest improvements in compression technologies, we are likely to see strong demand from new video formats - with a move from standard definition video (at 720 x 576 pixels) to high definition video (at 1080 x 920 pixels), together with a requirement for three-dimensional information. The move from standard definition to high definition formats will increase the number of bits per minute of video by a factor of five, while the addition of 3-D information might further increase traffic volumes by 30%[31].

The increase in traffic volumes from using new video formats will more than use up all of the improvements in compression which are likely in the next 20 years. For example the 2 GB of storage currently required for one hour of standard definition video will, by 2028, be capable of holding 25 minutes of 3D high-definition video.

[31] In addition Ultra-High Definition (UHD) at 7680 x 4320 pixels is now in development. With expected improvements in compression, this will require a bit rate perhaps four times greater than that required for HD. We assume that UHD will take as long to become ubiquitous as the HD format, so that, by 2028, it might be used for production of some entertainment content but will not yet be a mainstream format for content distribution.

4.3 The capability of devices used for entertainment

We are likely to see two main types of devices used for the storage and consumption of entertainment by 2028:

- A varying set of ***modular devices*** at fixed locations in the home. These devices could include monitors for TV and computer display, TV receivers, digital video recorders, content stores, computers, and controllers, which are wirelessly networked together by a home server which automatically detects and connects new devices[32] to the network as they enter the home. This home server might, for example, use second generation fixed broadband to access the Internet and provide storage for over 20,000 hours of high-definition video content[33].
- Portable multi-function ***personal devices.*** These might offer interfaces to WiFi and cellular wireless networks, substantial processing power, and storage for a wide range of applications and over 1000 hours of high-definition video content[34]

When compared with home networked devices the performance of the personal device will be limited in three main ways:

- By the power available from its batteries. Fuel cells might help weaken this constraint.
- By the strength of the electromagnetic radiation which the device can emit for health reasons. This might be an important constraint on the uploading of user generated content. We consider this issue further in Chapter 6.
- By the small size of the screen in the device. Large roll-up screens should be available well before 2028. But it is not clear whether they will be popular, or whether users will prefer to dock wirelessly with large high definition monitors wherever these are available.

The current limit on the user interface for text input should be less of a problem in some circumstances. Voice recognition software should be able to deal with this problem in some, but by no means all, environments before 2028.

4.4 Home networking

Current home WiFi implementations do not have sufficient capacity to carry streamed video at acceptable quality levels. At the same time dedicated wiring is only likely to be practical as a home networking solution in newly built or newly renovated homes.

We estimate that the 802.11n standard for WiFi, and its likely successors, should offer sufficient capacity, using licence exempt spectrum at 2.4 and 5 GHz, to carry several streams of HD/3-D video around the home by 2028. See Chapter 6 for a more detailed discussion.

[32] Including authorised personal devices.

[33] At 4.7 GB per hour, assuming a 500 fold increase in storage capacity, and from a starting point of 200 GB.

[34] At 4.7 GB per hour, assuming a 500 fold increase in storage capacity, and from a starting point of 10 GB.

4.5 Distribution platforms

In future it is possible that a new platform will emerge which will radically change the economics of distributing entertainment (and other) content. But there are no signs of such a platform emerging. Given that it would take more than 20 years for a new platform to approach ubiquity, we do not consider this possibility any further. Instead we consider the development of existing distribution platforms – terrestrial and satellite broadcasting, fixed broadband and cellular mobile networks.

It is also possible that the bulk of commercial spectrum in the range of 400 MHz to 1000 MHz will be allocated to a common pool for use by a common IP network with radio access tails. Spectrum could then be allocated dynamically to all the various entertainment (and other) applications rather than having separate platforms use separate parts of this spectrum. This solution makes more efficient use of spectrum and is much more adaptable as demand changes. But it is very hard to implement because it requires high levels of cooperation between rival platform operators. So again we do not consider this possibility further.

Terrestrial TV broadcast platforms

By 2013 terrestrial broadcasting will have moved to digital transmission only, based on a multi-frequency network supporting mainly standard definition channels with a few high definition channels. It is clear that HD channel capacity on this platform will be limited, even if it is not clear what proportion of the spectrum released from digital switchover will be used for terrestrial broadcast from then on. There is a range of possible outcomes within the following upper and lower bounds:

- If all of the UHF spectrum were made available to broadcasters, and transmission moved to a single frequency network using DVB2, a theoretical maximum of between 195 and 245 HD nationwide channels[35] would be available. But requirements to share spectrum with neighbouring countries would halve this number, while regional programming would not sit well in such an architecture.
- If the digital dividend spectrum were all used for other applications, and the UK stayed with the current multi-frequency network, then the terrestrial platform would have a maximum capacity of 24 high-definition channels using MPEG 4.

Satellite broadcast platforms

Satellite broadcast platforms operate using spectrum at 12 GHz where there are few if any spectrum supply problems. So, technically, satellites could broadcast many hundreds of high-definition 3-D channels to UK homes. At the moment, the main limitation on the use of satellite broadcast video is the installed base of user dishes pointed at a single orbital slot at 28.2° East. But it would be possible, over the 20 year time horizon of our study, to introduce multi-slot dishes, like those used in the US, to increase capacity as required.

[35] With 49 RF channels and 4 or 5 HD channels per multiplex.

Wireline networks

We need to consider both fixed broadband access and the capability of the core network in assessing the capacity of wireline networks to deliver entertainment services in future.

First-generation ***fixed broadband access*** is based on use of copper local loops upgraded using DSL modems. The broadband speeds possible vary with the length of the local loop. For those living next door to a local exchange, download speeds of up to 24 Mbit/s are possible. But for the median user, a download speed of 3 to 4 Mbit/s is more typical. This is clearly inadequate for video applications.

Second generation broadband, based either on fibre to the node (FTTN) or fibre to the home (FTTH) technologies, offers a 20 fold or greater increase in median download speeds. At such speeds fixed broadband access is unlikely to constrain the development of entertainment services over the next 20 years.

The central issue is whether the investment required to provide the whole population with such broadband access will be made. The cost of FTTN deployment to the first 80% of households is a relatively modest[36] £8 billion[37]. But it might then cost another £5 billion to roll out second generation broadband to the remaining 20% of the population[38]. So it seems likely that the first 80% of the population will enjoy second generation broadband by 2028. But the broadband speeds available to the remaining 20% of the population are a matter of some uncertainty.

The capacity of the ***core network*** is unlikely to be a constraint on the development of entertainment services:

- As Figure 4.1 shows, Gilder's law means that transmission capacity is unlikely to create any capacity constraints.
- Moore's Law may break down by 2018. So improvements in the price performance of electronic switches might not keep pace with rising traffic volumes, and core network switching could become a constraint at constant capital expenditure levels. However, we expect that improvements in optical switching technologies will overcome this potential problem.

Wide area wireless networks

We might see a combination of wireless networks offering wide area delivery of entertainment content and services by 2028 with services offered via:

- Cellular mobile networks using technologies such as OFDMA and offering download speeds of several hundred Mbit/s and
- Base stations at public wireless hotspots such as cafes, hotels and stations, offering broadband connections to nomadic but stationary users in public hotspots. There are currently 11,000 such networks in the UK using WiFi technology.

[36] Compared with the UK telecommunications industry's annual investment of around £6 billion.

[37] *The cost of deploying fibre-based next-generation broadband infrastructure*, Broadband Stakeholder Group, July 2008

[38] *The cost of deploying fibre-based next-generation broadband infrastructure*, Broadband Stakeholder Group, July 2008

These networks will most likely complement rather than compete with each other. WiFi networks might provide end-users with wireless connectivity for their personal devices in the majority of cases[39], while cellular mobile networks provide wireless connectivity the rest of the time.

Maximum download speeds are unlikely to constrain use of wide area wireless networks for entertainment. But building sufficient capacity could be a major problem, especially if demand to upload user generated video content from mobile devices is strong. In these circumstances the cellular wireless networks will need to offer a much higher density of cells than at present. We discuss these issues in detail in Chapter 6.

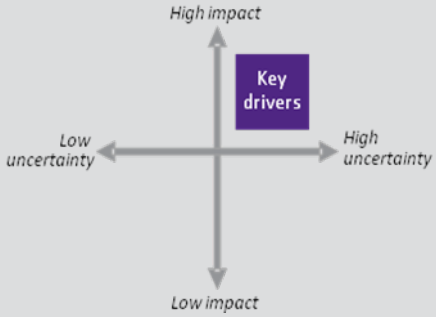
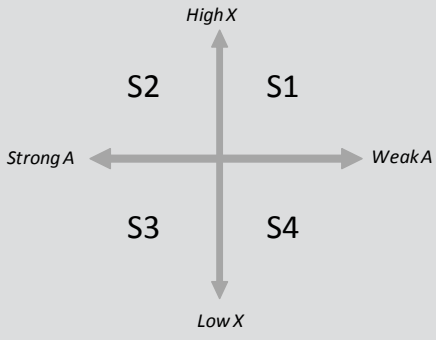
[39] Over 70% of personal device transactions take place when users are stationary in locations which are likely to have WiFi networks in future.

5 Scenarios for the distribution and consumption of entertainment in 2028

5.1 Introduction

Using the findings from Chapters 2 to 4 as our starting point, we have developed possible scenarios for the distribution and consumption of entertainment in 2028 using standard scenario development techniques developed by Shell in the 1970s. Figure 5.1 outlines the process used.

Figure 5.1: The scenario development process

Step	Description	
1	Identify the main purpose of developing the scenarios.	
2	Identify the main drivers of change in the entertainment sector using the findings of Chapters 2 to 4.	
3	Classify drivers to distinguish between: Those with high and low impact on the development of entertainment. Those high impact drivers where there is a high rather than low level of uncertainty over outcomes. These are the key drivers.	
4	Analyse the key drivers to see how they relate to each other and to specify opposing outcomes in 2028.	
5	Pick the two dimensions which capture as much as possible of the uncertainty generated by the key drivers and select from the four quadrants the most likely scenarios for detailed development.	

In applying this process we:

- Develop scenarios so as to enable us to assess how changes in the UK entertainment sector will impact UK spectrum requirements in 2028. This means paying particular attention to video-based entertainment applications, which are particularly spectrum hungry, in developing our scenarios.

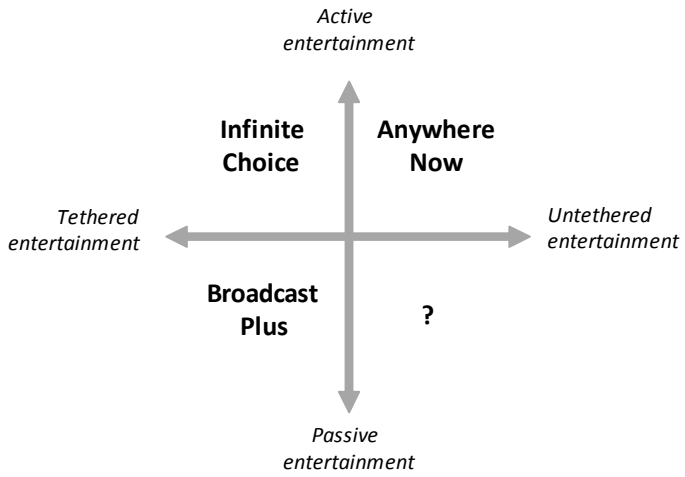
- Take the view that the pace of change is likely to be greater in the next 20 years than in last 20 years. Broadcasting has dominated the entertainment sector for the last 20 years. Now it is challenged by Internet-based entertainment. The struggle between these two business models will generate major change, whatever the outcome.
- Focus on describing the behaviour of the majority of consumers rather than all of them. There is a great diversity of needs - within any given scenario significant minorities of consumers will consume entertainment in other ways.

5.2 The scenarios which emerge

Using Figure 5.1's process, we identified for detailed development the three scenarios of Figure 5.2. We chose as our primary dimensions for scenario creation two drivers which reflect the greatest uncertainty over future end user demand for entertainment:

- The extent to which consumers seek ***active*** rather than ***passive*** entertainment, in which they search out content for themselves, recommend it to others, engage in immersive entertainment such as games, or create content for others (UGC). This active/passive entertainment dimension is closely correlated with uncertainty over the extent to which Internet-based entertainment rather than broadcast-based entertainment might dominate in the UK by 2028.
- The extent to which consumers want entertainment services which are ***untethered*** rather than ***tethered*** to a location. Tethered use might involve both consumption in the home and consumption via a WiFi connection in a mobile device at an office or public place while stationary.

Figure 5.2: The three scenarios selected



We label the three scenarios of the first three quadrants as:

- ***Broadcast Plus***. Under this scenario, most end users continue to adopt their traditional, passive role in consuming entertainment. Most of them prefer scheduled broadcast television and enhanced versions of it (Broadcast Plus) to the more active Internet-based entertainment.

- ***Infinite Choice***. Here most consumers actively seek out entertainment services and content, which are now delivered primarily from the Internet, via home servers, to give almost infinite choice. The characteristics of this new world of Internet based entertainment are set out in Figure 5.3.
- ***Anywhere Now.*** Under this scenario, entertainment becomes an untethered and much more personalised experience. The personal mobile device, rather than the home server, becomes the gateway to Internet-based entertainment which is available anywhere now - on the move as well as on a tethered basis.

Figure 5.3: Possible characteristics of Internet-based entertainment

The primary source of entertainment shifts from broadcast platforms and printed newspapers to the Internet.
Content provision becomes a global market generating significant economies of scale in distribution which favours global players.
Web based aggregators offer novel combinations of music, video, speech, audio, news and games from their servers.
End users use new mechanisms to decide what to watch, including active search and personalised channel offerings and recommendations, e.g. via social networking sites
Global Web stores and search engine providers dominate the value chain for distribution and aggregation of content, and control consumer profile information which is then used for targeted advertising.
Fixed and mobile operators struggle to compete with the Web stores to offer value-added services.
Broadcasters, newspapers and many magazines refocus on content provision rather than on aggregation and distribution. Many of them fail.
Pay per use revenues become significant as content providers sell directly to end users rather than via subscription service-based aggregators.
Targeted advertising becomes a major source of revenue.
Content providers are able to exploit archives to meet the needs of ethnic and special interest groups.

The scenario described in the fourth quadrant, in which consumers who prefer passive entertainment seek it in an untethered form, does not look likely when compared with the other three scenarios:

- Mobile TV might deliver live schedules untethered at reasonably low cost. But this represents only a minor modification to the *Broadcast plus sce*nario.
- Consumers might view their personal schedules, side loaded to the personal device, while on the move. But this is just a feature of the *Broadcast plus* scenario.
- It seems unlikely that consumers would want to pay the substantial premium required for untethered and immediate consumption of personalised schedules while on the move, given the limited value of such functionality.

We describe the three scenarios in more detail in Sections 5.3 to 5.6 and provide a comparative, tabular specification in Annex D. Figure 5.4 provides a summary description of the key characteristics of the three scenarios, and how they use platform and devices, in a comparative format.

Figure 5.4: A summary description of the three scenarios

Area	Measure	Broadcast Plus	Infinite Choice	Anywhere Now
Economy	Growth in GDP at constant prices – 2008 to 2028	15 %	40%	
End user preferences	Active vs. passive entertainment	Passive	Active	
	For entertainment on the move	Weak		Strong
Business models	Who dominates	Broadcasters	Global Internet based aggregators	
Devices	Use of personal devices for entertainment on the move	Pre-stored content	Pre-stored content + access to IBE[40] at public wireless hotspots	IBE anywhere and any time
Platforms	Use of a home server	Stored broadcast content used to provide personal channels, targeted advertising and catch up TV	Used as gateway and cache for IBE	Used mainly to archive prized content
	Fixed network supply	Patch 2nd generation broadband	Near universal 2nd generation broadband	
	Terrestrial broadcast	Limited HD provision		Switched off and spectrum used for mobile services
	Satellite broadcast	Strong demand for and extensive provision of HD broadcast	Extensive HD provision but declining demand	
	Cellular mobile for entertainment	Sufficient capacity for non-video applications only		Support for video applications when supplemented with public wireless hotspot capacity

5.3 Common features of the three scenarios

There are a number of changes to the entertainment sector which are common across all three scenarios. In particular we assume that, in 2028:

- Home servers and networks are readily available, affordable and easy to operate. Such home equipment:
  - Automatically connects wirelessly to each new electronic device as it is introduced into the home.
  - Has the capacity to store over 20,000 hours of high-definition video content.
  - Automatically updates the personal device of each household member (wirelessly) with e-mails and entertainment content of interest when he or she arrives home.

[40] Internet based entertainment as described in Figure 5.3.

  - Offers household members personal video schedules, together with search and time shift viewing functionality.

- Personal devices with storage for over 1000 hours of high-definition video, multiple applications and functions, and interfaces to both cellular and WiFi networks are used by virtually everyone.
- HD/3-D video formats are standard for most video content, although video distributed primarily for viewing on personal devices is not.
- Substantial public funding of UK originated entertainment content remains for a mix of social cohesion and industrial policy reasons.
- Fixed and mobile operators focus on selling their access products to consumers and on selling other services[41] wholesale to retail service providers. Their attempt to sell vertically integrated bundles of network, services and content directly to end users has failed. End users have rejected the idea of a secure, walled garden approach and now assemble their own bundles of entertainment and communication services largely sourced from Internet-based specialist providers at low cost instead.
- Only a minority of people now turn to printed newspapers for their news. Most get news online, and news publishers generate the bulk of their revenues from a mix of syndicated online content and their own websites.
- Radio remains popular - largely as a complement to other activities such as housework, driving and many forms of paid work. Analogue radio was switched-off in 2025 and digital receivers are embedded into a wide range of entertainment devices.
- Local radio and newspapers have largely been replaced by Internet-based community services offered over global platforms and are subject to light touch regulation.

5.4 The *Broadcast Plus* scenario for 2028

There is strong demand for Internet-based entertainment among the young by 2028. But the majority of the population makes only occasional use of the Internet to search for specialist and archived material. Instead they prefer scheduled video delivered through a mix of subscription and advertising funded services. They are attracted by:

- Live coverage of major events.
- The convenience and ease of use of schedules.
- The structure which an appointment to view video content at specific times provides.
- The opportunity to chat about last night's TV with friends.
- The high quality experience provided by professionally generated content shown on big high definition screens and viewed from the comfort of the sofa or bed.

[41] Such as guaranteed quality of service, storage and caching, and content recognition services.

At the same time they find that:

- Their need for flexibility over when they view is met by accessing the catch-up facility on their home server. This server stores all of the last month's broadcasts from the 50 HD channels they have selected from the hundreds which are broadcast in the UK.
- Their need for more personalised content is met by personal schedules delivered locally through intelligent assembly of the material on their home servers.

These personal video schedules have proved very popular. Faced with the growing challenge from Internet-based entertainment services in the 2010s, the main broadcasters developed software to install on home network servers which:

- Collects information on the entertainment consumption habits and preferences of household members and up-loads this data to the Internet for analysis.
- Uses this information to assemble personal schedules from the programmes stored on the home server.
- Enables the broadcasters to embed appropriate advertisements in the personal schedules from among all the advertisements stored on the home server from the last month's worth of broadcasts.

As well as meeting much of the consumer's need for personalised video, this enhanced service also generates significant revenues through targeted advertising.

Various service providers have attempted to move Internet based entertainment into the mainstream but have so far failed for a combination of reasons:

- Content providers are still reluctant to sell direct to end users due to fear of cannibalising revenues generated via mobile operators and subscription based aggregators.
- The repeated failure of DRM software to protect video content sold directly over the Internet has made it hard to monetise such a sales channel.
- Repeated high-profile security breaches of the Internet in the 2010s set back growth in the use of Internet applications by many years. This has dampened demand for Internet-based entertainment.
- Regulatory measures to protect children from violent and pornographic material on the Internet have constrained market growth.

The patchy provision of second-generation broadband within the UK has also restricted demand. It took the UK nearly 10 years to recover from the financial crisis of 2008. This severely limited capital expenditure on the next-generation access networks required to provide second-generation fixed broadband. It also limited mobile broadband which requires fibre access networks for backhaul. As a result mobile broadband prices remain (relatively) high in 2028, while a substantial proportion of households still only receive ADSL speed fixed broadband. This slow development of unicast platforms has limited their role in the delivery of entertainment services.

Mobile broadband services are now the major source of revenue for mobile operators who offer near 100% coverage using LTE technologies. But lack of ubiquitous fibre, relatively limited access to UHF spectrum, and capital expenditure restrictions during the long recession of the 2010s, means that the capacity of the radio access networks has grown much more slowly than the mobile operators had hoped over the past 15 years. As a result the price premium for unicast video streams remains

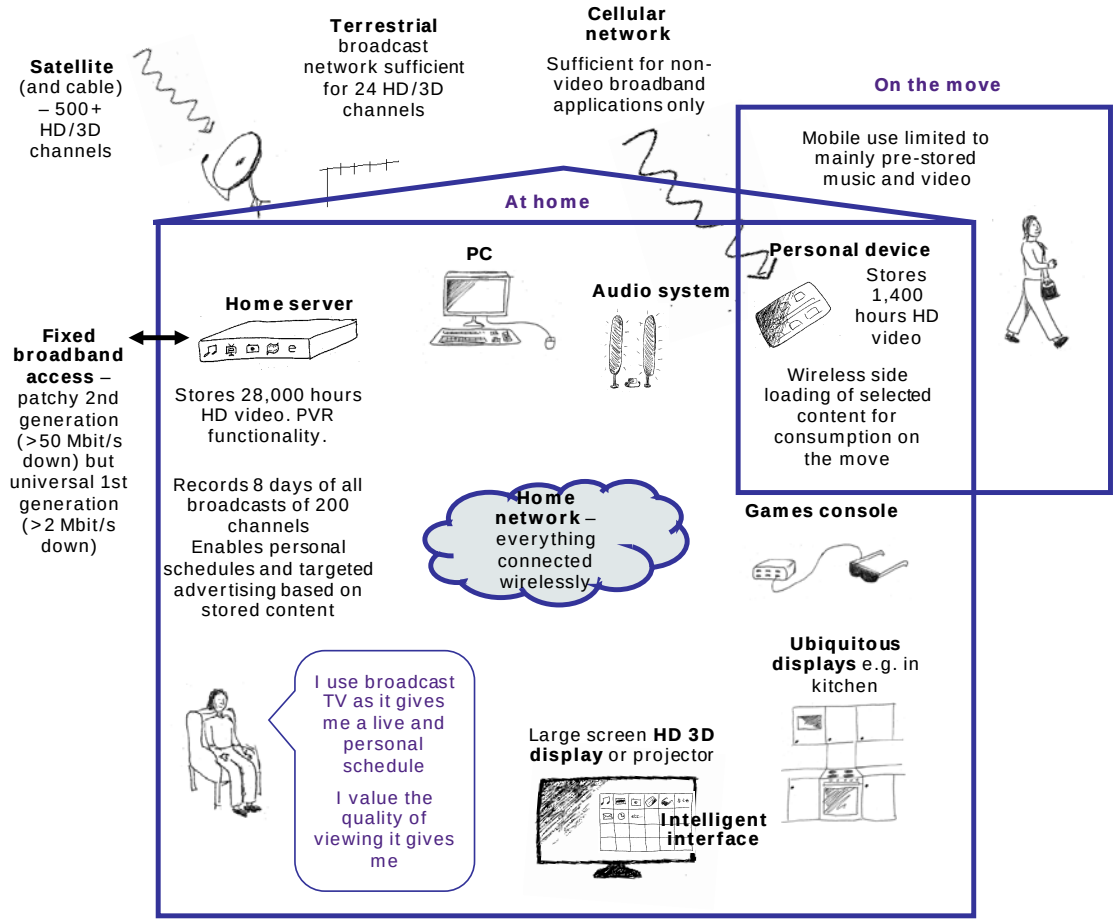
substantial. Mobile broadband is used mainly for personal communications, Web browsing, and for delivery of news, music, and games which only require limited bandwidth. The price of video streaming and video downloads remains prohibitive. So consumption of video on personal devices is restricted to reception of mobile TV services[42] and viewing of pre-stored content side-loaded from the home server.

Under the *Broadcast Plus* scenario:

- Broadcasters remain strong in their traditional roles of commissioning and producing content, aggregating content and advertisements into channels, and promoting programmes so as to maximise audiences.
- A handful of broadcasters now dominate in the new markets of targeted advertising and the supply of personalised channels. It is also these broadcasters who, with the biggest profit streams available to fund content, are the most successful in supplying traditional scheduled television.
- Rights holders and content producers continue to sell their content via the broadcast aggregators.

Figure 5.5 provides an illustrative sketch of some of the key features of the *Broadcast Plus* scenario.

Figure 5.5: The *Broadcast Plus* scenario - key features



[42] Broadcast over a dedicated mobile broadcast network built in the late 2010s.

Figure 5.6 then provides one of many storyboards on how entertainment services might be used under this scenario.

Figure 5.6: A story from the *Broadcast Plus* scenario

1

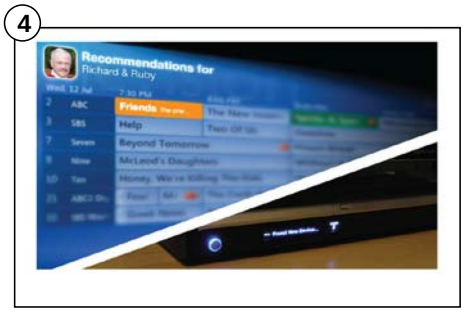
2

Richard and his family buy a new home server. The server automatically detects local devices and prompts the account to be uploaded.

3

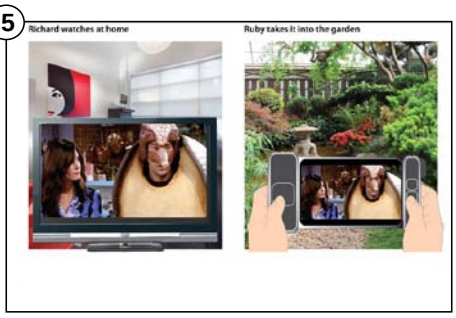
The profile includes: Preferences | Email Accounts | Watched & Unwatched TV etc.

4



The home server collects information on the entertainment consumption habits and preferences of household members and makes a recommendation for Richard and Ruby.

5



They watch the programme together in the living room, then Ruby decides to continue her viewing in the garden, by transferring to a mobile device.

6

The system supports targeted advertising. Richard and Ruby see different ads in the same break.

7

Meanwhile Kate watches live coverage of a U2 comeback tour while chatting to her boyfriend using an on-screen chat application.

5.5 The *Infinite Choice* scenario for 2028

By the early 2020s consumers of virtually all ages had embraced the participative and immersive experiences of entertainment which the Internet can offer over second-generation broadband networks. As a result the bulk of entertainment content and services are now delivered over the Internet, although a minority of the population still watches broadcast television.

Consumers are attracted to Internet-based entertainment by:

- The almost infinite variety of content which is available.
- The immersive nature of the experience, particularly in games and in the virtual reality material involving multiple players delivered over the Internet.
- The innovative combinations of music, video, speech, audio, news and games which are offered.
- The relevance and immediacy of the available content. With the near universal availability of high upload speeds, user generated content has flourished. Such content more than makes up for, in its relevance for its target audience, what it lacks in production values.

Users find the entertainment they want through a variety of means. Some use active video search. Others rely on recommendations from social networking with friends and from entertainment stores. Yet others subscribe to personalised schedules, offered by service providers who trawl the many entertainment websites to assemble content which matches their subscribers' expressed preferences and previous consumption behaviour.

The number of broadcast TV channels has fallen from its peak of over 500 in 2010. The audiences for the small multichannel TV stations of 2010, which typically broadcast specialist, archived or repeat content, have largely switched to Internet-based entertainment services which offer a much wider choice than the multi-channels which they replace. Many TV channels continue to broadcast, but to very small audiences, and remain viable only because the content and broadcast platforms are available at low marginal cost.

The tipping point to Internet-based entertainment came in 2020. By then all the necessary components required were in place. For example a high proportion of homes:

- Subscribed to next-generation access fixed broadband. This was rolled out across the UK from 2012 on, following a short, sharp, economic recession
- Used home network servers which stored many thousands of hours of entertainment content for wireless distribution to electronic devices in the home. In effect the home network server became an Internet cache for entertainment content.
- Service providers had demonstrated by 2020 that Internet-based entertainment offered effective targeted advertising.
- Major content owners had started to sell their content direct to end users via the Internet, attracted by higher margins and the additional revenue streams which were possible through packaging and pricing their content in a variety of new ways.

In combination these factors led to a massive migration from broadcast to Internet-based entertainment. Today in 2028 there are two main business models for Internet based entertainment:

- Older and time-poor people mainly pay for on-demand content, which is free from advertising, through web stores.

- Younger and time-rich people want free content - whether user generated or professionally generated. They use search engines to find free content which comes with targeted advertising.

Both these models are dominated by US-based global service providers. The major role of UK companies is to provide content to the web stores, to run entertainment websites, and to provide the fixed and mobile networks over which users can access Internet-based entertainment.

Mobile broadband is very successful. But, even with extensive rollout of fibre across the UK, the mobile operators have found that the cost of unicast video streaming and downloads remains high and this is reflected in their end user pricing. So demand for mobile broadband is limited to other less bandwidth hungry applications. This includes entertainment applications such as music, games and news services. Personal devices are also used for video consumption. But this use is confined to downloading and streaming via local wireless tails, such as WiFi, and to the viewing of pre-stored content.

Public wireless hot spots, based on WiFi technologies, are now important in the delivery of entertainment services. Many retailers offer free wireless access as a way to attract customers, while mobile operators bundle hot spot use with mobile subscriptions so as to encourage efficient use of scarce spectrum.

After some initial difficulties, regulation of this Internet-based entertainment world has done little to constrain market development:

- Consumers accept the use of data on their consumption habits for targeted advertising in return for the ability to consume Internet based entertainment services without charge.
- Those consumers who want advertising free entertainment can purchase subscriptions or one-off content from service providers.
- Government schemes to promote end user awareness of harmful Internet content have worked well. There is now a healthy market in software that enables parents to protect their children from such content.

Under the *Infinite Choice* scenario:

- Only a few UK broadcasters survive. The business is centred around promoting and broadcasting major public events - both in the studio and through outside broadcasts.
- The entertainment sector is dominated by global service providers - a mix of global search engines offering free content with associated targeted advertising and global Web stores offering both easy to buy and advertising free content on a pay per use basis and on subscription-based personalised channels.
- These global service providers now enjoy two substantial new revenue streams. First they have exploited their ability to collect information on entertainment consumption by end users to generate additional revenues from targeted advertising. And second, they now enjoy commission revenues on the purchase of goods and services promoted by Internet-based entertainment.
- Local service providers struggle to compete with these global service providers. The traditional market of the local ISPs, offering e-mail, websites, anti-virus software, WiFi, storage and access has disappeared and local UK-based service providers have difficulty in competing with the much lower unit costs of the global service providers.

- Content producers have switched distribution channels, away from the broadcast aggregator. Now they sell their content primarily through Web stores and directly from their own websites to consumers. This has reduced their distribution costs considerably while, at the same time, giving them new ways to package and price content so as to extract more of the willingness to pay from the different segments of their markets.
- The move from broadcast-based to Internet-based entertainment has led to new forms of content discovery. In particular social networking sites now play a central role, both in generating end user recommendations on worthwhile entertainment services and in viral marketing campaigns by content owners and Web stores.

Figure 5.7 provides an illustrative sketch of some of key features of the *Infinite Choice* scenario in which the main differences from the Broadcast Plus scenarios are highlighted. Figure 5.8 then provides one example of how entertainment services might be consumed under this scenario.

Figure 5.7: The *Infinite Choice* scenario - key features

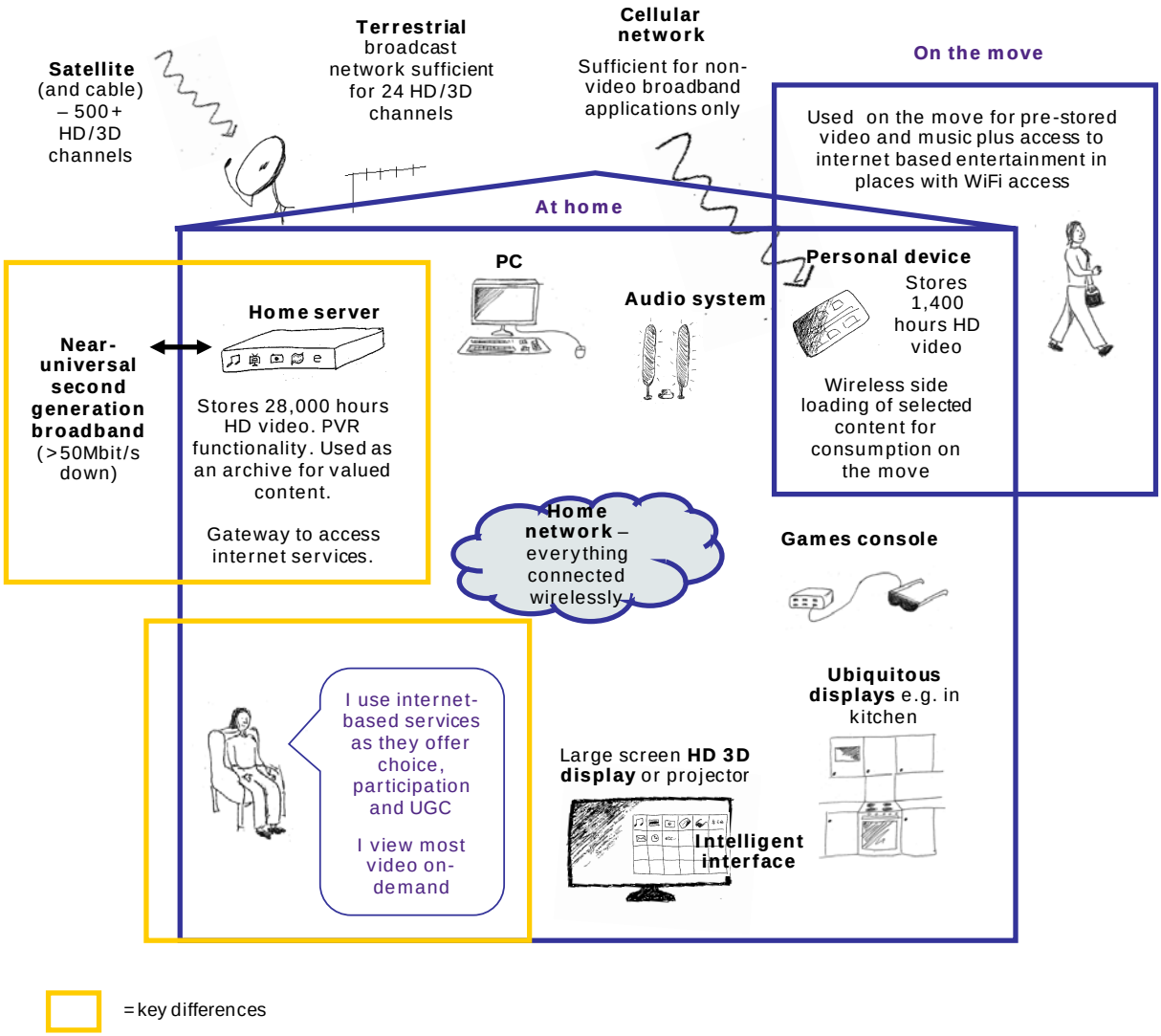


Figure 5.8: A story from the *Infinite Choice* scenario

Josh has started judo lessons at college. When he gets home he wants to watch something on martial arts. He types "Judo" into virtual keyboard and chooses an obscure film from the results.

He starts watching the film and at the same time chats on a martial arts community site. Someone recommends user-generated film of a fight. Josh bookmarks this for viewing later.

When his film finishes the bookmarked programme starts to play. The programme's presenter mentions "The Zen of Judo" an e-book on judo. Alongside the programme is a stream of links relating to what's on-screen at the time. This includes a link to an e-book written by the coach of the contestant.

Josh clicks on the link to the e-book to buy it. The home server automatically transfers the book to his e-reader.

5.6 The *Anywhere Now* scenario for 2028

Most people now use their mobile personal devices as the primary means to control their consumption of entertainment, so making it a more personal experience. Services are available anywhere, and at any time, by using the personal device to access services via a mix of WiFi and cellular network connections.

As in the *Infinite Choice* scenario:

- Consumers are attracted to Internet-based entertainment by the wide variety of available content, the innovative services on offer, the user generated content and the immersive experience.
- Rollout of NGA fixed networks is complete.

- Users find the entertainment they want through a mix of searching, recommendations and personalised channels.
- Services are funded through a mix of on-line payments and targeted advertising, and are dominated by US-based global players.
- Privacy and content regulation has done little to constrain market development.

But in the *Anywhere Now* scenario it is the personal device rather than the home network server which is the key to consumption of entertainment. Consumers use their personal device directly to download or stream content from the Internet rather than side-loading it via the home network server. If they want a "sofa cinema" experience they link their personal device to a large high-definition screen to view in the living room or bedroom - either alone or as a shared experience. But it is the personal device which controls the viewing experience and through which the content is downloaded or streamed from the Internet. Use of home network servers is limited to providing an archive for prized entertainment content which is collected for repeated viewing.

Driven by strong end-user demand for Internet-based entertainment on an "anywhere any time" basis, the mobile operators formed two rival consortia in 2022 to build high density radio access networks across the UK. These now have the capacity to handle all the Internet-based entertainment traffic generated on the move at relatively low cost. These low unit costs are made possible by a combination of factors:

- The roll out of fibre to within a few hundred metres of every home, so as to enable second generation fixed broadband, has also provided cheap, high capacity backhaul to the mobile operators.
- Sharing of radio access networks more than halves unit costs.
- The deployment of LTE technologies, and their successors, has increased spectral efficiency.
- Terrestrial broadcast switch-off has led to the release of a substantial quantity of UHF spectrum. This has increased the capacity of a given capital investment in radio access networks by a factor of three.

In addition over 80% of traffic generated by Internet-based entertainment is now routed to avoid the cellular radio access networks and to use wireless access points in homes, offices or public places instead.

Terrestrial switch-off has been an important factor in enabling users to access Internet-based entertainment services on an anywhere any time basis. This switch-off, which occurred in 2026, was made possible by a number of interrelated events:

- Most users switched from terrestrial to satellite broadcast in the early 2010s in order to receive full multichannel broadcast in high definition format[43].
- The move to Internet-based entertainment in the late 2010s further reduced demand for terrestrial broadcast.
- The UK Government included second generation broadband access in its definition of universal service in 2020. This increased pressure for a terrestrial switch off, once it was realised that UHF spectrum offered the cheapest way to rollout second generation broadband in rural areas.

[43] Terrestrial broadcast had capacity for only 30 HD channels in the UK

- At the same time the mobile operators pressed hard for release of the UHF spectrum used for terrestrial broadcast and, in the UK, were prepared to pay several billion pounds for such access to help meet the growing demand for mobile broadband.
- The revenues from the sale of UHF spectrum to the mobile operators enabled the UK Government to fund mandatory switchover from terrestrial to satellite broadcast for the small proportion of the population who continued to view terrestrial broadcast TV.

The business models and value chains of the *Anywhere Now* scenario, and the regulatory issues which they generate, are similar to those of the *Infinite Choice* scenario. There are two significant differences however:

- The use of a personal device rather than a home network server to control consumption of entertainment services means that the end user consumption data collected from the device is unambiguously associated with its owner. This makes targeted advertising more accurate and effective.
- The personalised information stored on the personal device represents a substantial investment of time by its owner. This information is stored in backup form on the Web, creating an additional revenue stream for the global service providers and an additional way to lock-in customers who use this service.

Figure 5.9 provides an illustrative sketch of some of key features of the *Anywhere Now* scenario and Figure 5.10 provides an entertainment storyboard under this scenario.

Figure 5.9: The *Anywhere Now* scenario – key features

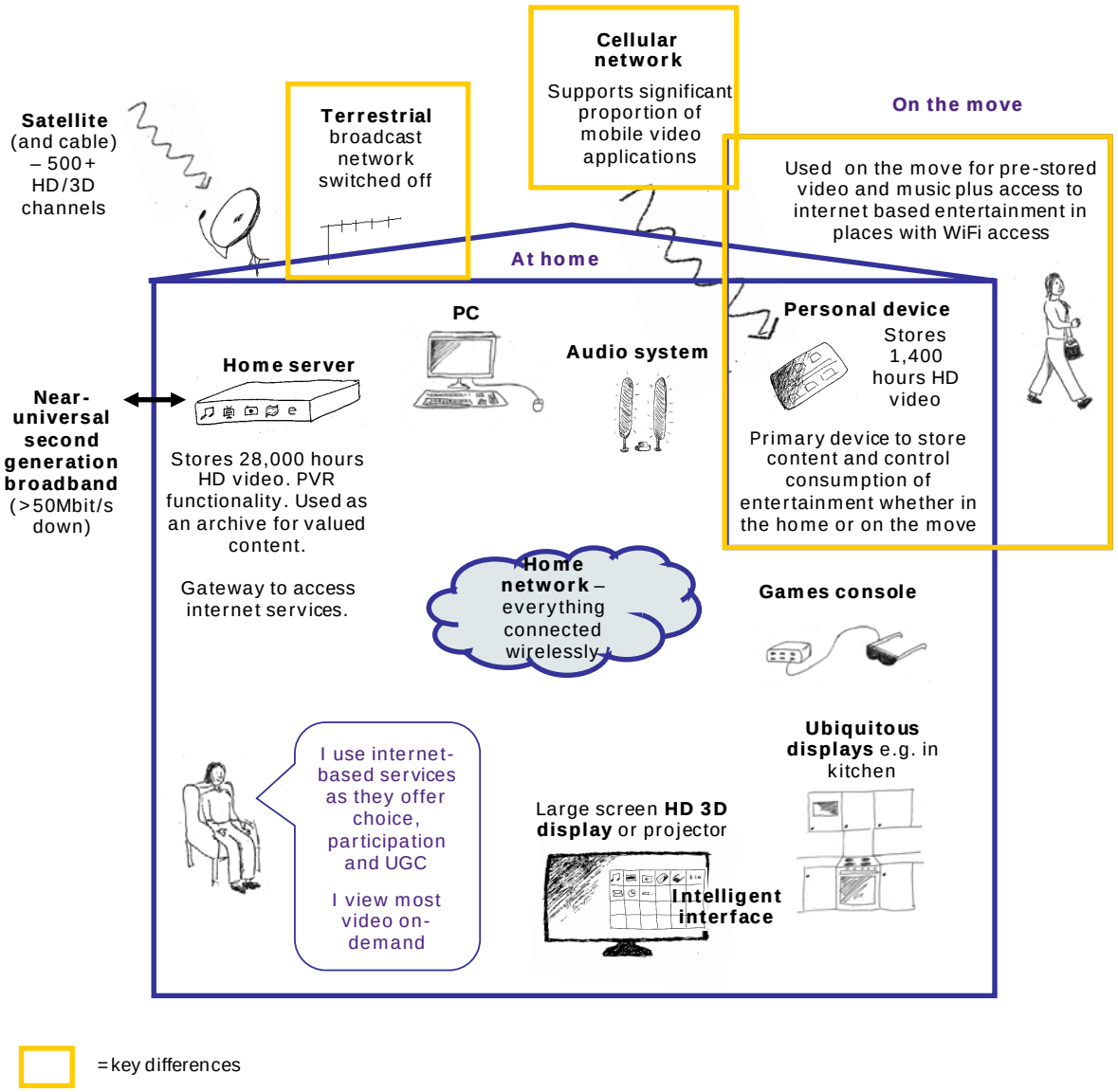


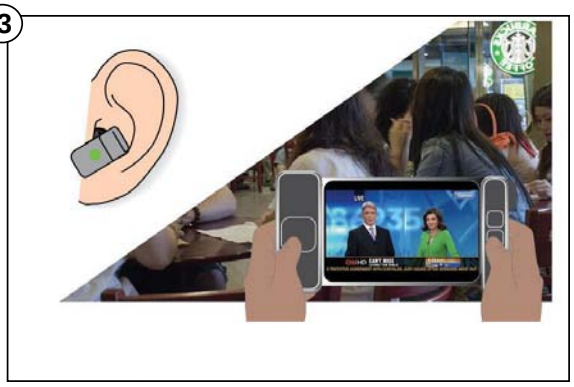
Figure 5.10: A story from the *Anywhere Now* scenario

1

2

Tom is watching CNNHD.tv on his OLED mobile device on the bus home.

3

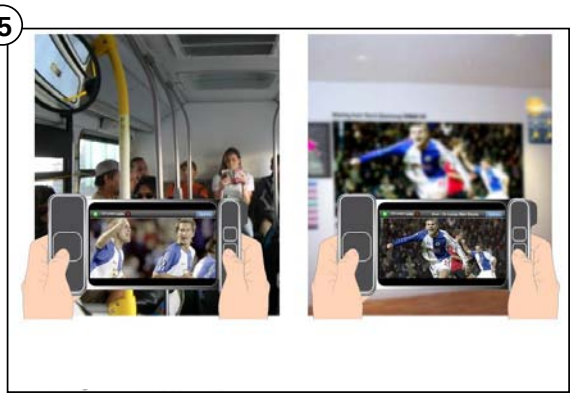


He receives a VoIP call from his friend John who is watching live football from the FIFAHD.tv site using the network in his local Starbucks.

4

John shares his selection of channel and viewing angle with Tom during the call and it immediately starts to stream over Tom's device during their conversation.

5



Tom continues to talk to John about the match. As soon as he reaches home he automatically transfers the A/V to the screen in his lounge. The device allows him to have full control of the display unit while continuing his conversation with Tom.

6 Spectrum for entertainment distribution in 2028

6.1 Introduction

Several key platforms will distribute entertainment under the scenarios of 2028. Figure 6.1 lists them and summarises the main demands which each of the scenarios puts upon them. We consider the spectrum demands of each platform in the rest of this chapter and provide more detailed analysis in Annex F. We also show in Annex G that the fixed telecommunications network - both core and access - should have sufficient capacity to carry the traffic generated under all three scenarios.

Figure 6.1: Demand for distribution of entertainment by wireless platform

Platform	Baseline – 2008 - current use of platforms	Broadcast Plus - broadcast oriented entertainment	Infinite Choice - tethered Internet based entertainment	Anywhere Now - untethered Internet based entertainment
Home entertainment network and server	Limited	Near ubiquitous	Near ubiquitous	Home network but no central home server
Terrestrial broadcast	500 channels of SD	Capacity for HD limited	Capacity for HD limited	Terrestrial switch off
Satellite broadcast	Sky + Freesat	Major platform – 500+ HD channels	Big on HD but in decline	Big on HD but in decline
Wide area wireless access, e.g. public wireless hotspots	Widespread but limited bandwidth	Limited demand for entertainment	Substantial demand for entertainment	Substantial demand for entertainment
Cellular network access	Very limited for entertainment	Limited importance	Limited importance	Major demands

6.2 Spectrum for home networking

The home network provides the interface between other delivery platforms and user devices in the home - whether they are fixed units such as TV monitors or personal mobile devices. The home network will therefore consist of some combination of the following:

- A gateway to other networks, e.g. via second generation fixed broadband.
- A server[44] with intelligence and storage.
- A communications network within the home (wired and/or wireless).

The spectrum demands placed on home networks is very similar across all three scenarios. There are two main requirements:

- To carry content from the home network server to remote devices for viewing around the home. In HD and 3-D formats, we calculate that this will require a home network which can carry 36Mbit/s of user data.

[44] It is not necessarily the case that a home server is a single machine. It is sensible that a single controller be involved but multiple machines on the home network could exist and serve material.

- To provide side loading from the home network server to personal mobile devices. To keep transfer times down to periods measured in minutes rather than hours requires significantly higher data rates, and wired connections or wireless connections based on Bluetooth or UWB might be required.

Overall it is unlikely that home distribution will require more than four 20 MHz channels. This is well within the supply of spectrum currently allocated to WiFi. The 2.4 GHz band provides three non-overlapping 20 MHz channels and the 5 GHz band provides 19 such channels.

In well spaced residential districts there should not be an issue of interference with the amount of spectrum currently available. But in the case of high density flats there is the potential for interference, given that radio LANs are generally uncoordinated. However, it is reasonable to expect that techniques used in enterprise access points, such as intelligent channel and power selection, will improve the situation significantly over the next 20 years. Our overall conclusion is that we do not expect a need for additional spectrum for home networking platforms[45].

6.3 Spectrum for terrestrial broadcasting

There are three main applications of terrestrial broadcasting for entertainment - fixed TV broadcasting, radio broadcasting and mobile TV broadcasting. Demand for spectrum for radio broadcasting is unlikely to increase significantly beyond current allocations, and we do not consider it further.

We anticipate strong demand for broadcasting of high-definition television over the next five to 10 years under all three scenarios[46]. But there is insufficient UHF spectrum to satisfy future requirements for HDTV broadcasting via terrestrial means. Indeed it is virtually impossible that sufficient spectrum could be provided for the hundreds of channels which our scenarios envisage. Even if all of the UHF spectrum were made available to broadcasters, and transmission moved to a single frequency network using DVB2, only a theoretical maximum of 188 HD nationwide channels would be available. But requirements to share spectrum with neighbouring countries would reduce this number significantly while regional programming would not sit well in such an architecture,

The spectrum requirement for broadcast mobile TV networks, which support real-time channels such as news and sport, is likely to be modest. Using a single frequency network, up to two (8 MHz) channels would be required to support a pair of multiplexes. This is the likely requirement for providing a cost effective service. Based on developments elsewhere in the world we might expect one to two such networks to be built[47].

6.4 Spectrum for satellite broadcasting

There are few spectrum constraints on the delivery of the many hundreds of satellite high definition channels which are envisaged under the *Broadcast Plus* scenario. The two other scenarios are even less demanding. The satellite downlink allocations at Ku-band are extensive (10.7 to 12.75 GHz) and should be adequate for future needs.

[45] Especially since there is also the possibility that cognitive access in white space will yield an additional 100 MHz of spectrum for home distribution.

[46] Although this demand will reduce under the *Infinite Choice* or *Anywhere Now* scenarios in subsequent years.

[47] With the networks' operators perhaps acquiring some of the UHF spectrum released through digital switchover.

6.5 Spectrum for cellular mobile networks

Spectrum supply

We can divide the spectrum which might be used by cellular mobile networks into four categories. There is:

- 360 MHz of ***existing spectrum*** which is already assigned to mobile operators.
- 277 MHz of ***imminent spectrum.*** This spectrum, which is suitable for cellular use, is likely to be made available for cellular use in the next 2 to 3 years and offers good prospects of harmonisation with the rest of Europe. As part of this category we assume that 72 MHz of UHF spectrum is awarded for cellular use from the digital dividend.
- 104 MHz of ***partially harmonised spectrum*** from the WAPECs bands which may be harmonised across some countries.
- Large quantities of unharmonised spectrum which might be released for cellular use from the MoD and other shared bands.

Demand for cellular spectrum

We cannot model demand for spectrum which will be used for entertainment applications in isolation from other mobile broadband applications. Figure 6.2 shows how we made demand projections while Annex F provides the details of these projections. We note that our assumption about the proportion of traffic generated by mobile devices routed via public wireless hotspots is no more than a credible guesstimate. We made it following discussions with stakeholders and by taking account of the fact that over 70% of calls from mobile devices are currently made when the user is at home, at work or in a public place with WiFi coverage. We also note the trend for mobile operators such as 3 and O_2 to bundle public WiFi services with their mobile offerings. In practice this proportion will depend upon the prices, ease of use, and handover functionality between cellular and WiFi networks experienced by end users.

Figure 6.3 provides our projections of demand in the 218 square kilometres of central London, where the population density is highest in the UK during the working day[48]:

- Demand under the *Anywhere Now* scenario is represented by the curve for the sum of the three categories in 6.3.
- Demand under the *Broadcast Plus* and *Infinite Choice* scenarios is represented by the curve for IP data plus voice.

[48] The population density in central London during the working day reaches over 12000 people per sq km compared with an average for the UK of 245 per sq km.

Figure 6.2: Making projections of cellular mobile traffic in Central London

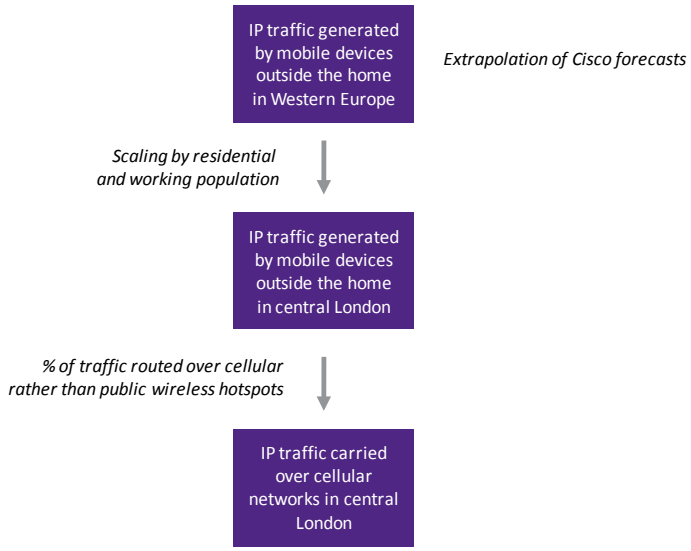
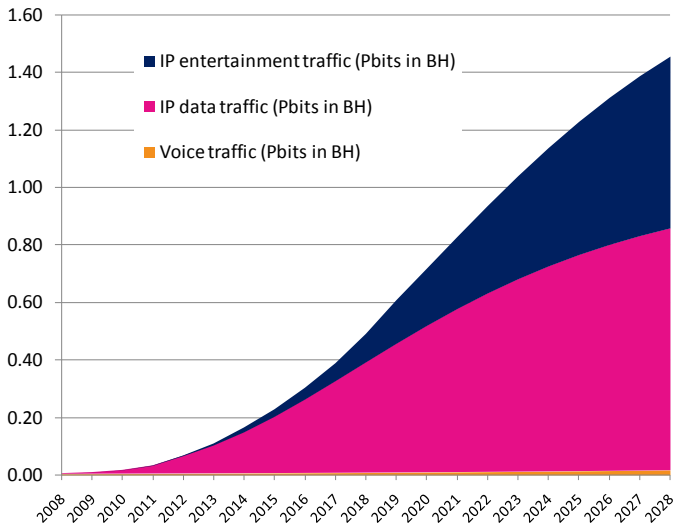


Figure 6.3: Projections of cellular mobile traffic for central London – *Anywhere Now* scenario



Source: Plum projections

Cellular network capacity in central London

We have also built a cellular mobile capacity model (See Annex F for detailed assumptions) which indicates that 275 MHz of the 360 MHz which is currently available is required to meet existing demand. We then assume that capacity increases over time in proportion to:

- The total spectrum available for use by mobile networks. Initially we kept the supply of spectrum constant in comparing demand with capacity.

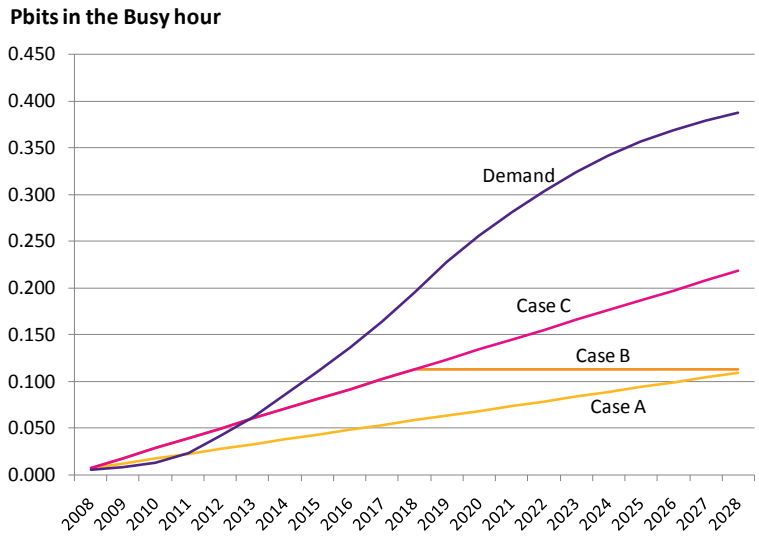
- The level of spectrum efficiency. We expect significant increases in throughput per cell and assume a ***fivefold increase*** following the deployment of OFDM technologies like LTE.
- The number of cells per operator in a given area[49]. There are substantial problems, both in reducing macro cell spacing from (the currently assumed) 1000 metres to less than 600 metres, and in increasing microcell density, in the 5 square km in which they are deployed, by more than a ***factor of three***. This leads us to assume a threefold increase in cell density.

In combination these changes give us a 15 fold (5 x 3) increase in network capacity for a constant supply of spectrum.

Demand versus capacity

Figure 6.4 plots demand under the *Anywhere Now* scenario against capacity in central London for the next 20 years assuming no additional spectrum is made available.

Figure 6.4: Cellular demand vs capacity in central London – *Anywhere Now* **scenario**



Source: Plum projections

We consider three cases:

- ***Case A***: Capacity increases linearly by 15 fold between 2008 and 2028.
- ***Case B***: Capacity increases linearly by 15 fold between 2008 and 2018 and there are then no further increases in network capacity.
- ***Case C***: Capacity increases linearly by 30 fold between 2008 and 2028. Here we assume that capacity gains continue at the same rate between 2018 and 2028 as in the previous 10 years. At

[49] Note that capacity is a function of the number of cells per operator rather than the total number of cells for a given assignment of spectrum for cellular mobile use. This reflects the fact that, if the number of operators increases while the number of cells per operator is held constant, then the total number of cells increases but the spectrum per operator declines and with it the capacity per cell.

the moment we do not know where such improvements in network performance will come from. But it seems reasonable to assume some continuing increases in cellular network capacity[50].

We consider that an outcome somewhere between Case B and Case C is the most likely.

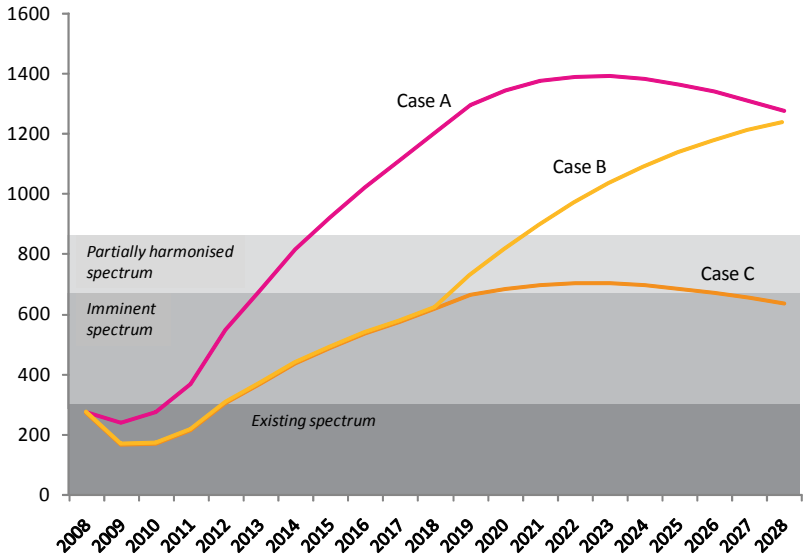
Additional spectrum required

Given the plots of Figure 6.4, how much additional spectrum is required so that capacity just meets demand? Figure 6.5 and 6.6 present our estimates for the *Anywhere Now* and *Infinite Choice/Broadcast Plus* scenarios respectively. They show the additional spectrum required to close the gap between the capacity curves of Figure 6.4, which assume no additional spectrum is provided, and the appropriate demand curve. For the *Anywhere Now* scenario of Figure 6.5 we use the total demand curve of Figure 6.3; and for the *Infinite Choice* and *Broadcast Plus* scenarios we use the demand curve represented by IP data traffic plus voice traffic of Figure 6.3.

Our estimates show the minimum spectrum which is required. Supply of more spectrum than is shown in Figures 6.5 or 6.6 would lead to lower capital expenditure, since fewer base stations would then be required.

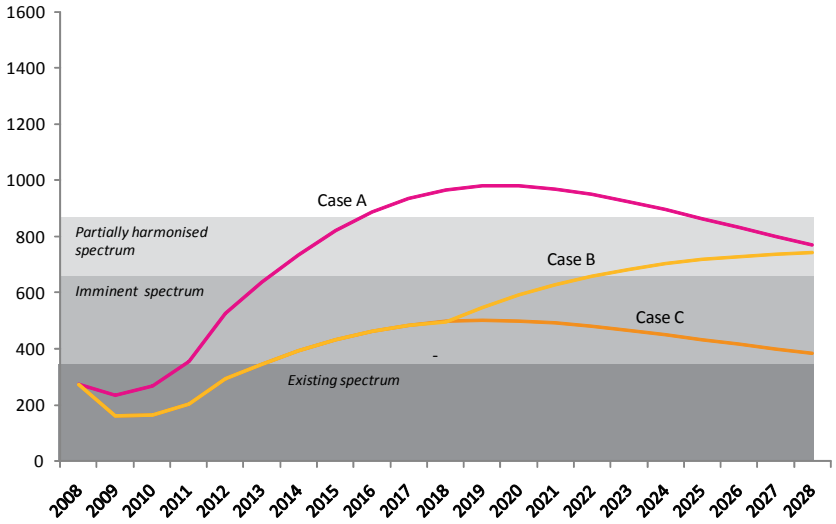
The two figures show demand for spectrum declining slightly from 2021 on. This decline reflects the fact that after 2021, our estimate of capacity grows more quickly than estimated demand. In practice it is unlikely that mobile operators would hand back the surplus spectrum created by this decline. It is more likely that they would use it to reduce their capital expenditure on base stations. In any case it is quite likely that new, and as yet as unforeseen, applications would emerge to use this surplus spectrum.

Figure 6.5: Additional spectrum required in MHz – *Anywhere Now* scenario



[50] Cooper's and Edholm's "laws", as set out in Figure 4.1, state that we can expect a 250 fold increase in the capacity of the cellular network over the next 20 years if the historic trends of the last 20 years continue.

Figure 6.6: Additional spectrum required in MHz – *Infinite Choice* or *Broadcast Plus* scenario



Figures 6.5 and 6.6 show that:

- In Case C there are no significant problems from increased spectrum scarcity under any of the three scenarios.
- In Case B there is adequate spectrum at least until 2018 under the *Anywhere Now* scenario, and until 2023 under the *Infinite Choice* or *Broadcast Plus* scenarios.
- Only in Case A is there an imminent spectrum problem. Here demand for spectrum exceeds the imminent supply level by 2013 or 2014 under any of the scenarios.

Our estimates are very sensitive to the assumptions we make about demand projections. These are uncertain and need monitoring to see whether the problem situations identified above will be realised. We discussed this idea further in Chapter 8.

6.6 Spectrum for public wireless hotspots

Definition and current use

We define a public wireless hot spot as a base station where:

- Coverage is provided outside the home environment or private premises.
- Each site incorporates a low power transmitter and has a small coverage area (within buildings or an open concourse).
- Equipment uses non-proprietary access technology commonly available in end-user devices.
- End user access may be free, charged through a subscription to the public wireless hotspot operator or bundled with cellular mobile subscriptions.

Currently public wireless hotspots use WiFi technology based on the IEEE 802.11 standard. The hotspots are typically used by:

- Laptops for Internet and email access.
- Mobile phone users. For example, iPhone 3G users with O2 are now able to access BT Openzone and The Cloud WiFi hotspots.

Hotspots are typically located in airport lounges, cafes and public places. Access speeds are limited by the fixed network connection and the number of users concurrently using the hotspot, with a typical hotspot currently providing shared access for its users to a 2 Mbit/s ADSL link.

Capacity of a public wireless hotspot

We can expect the capability of hotspots to increase in the future in a number of ways:

- Increased access speeds to the Internet through ADSL2, ADSL2+, VDSL and fibre access.
- Increasing numbers of hotspots for more ubiquitous coverage in urban areas.
- Technology migration to IEEE 802.11n and other subsequent standards in the longer term for faster access speeds.
- Hotspots which incorporate 5 GHz spectrum as this becomes more popular in user terminals.
- Use of new technologies such as WiMAX for hotspots. These have potential to provide high access speeds over a wider area.
- Possible use of other licence exempt bands.

Based on these developments, we estimate that the capacity of a public wireless hot spot will increase as shown in Figure 6.7. In making this assessment we assume that:

- WiFi technology is used with channel bonding and MIMO to increase capacity.
- There is take up of dual band (2.4/5 GHz) devices in end-user equipment by 2015. With 19 non-overlapping channels compared to only 3 in the 2.4 GHz band, capacity increases rapidly once end-user demand stimulates inclusion of 5 GHz within end-user devices.
- Theoretical throughput is reduced by 65% because of interference between sites.

Demand

Demand for public wireless hot spots is a function of both entertainment and non-entertainment applications. We estimate this demand as follows:

- The projections of Section 6.5 give us the total UK mobility traffic which is generated in public wireless hot spots in a busy hour.
- We assume that the number of public wireless hot spots grows from 15,000 to 50,000 over the next 20 years.
- We further define a busy public wireless hotspot as one which generates ***five times*** the traffic generated by the average hotspot.

Figure 6.8 plots the resulting projections and compares them with the capacity of a hotspot which uses WiFi technology and currently assigned spectrum.

Figure 6.7: Estimate of future capacity of a wireless hotspot

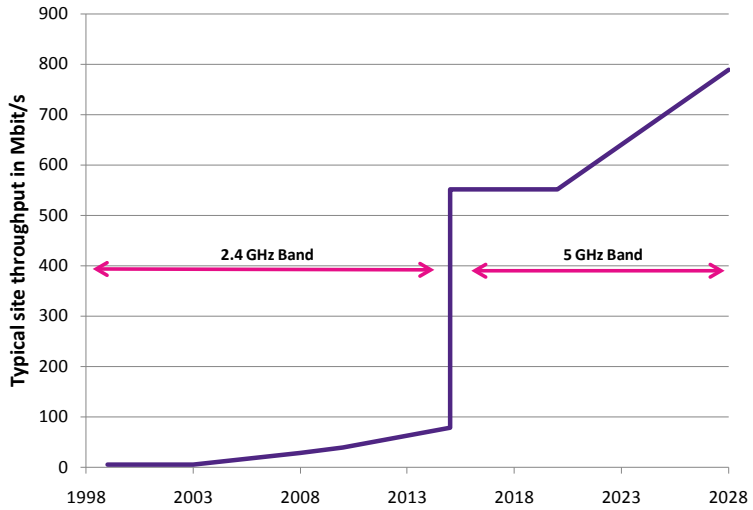
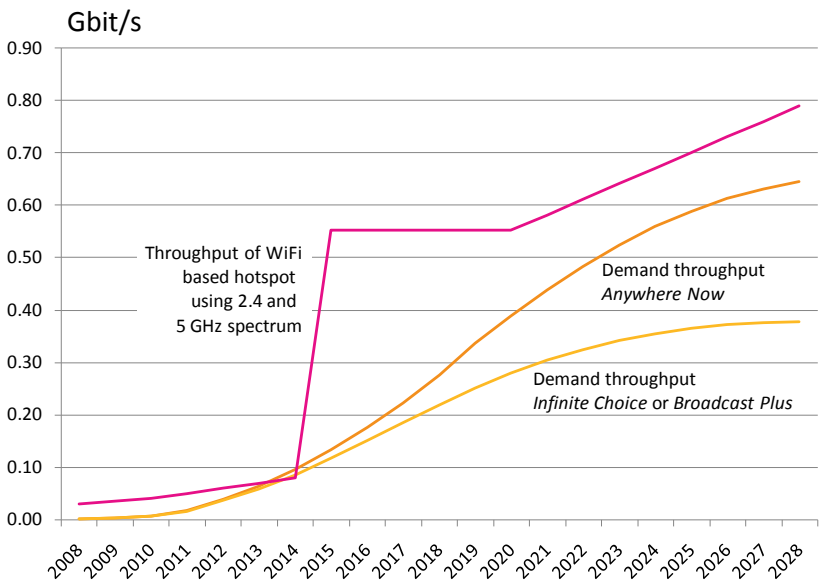


Figure 6.8: Demand vs. capacity at a busy wireless hotspot



Demand versus capacity

The plots of Figure 6.8 suggest that the capacity of hotspots will increase at a sufficient rate to deal with demand, even under the more challenging *Anywhere Now* scenario. There may be a need to bring forward the introduction of 5 GHz-based services by one or two years from the assumed date of 2015. Market mechanisms should enable this to happen.

We note however that the projections of Figure 6.8 are very sensitive to the assumptions which we have used to calculate demand in the busy hour and that relatively small changes in these assumptions could lead to capacity problems at the busiest public wireless hotspots.

6.7 Conclusions

We summarise our assessment in Figure 6.9. In summary we find that:

- Demand for spectrum for cellular services could exceed expected supply under the *Anywhere Now* scenario. But this gap is not likely to occur before 2018.
- Our calculations suggest that existing spectrum at 2.4 and 5 GHz should be sufficient to meet demand from public wireless hotspots. But the surplus capacity is modest and capacity problems could arise, especially under the *Anywhere Now* scenario.
- Our assessment of spectrum scarcity is sensitive to certain key assumptions which need monitoring.

Figure 6.9: Possible spectrum supply problems by 2028

Platform	Broadcast Plus	Infinite Choice	Anywhere Now
Home networking	No problems anticipated but possible congestion in blocks of flats without more intelligent frequency management		
Terrestrial broadcasting	Inadequate for multi channel HDTV demand		
Satellite broadcasting	No spectrum problems		
Cellular networks	Spectrum problems likely from 2023 on		Spectrum problems likely from 2018 on
Public wireless hot spots	No problems anticipated but assumptions on demand need monitoring		

7 The production of entertainment

7.1 Introduction

In this chapter we consider what might happen to the production of entertainment content, rather than its distribution and consumption, over the next 20 years and how these changes increase demand for spectrum.

We exclude from our analysis the production of newspapers, books, games and CDs which have no need for wireless technologies. We focus instead on:

- Production which is not possible without using wireless technology. Many outside broadcasting events, such as golf tournaments, can only be linked back to the broadcast studio by means of wireless, and modern musicals would be impractical if all the actors had to trail a lead to their microphone instead of using radio microphones
- Production where wireless is not essential but adds value by enabling new views, such as the view from the cockpit of racing cars in action, or a news reporter presenting from closer to the scene of interest.

We provide more detailed analysis in Annex E.

7.2 The use of wireless in the production of entertainment

Wireless technologies are used extensively in the production of entertainment content and we can expect demand to continue to grow over the next 20 years. There are four main forms of production – news gathering, outside broadcasts, local entertainment and studio-based production.

Newsgathering

Radio and TV reporters need to be able to report the news from wherever it happens, often at short notice. Wireless gives them the ability to provide live reports directly from the scene of interest.

Typically the news reporter's microphone and the camera man's camera are both wirelessly linked back to a control vehicle. A separate radio link (referred to as talkback) enables the producer in the control vehicle to talk to the reporter and camera man so that he can cue and coordinate their actions. The distance between a reporting team and its control vehicle is short, typically less than 100m. News reports are then transmitted live back to the studio via a longer distance video link (typically several kilometres), or recorded and edited prior to transmission back to the studio.

Over the next few years we are likely to see news gathering teams:

- Make increased use of wireless cameras.

- Increase their deployment of cellular receive sites[51] allowing wireless cameras to link directly back to the studio or to be relayed through wireless equipment mounted in a car or on a motorcycle.
- Increase their deployment of modern, small satellite equipment which can be car mounted (as opposed to requiring an OB van).
- Move to the use of HD format wireless cameras[52].

In the somewhat longer term it is conceivable that public networks could be used to provide news teams with live video links back to their studios, providing the quality of service is adequate[53]. This might be achieved with future mobile networks, which are expected to support bit rates of 100's of Mbit/s. Alternatively, if high capacity wireless broadband access points become commonplace within urban areas, news teams could link directly through them into the telecommunications infrastructure.

Outside broadcasts

Outside broadcasts (OB) require the temporary establishment of radio or TV programme making facilities outside of a studio to cover events other than news events. A large proportion of these outside broadcasts are of sports events, but indoor and outdoor concerts, pageants such as the Trooping the Colour, and exhibitions are also broadcast. The majority of such broadcasts are transmitted live.

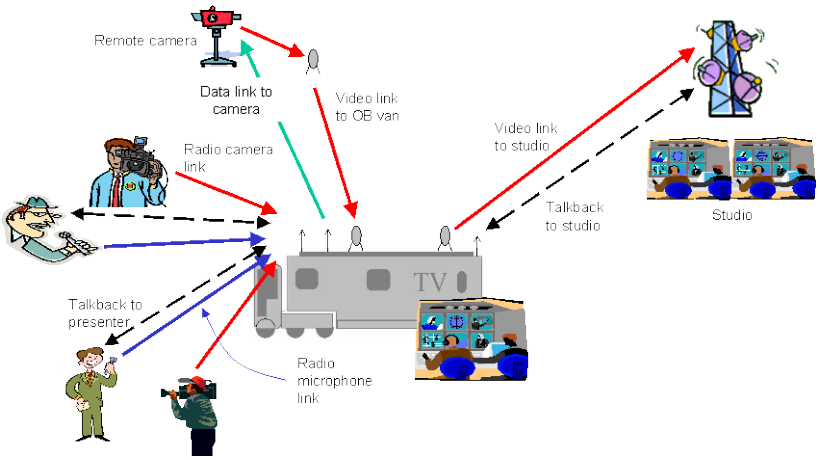
The use of wireless in the production of small outside broadcasts is similar to that of news gathering using radio microphones, wireless cameras and talkback in much the same way. Larger events will of course use more frequencies to support the larger number of wireless cameras, presenters and production staff. Figure 7.1 illustrates.

[51] This is where one or more radio sites are established in a city such that news gathering teams can establish a wireless link back to the studio, ideally without regard to their location, and so provide live reports from wherever the news happens.

[52] It is already used for news in the USA.

[53] Video material is today uploaded to studios over public networks in non-real time.

Figure 7.1: An illustration of the use of wireless in the production of an outside broadcast[54].



It should be noted that the use of wireless at outside broadcast events is by no means universal:

- Many venues have pre-wired camera, microphone and presenter positions which are then connected to the outside broadcast vehicles by cable. In such cases the use of wireless equipment is confined to any roving cameras and presenters operating, for example, on the touch line.
- Wireless links, either terrestrial or satellite, are commonly used to carry the broadcast material back to the studio and to provide the talkback communication links. However, major regularly used venues are increasingly equipped with fibre or cable connectivity.

Developments foreseen within the next 5 to 10 years include:

- Greater use of wireless cameras, with HD format becoming the norm.
- Use of telemetry across a wider range of sports to track and/or monitor participants so as to generate statistics for the viewers and provide information to team managers.
- Further development of graphic capabilities to give the viewer greater insight into the action.
- Continuous 360 degree viewing which will allow the viewer to choose any (within reason) viewing position, and to zoom in and out at will. This is technically possible today and is becoming more practical and less expensive with time.
- 3-D TV which will further enhance the realism of the viewing experience.
- Real time rendering of realistic computer-generated images enabling the broadcasting of large scale or otherwise difficult to capture events.
- The fusion of games with sports broadcasting allowing, in the longer term, a viewer to become a virtual participant in an event, perhaps racing alongside a Formula One race as it happens.

[54] *Supply and demand of spectrum for Programme Making and Special Events in the UK*, Report to Ofcom, Quotient Associates Limited, December 2006.

- Ultra HD, which gives a 16-fold increase in resolution[55], is in the research laboratories today. In the longer term it could become the standard for TV programming.

Local entertainment

This category covers theatres, concerts, touring shows, sports and other local events which provide entertainment. Musicals and rock concerts are particularly large users of radio microphones and also use talkback to provide communications for production and stage staff. Other events will typically use just a few (and very often just one) radio microphones[56].

In addition, there is a small but growing use of wireless to enhance the experience of the spectators at sports fixtures. This takes the form of local radio or TV broadcasts (essentially confined to the site of the event) which can be picked up by special receivers purchased or hired by members of the crowd. These are designed to enhance the spectator's enjoyment of the event by providing additional information and views, including replays, as well as guides to the venue.

We expect relatively little further growth in use of wireless equipment at theatres and concerts from growth in the size of productions. However new types of show, although impossible to predict, could make significant additional demands on spectrum.

We can also foresee an increase in the use of wireless to enhance local sports events such as:

- Ref!Link which allows spectators to hear the referee's comments and other commentary on personal radio receivers.
- Kangaroo TV receivers which allow spectators to views from other parts of the venue and access action replays, check the scoreboard and other statistics, and view the concurrent TV broadcast.
- Increased use of wireless technologies to improve the decisions of referees and umpires at sports events.

Studio production

This category encompasses TV, video[57], film and radio studios although the largest use of wireless occurs in TV studios.

Studios are mainly cabled. The key advantage that wireless brings to studio production is the increased freedom of movement it enables for presenters and actors. It can also improve productivity by, for example, reducing set up times between scenes. Talkback also provides an effective means of communication between the production team and the presenters, particularly in the case of live broadcasts. For these reasons, radio microphones and talkback are used extensively in TV studios. But wired cameras are preferred to wireless. They are considered more reliable, give better quality images and are less expensive.

[55] And, with suitable compression, a four to five fold increase in the required information rate.

[56] The one exception is Hospital radio which use wireless links to transmit programmes between hospital buildings. Note, Hospital radio does not broadcast over the airwaves but is distributed around hospital buildings by wire.

[57] A video studio captures and stores video material in electronic form and may produce material for a wide range of uses including TV broadcasting, public and private corporate communications, advertising and Internet video streaming. A TV studio uses essentially the same techniques but is dedicated to TV programming and will produce both pre-recorded and live shows.

There is a general expectation that cable, and fibre for HD cameras, will continue to be preferred over wireless. So we expect only limited additional requirement for wireless within studios. This might be generated by:

- Greater use of HD wireless cameras and wireless directors' monitors.
- Greater use of in-ear monitors by performers and presenters.
- Wireless control of special effects.
- Use of miniature wireless video cameras.

7.3 Scenarios for entertainment production

All three of the scenarios for the distribution and consumption of entertainment identified in Chapter 5 require high quality production of video content to attract audiences. The extent to which this demand is met is primarily determined by GDP growth. GDP growth influences the rate of growth in the revenue generated by the entertainment sector and its investment in new production technologies. So we define two scenarios for the production of entertainment content:

- The *Low Production* scenario. This corresponds to GDP growth of 15% over the next 20 years and aligns with the *Broadcast Plus* scenario of Chapter 5.
- The *High Production* scenario. This corresponds to GDP growth of 40% over the next 20 years and aligns with the *Infinite Choice* and *Anywhere Now* scenarios of Chapter 5.

7.4 Demand for spectrum from entertainment production

Our review of how spectrum is used in the production of entertainment shows that demand is localised and/or of limited duration so that the spectrum required is determined by the size of the largest events rather than by the number of events. The largest demands come from events such as Formula One Grand Prix races and major golf championships. The largest outdoor concerts and the major TV studio complexes also make substantial demands on specific sections of this spectrum[58].

The developments with the potential to generate the biggest, although uncertain, additional demands for spectrum are:

- ***Enhanced*** outside broadcasting events which involve the use of new technologies to enhance the viewing experience for outside broadcast events, particularly sports events, for both spectators and TV viewers. The major impact will be on the spectrum requirements for wireless cameras and video links
- ***New genre formats*** for concerts, theatre or TV shows which require greater use of radio microphones or other wireless devices. The major impact will be on the use of radio microphones (and in-ear microphones) with rock concerts expected to be a key driver of spectrum demand.

[58] Some events, such as the Olympic and Commonwealth Games occur infrequently but make very substantial calls on spectrum. In these cases special measures are taken to make the necessary spectrum available and it would exaggerate the apparent spectrum requirement to include such events in the analysis. Our analysis therefore considers only those events which occur at least once a year.

Figure 7.2 lists the assumptions we make about the capability and spectrum requirements of key technologies within our two scenarios. Figure 7.3 then lists the main developments which will generate additional demand for production spectrum, and highlights the differences between the Low and High Production scenarios.

Figure 7.2: Summary of relevant technical developments by 2028

Technical development	Performance in 2028
Frequency agility	Equipment is expected to be significantly more frequency agile and frequency assignment more efficient with the result that equipment is inter-operable over multiple bands (as summarized in Figure 7.4).
Wireless camera frequency bands	Usable up to 12 GHz[59].
HD format wireless cameras & video links	Full quality requires channel bandwidths of 10 MHz.
3D wireless cameras & video links	Full quality requires channel bandwidths of 15 MHz.
Ultra HD wireless cameras and video links	Requires channel bandwidths of 40 MHz but deployment limited to ~250%.
Radio microphone frequency bands	Available in Band III, UHF TV & 1800 MHz bands.
Digital radio microphones	Ubiquitous with an increased packing density of 15 per TV channel[60].
Talkback and audio links	Channel bandwidths halved giving a net reduction in occupied spectrum of 25%.

[59] Wireless cameras operating in the expected 60 GHz licence exempt band are likely within the time scales considered here. However, the proliferation of other licence exempt devices is expected to limit their use in professional applications.

[60] Higher packing densities are likely to be achievable in particular well controlled environments. The figure given is considered representative for the key drivers of spectrum demand considered here.

Figure 7.3: Likely future developments and their incorporation into the production scenarios.

Enhancement technique	Comment	Included in Low Production scenario	Included in High Production scenario
HD format	Expected to be ubiquitous within a few years.	✓	✓
3D TV	Expected to be widely adopted within 20 years and probably sooner.	✓	✓
360° viewing	Expected to be widely adopted within 20 years.	✓	✓
Localised on-site broadcasting	Assumed to use PMSE spectrum only where there is spare capacity.	×	×
Ultra HD format	Research and new standards required so unlikely under the Low Production scenario.	×	✓
Enhanced graphics & computer generated video images	Processing is carried out after content capture and will require little additional spectrum.	×	×
Fusion of games and real time events	Largely a question of processing after content capture with little additional spectrum required.	×	×
Greater deployment of in-ear microphones (IEMs)	The maximum demand will be when all performers are equipped both with radio microphones and IEMs.	✓	✓
New genre shows	Unpredictable but assumed to double the amount of spectrum required for a single show.	×	✓
Video backhaul replaced by satellite, fibre and/or wireless broadband	This trend is already underway.	Trend continues	Satellite, fibre wireless broadband become ubiquitous

7.5 Demand versus supply

Figure 7.4 compares the likely demand for spectrum under the Low and High Production scenarios with likely future baseline supply. We assume that this baseline supply is the same as that currently identified by Ofcom for transfer to the proposed new band manager[61]. This spectrum, grouped into five blocks, is specified in Figure 7.4.

The surpluses and shortfalls are then shown graphically in Figure 7.5. We can see that:

- Under the *Low Production* scenario the future band manager is likely to suffer a shortfall in Block 5, which is used for wireless cameras and video links, of 200 MHz.
- Under the *High Production* scenario this shortfall rises to 1800 MHz and there is also a shortfall equivalent to 2 to 3 TV channels in the spectrum available for radio microphone use in Block 3.

[61] *Digital dividend review: Band manager award*, Ofcom consultation, 31 July 2008.

Figure 7.4: Demand vs supply of spectrum (MHz) under the two production scenarios (MHz).

	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Bands	Note 1	Note 2	Note 3	1.5 GHz	2, 3.5, 5, 7, 8, 10 & 12 GHz	24 & 48 GHz
Expected band manager allocation	6.6	6.3	254.6	8.0	1055	650
"Borrowed" spectrum available to the band manager	0.0	3.2	0.0	0.0	536	0
Expected demand under Low Production scenario	3.4	6.3	60.6	2.0	1794	431
Surplus under Low Production scenario	3.2	3.1	39.6	6.0	-203	219
Expected demand under High Production scenario	6.9	12.7	121.1	4.0	3437	209
Surplus under High Production scenario	-0.3	-3.2	-21.0	4.0	-1846	441

Note 1 = Band 1 (47 to 62 MHz) and Low Band (67 to 86 MHz).

Note 2 = High Band (139 – 148 MHz), Band III (181 – 200 MHz for talkback), UHF 1 (420 – 450 MHz) and UHF 2 (450 – 470 MHz).

Note 3 = Band III (173 – 210 MHz for radio microphones), UHF TV (470 – 862 MHz) and 1.8 GHz. We have assumed in the table above that the re-organisation of the UHF TV bands recently proposed[62] has no net effect on the availability of interleaved spectrum.

Note 4: All results are given in MHz with negative values representing a shortfall relative to the assumed band manager allocation.

Note 5: The shortfall in spectrum can be less than the difference between the expected band manager allocation and expected demand due to the ability of the band manager to "borrow" spectrum[63].

Note 6: The allocation given for Block 3 gives the total from within which the interleaved spectrum is derived and includes Channel 69 and the radio microphone frequencies in Band III. The actual interleaved spectrum is less than this and varies with location.

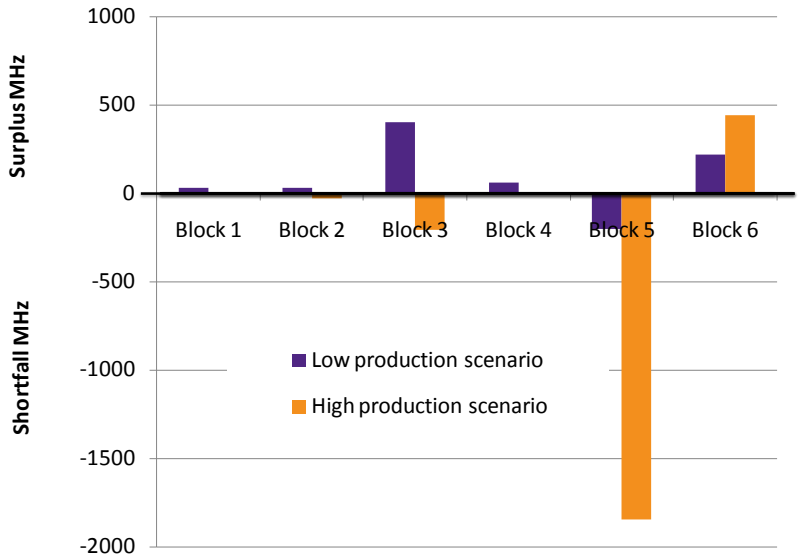
Note 7: The licence exempt bands at 2.4 GHz and 5 GHz have been excluded from Block 5 as the quality of service required for professional PMSE applications is difficult to guarantee with licence exempt spectrum.

Note 8: The surplus in Block 6 is larger in the High Production scenario due to the greater take up of satellite and fibre backhaul in this case.

[62] See *Digital Dividend: Clearing the 800 MHz band*, Ofcom consultation, 2 February 2009.

[63] A small number of the larger outside broadcasting events require more spectrum than is available within the PMSE bands. On these occasions, JFMG's current practice is to temporarily borrow spectrum (through the offices of Ofcom) and we have assumed that this practice will continue at a level similar to that achieved historically.

Figure 7.5: Spectrum surplus for each spectrum block by 2028[64]



7.6 Satisfying unmet spectrum demand

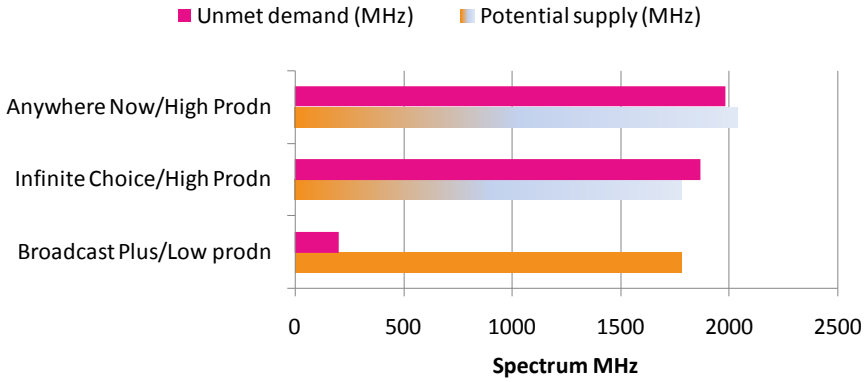
How might the unmet demand shown in Figure 7.5 be satisfied? We estimate that 1780 MHz of spectrum in the range from 1.4 to 13 GHz might be released over the coming years - largely from Ministry of Defence applications. Under the *Anywhere Now* variant of the *High Production* scenario terrestrial TV platforms are also switched off. This releases additional UHF spectrum.

There is no technical reason why radio microphones could not be redesigned to use higher frequency bands where spectrum is more readily available[65]. So, in comparing the unmet demand for spectrum with the potential supply of alternative spectrum, we consider the combined amount required for radio microphones, wireless cameras and video links. It is also possible that some or all of the demand for radio microphones would be met by MoD spectrum in the VHF and UHF bands that may become available in the coming years. The comparison is shown in Figure 7.6.

[64] The surplus and shortfall for Blocks 1 to4 are shown at 10x actual value

[65] Although this would lead to additional costs to the industry if equipment had to be developed specifically for the UK market.

Figure 7.6: Unmet demand and potential new spectrum



There are three cases to consider:

- The *Low Production* scenario. Here there is an unmet demand of 203 MHz compared with the 1780 MHz of potential new spectrum. With relatively low levels of competition for spectrum expected from other quarters, there is a high probability that the needs of the production sector can be met in full at prices well within the sector's willingness to pay
- The *Infinite Choice* variant of the *High Production* scenario. Here the unmet demand of 1865 MHz exceeds the potential new supply of 1780 MHz. At the same time there could also be strong demand from other users for access to additional spectrum - both for the band manager's spectrum and for the new spectrum – for fixed links, wireless access, satellite or new applications.
- The *Anywhere Now* variant of the *High Production* scenario which assumes terrestrial broadcast TV platforms are switched off before 2028 and the UHF spectrum refarmed. This both increases unmet demand, since interleaved spectrum is no longer available to the band manager, and increases the potential new supply of spectrum as a result of terrestrial TV switch off. As a result the overall unmet demand[66] would rise to 1980 MHz and the potential new supply to 2035 MHz. In addition the closure of the terrestrial broadcasting network would remove the major current source of radio microphone spectrum in the UK - although this would depend upon refarming decisions and demand from other services.

7.7 Conclusions

Under the *Low Production* scenario, the production sector's unmet demand for spectrum in 2028 is unlikely to exceed 10% of the supply of additional new spectrum. As a result it is highly likely that the production sector would be able to source spectrum to meet its demands at prices well within its willingness to pay.

Under either variant of the *High Production* scenario, unmet demand and the supply of additional new spectrum are similar. But strong economic growth is assumed to lead to strong competition for spectrum from other users - both for the additional new spectrum and for that controlled by the band manager. This would drive up the price of spectrum for the production of entertainment. We expect that the larger and more popular production events would have sufficient revenues to make them

[66] This is of necessity a very rough estimate, as a geospatial analysis of the demand for wireless microphones across the UK would be required to establish a firmer value.

competitive with other bidders for the spectrum[67]. But access would be more difficult for small and mid-sized production events. In such cases, event organisers would probably have to choose between:

- Reduced use of spectrum or increased use of licence exempt spectrum, both of which would lead to a reduction in production values, and
- Bearing the cost of installing more fibre links within the venue (depending on the type of event).

However we note the possibility that Ultra HD will not be widely adopted because of the large capacity increases required for its storage and distribution.

Finally the production sector faces the possibility of terrestrial TV switch off under the *Anywhere Now* variant of the *High Production* scenario. Depending on what refarming decisions are made, this could remove the main source of supply for radio microphones and users would need to move to other frequencies. In addition to the costs associated with this restructuring, there could be additional costs to radio microphone users if the equipment had to be re-banded to frequencies specific to the UK. Whether this will happen is debatable. We might expect terrestrial shutdown to happen elsewhere in Europe and/or in the US, in which case equipment re-banding might not be UK specific.

[67] Production companies have wide experience of operating in spectrum on a shared basis. This should give them an advantage over those wanting dedicated access when bidding for spectrum made available on a shared use basis.

8 Conclusions

8.1 An era of major change

The UK's entertainment sector is entering a period of radical change. Broadcasting has dominated the entertainment sector over the last 20 years. Now it is challenged by Internet-based entertainment. The struggle to find the business models best suited to these two very different platforms will generate major change, whatever the outcome.

We have identified three likely scenarios for the state of the UK entertainment sector in 2028:

- ***Broadcast Plus***. Under this scenario most end users continue to adopt their traditional, passive role in consuming entertainment. They prefer scheduled broadcast television and enhanced versions of it to the more active Internet-based entertainment.
- ***Infinite Choice***. Here most consumers actively seek out the entertainment services and content, which are now delivered primarily from the Internet, via home servers, to give almost infinite choice.
- ***Anywhere Now.*** Under this scenario entertainment becomes a much more personalised experience. The personal device, rather than the home server, becomes the gateway to virtually all entertainment, which is available on the move as well as while stationary, and which is delivered mainly via the Internet.

8.2 General regulatory and policy issues

The sector's evolution towards one of the states described in the three scenarios raises a number of important policy issues. These provide Ofcom with an early warning of possible problems, rather than representing issues which require immediate action.

We have identified six main issues here:

- ***Issue 1:*** *universal service obligations for broadcasting.* Universal service requirements will need to change if market mechanisms are to play their part in enabling the terrestrial switch off envisaged in the *Anywhere Now* scenario[68]. Current universal service requirements assume that terrestrial broadcast is mandatory, and then specify coverage requirements over the terrestrial network. This requirement makes terrestrial switch off highly unlikely. Universal service in a convergent world might simply require public service content to be made available on a universally accessible platform. This would then allow migration from terrestrial broadcast to satellite broadcast and the Internet.
- ***Issue 2:*** *content regulation for different media.* All three scenarios envisage, to a greater or lesser extent, a shift from entertainment based on broadcast and print media to entertainment based on the Internet. Regulation of press, TV and Internet content is currently very different. Should these different regulatory regimes continue to apply to content as it moves to a converged Internet-based world? What, if any, principles should apply to enable consistent regulation of these three types of content in future?

[68] Terrestrial switch off is also a possibility over a longer time frame in the *Infinite Choice* scenario.

- ***Issue 3:*** *protection of children from harmful Internet content.* The switch from broadcast to Internet-based entertainment envisaged under the *Infinite Choice* and *Anywhere Now* scenarios would increase requirements for measures to protect children from harmful content. There is a range of options for consideration which include obligations on ISPs and raising parental awareness whilst relying on the market to supply the necessary protection software tools. Some options may be more robust than others. For example national ISPs might not exist by 2028[69].
- ***Issue 4:*** *permission to use consumption data.* Data on personal profiles and consumption habits held on the Internet offer valuable information for targeted advertising and exploitation by unscrupulous service providers – especially under the *Infinite Choice* and *Anywhere Now* scenarios. This raises important regulatory issues about the permissions which a user might give on how and when profile and consumption information can be used.
- ***Issue 5****: end user switching costs.* Already end users are starting to become locked into the services of content and application service providers through the effort they put into customisation of their user profiles. This factor would become much stronger under all three scenarios. There is currently no mechanism for users to transfer these profiles to other service providers and no incentives for the big service providers to provide them. This could lead to competition problems in the long term if the costs to end users of switching between service providers reach a level where end users are locked into their existing supplier.
- ***Issue 6:*** *safeguarding the supply of UK content.* The *Anywhere Now* and *Infinite Choice* scenarios both involve dominance of the entertainment value chains by global service providers like Google and Apple. Such dominance could mean limited funding for UK content providers and lead to a dilution of UK focussed entertainment content. This has substantial long term implications for UK content policy.

8.3 Spectrum implications of the scenarios

Distribution of entertainment content and services

The focus of our analysis on the spectrum implications of the scenarios is based on requirements to deliver ***video content*** – given that the spectrum demands of video content are so much greater than those for aural and written entertainment content delivered digitally. Within the category of video content, gaming is less important than passive video entertainment because relatively small amounts of data are transmitted in the former case.

All three scenarios envisage high end user demand for high-definition and 3-D video formats. ***Terrestrial broadcasting*** platforms will almost certainly not have sufficient capacity to meet market demand because of spectrum limitations. So we envisage a high proportion of the UK population shifting from terrestrial to ***satellite broadcasting*** platforms, where there are no spectrum constraints, over the next 10 years. This would lead to the possibility of terrestrial switch-off which would release significant additional UHF spectrum for other applications.

[69] The traditional local ISP, who offers a bundle of e-mail, web hosting, antivirus software, WiFi and access may not exist if end-users assemble their own bundle of these services from a variety of Internet based, typically global, specialist service providers at low cost.

We envisage the supply of spectrum to ***cellular mobile*** services under the *Anywhere Now* scenario to fall short of anticipated demand by 2019. Shortfalls are less likely under the *Infinite Choice* or *Broadcast Plus* scenarios.

Additional spectrum is unlikely to be required for ***home networks.*** Existing capacity at 2.4 and 5 GHz, together with anticipated technology improvements, should be sufficient to meet demand except in densely populated areas (and especially apartment blocks) where interference between uncoordinated radio LANs could occur. The development of co-operative/intelligent frequency management in radio LANs would solve these problems and we expect the cost and technical issues raised by these forms of management will be resolved over the next 20 years.

Our calculations suggest that existing spectrum at 2.4 and 5 GHz should be to sufficient to meet demand from ***public wireless hotspots***. But the surplus capacity is modest and capacity problems could arise, especially under the *Anywhere Now* scenario.

Production of content

A move to ultra high-definition video formats and new genre shows could lead to significant problems regarding spectrum availability. Wireless cameras, video links and possibly radio microphones under either the *Infinite Choice* or *Anywhere Now* scenario[70] would then generate spectrum demand well in excess of expected supply. However it is possible that ultra high definition 3D formats will not be widely adopted because of the implied capacity requirements for the storage and distribution of content. In this case the gap between spectrum supply and the spectrum demand of wireless cameras and video links is likely to be modest.

Terrestrial switch off under the *Anywhere Now* scenario could remove the main source of spectrum supplied for radio microphones, and users would need to move to other frequencies bands – either other bands at VHF and UHF or higher frequencies depending on the supply situation. In addition to the costs associated with this restructuring, there could be additional costs to radio microphone users if the equipment had to be re-banded to frequencies specific to the UK. We note, however, that if terrestrial switch-off happens in the UK it is likely to occur in other countries, particularly those with much greater penetration of fibre, cable and satellite platforms.

Dealing with increased spectrum scarcity

Two main sources of spectrum might be used to deal with increasing scarcity:

- Release of UHF spectrum currently used for TV broadcasting.
- Release of MoD spectrum, especially in the 3.4 to 3.8 GHz band and in the range from 4.4 to 5 GHz.

In terms of ***distribution of entertainment*** it might make economic sense to clear more spectrum in the range from 600 to 790 MHz[71], in addition to the 72 MHz of UHF spectrum already earmarked for mobile use. This would leave the lower UHF frequencies, which are of less value to mobile operators because of the large antennas required in mobile handsets, for use by the main public service

[70] Which map to the *High Production* scenario of Chapter 7.

[71] Mobile operators AT&T and Verizon recently paid $16 billion for spectrum in the 700 to 800 MHz range.

broadcast TV channels and for PMSE e.g. for radio microphones. But it is already questionable whether such action could be completed by 2019, the date from which we expect spectrum supply problems under the *Anywhere Now* scenario. The EU would need to obtain a co-primary mobile allocation in this frequency range, and would need to undertake the necessary European harmonisation before the clearance of DTT channels at the higher end of the UHF band could begin. Experience suggests this could take up to 10 years to achieve. In addition the MoD spectrum planned for release in the 3 and 4 GHz ranges might be used by IMT2000 services. But this would require the bands to be harmonised for this purpose across Europe.

On the ***production side,*** spectrum supply problems for wireless cameras and video links could largely be filled by spectrum which the MoD plans to release over the next few years in the 1.4 to 13 GHz bands. Some of this spectrum will be offered on a shared basis. Here PMSE use is ideal as demands are made intermittently and are likely to be in different locations from that which MoD demands. The quantities of spectrum available in the MoD bands are substantial – certainly more than the 200 MHz requirement forecast for the Low Production demand scenario. If the 1.8GHz of additional demand suggested by the High Production demand scenario emerges, then MoD releases may not be sufficient. In this case PMSE demand, together with demands from other applications[72], might push up the price of spectrum. This in itself will moderate demand somewhat. Alternatively a rising price may call forth more supply.

With respect to wireless microphones, additional spectrum is only required in the more extreme scenario. This points to a need to monitor developments in production formats. If additional spectrum is required, there is further MoD spectrum at VHF and UHF that could become available and the higher frequency bands may also be useful. If terrestrial broadcasting is completely shutdown, as is the case under the *Anywhere Now* scenario, then competition for the cleared spectrum will arise and PMSE may have to compete for the spectrum alongside other uses or seek resources in other bands.

8.4 The need for monitoring by Ofcom

It is impossible to say with certainty whether the shortfalls identified above will occur. They are largely absent from the *Broadcast Plus* scenario – which at this point in time seems just as likely as the other two scenarios. To deal with this irresolvable uncertainty we suggest that Ofcom should monitor key parameters so as to provide early warning of potential spectrum supply problems and give itself as long as possible to take remedial action.

In particular we suggest that Ofcom should monitor the following key developments. On the entertainment distribution side these include monitoring:

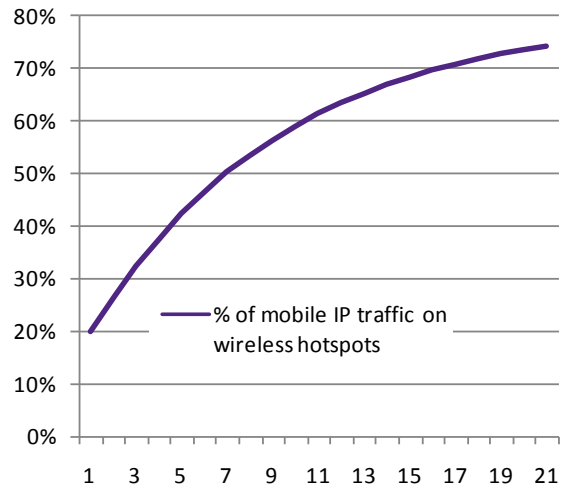
- The speed with which mobile subscribers are moving to personal devices which are designed for mobile Internet use.
- The growth of mobile data traffic, whether for entertainment or other applications, carried over the UK's cellular networks. The current statistics which Ofcom collects on the traffic generated by UK networks are oriented toward circuit switched networks. We suggest that Ofcom should, in addition, consider the collection of data on IP traffic from the mobile operators as part of this monitoring exercise.

[72] Such as satellite, fixed links and wireless access.

- Whether there are significant deviations between future Cisco predictions of IP mobility traffic (as updated annually as part of its visual networking index) and the projections of Figure 6.5[73] .
- Whether there are significant deviations between the percentage of traffic from mobile devices which is carried over public wireless hotspots and the proportion assumed in our projections. These are shown in Figure 8.1.
- How deviations from the two assumptions listed above impact the growth of traffic generated in public wireless hotspots by nomadic users from their personal devices. Our spectrum assessment suggests that demand will come close to exceeding capacity at these locations. So if demand turns out to be higher than our projections in this report, spectrum problems could arise.
- The development of technologies which might increase throughput per cell beyond the fivefold increase assumed in our assessment of cellular network capacity, and so might ease the expected spectrum scarcity problems for these networks.
- The progress of new TV broadcast standards, particularly 3-D TV and Ultra HD. This will provide an early indication as to the extent and timing of their introduction and the consequential increased demand for spectrum.
- The rate at which end users take up satellite-based high definition TV broadcast services such as those offered by Freesat and Sky. This should help determine whether and when some form of terrestrial switch off might be possible.

Armed with these estimates Ofcom can then check to see whether our projections of spectrum requirements remain valid and which of our scenarios the sector is moving towards.

Figure 8.1: The % of mobility traffic routed via public wireless hotspots



On the entertainment production side Ofcom might monitor:

- The level of applications by the new band manager to Ofcom to "borrow" spectrum. This would provide early warning of increasing spectrum scarcity for the production of entertainment.

[73] Note that Cisco makes projections for Western Europe rather than to the UK. So the Cisco projections need to be scaled to reflect the UK's population rather than that of Western Europe's.

- The extent to which ***licence exempt*** radio microphones and wireless cameras are used in professional productions. This would indicate a lower level of demand for ***licensed*** spectrum.
- Developments for the 2012 Olympic Games. These may reveal innovative ways of making more efficient use of spectrum which could then be utilised later by the production sector in general.
- The pace and size of proposed releases and/or sharing by the military. Such measures will provide an indication of whether spectrum supply will match demand - for both production and distribution of entertainment.
- The extent to which common equipment and frequency bands are used for major international events around the world. This will provide an indication of the extent to which additional demand in the UK could be met without recourse to UK specific frequency bands.

In particular it will be important to monitor whether scarcity of PMSE spectrum is weakening the current strong position of the UK's creative industries in global markets[74].

[74] For example might scarcity of PMSE spectrum affect the future TV presentation of the British Grand Prix and hence undermine the UK's position in Formula One motor racing? The arguments here do not appear compelling however. The major events that make the UK a global player are the ones that generate high revenues and can therefore afford to pay for access to scarce spectrum.

List of annexes

These are provided in a separate volume:

- Annex A The UK entertainment sector - markets and current trends
- Annex B End user behaviour preferences
- Annex C Technical developments affecting platforms and devices
- Annex D Tabular specification of the three scenarios for 2028
- Annex E Production of entertainment content
- Annex F Assessment of spectrum requirements in 2028
- Annex G Capacity of fixed networks - core and access

Entertainment in the UK in 2028

A report for Ofcom

Annexes

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Annex A The UK entertainment sector - markets and current trends

A1 The UK entertainment sector today

Figure A1 provides estimates, compiled from range of industry sources, of the size of the UK entertainment sector in 2006. We provide estimates of revenues by the activities with which we have defined entertainment, as agreed at the first Steering Group meeting. The revenues are then broken down by source into:

- End-user spend on subscriptions, outright purchases and pay per use
- Advertising revenues
- Public service broadcasting funding (of radio and television).

Figure A1 Revenues from the UK entertainment sector in 2007[1]

		End user revs (£m 2007)					
Activity	*Category*	*End user*	*Adverts (5)*	*PSB fund*	*total*	*cagr (1)*	*Source*
Play	Games - all (2)	1754	0	0	1754	7.0%	Screen Digest
Read	Books (4)	2578	0	0	2578	0.0%	The Publishers Association
	Consumer mags	2182	791	0	2972	-1.8%	Advertising Yearbook
	Newspapers	3208	4675	0	7884	-2.8%	Advertising Yearbook
Watch	TV (3)	5063	3544	2615	11222	1.2%	Ofcom
	Cinema	821	207	0	1028	-1.6%	Advertising Yearbook, UK Film Council
	DVDs and VHS	2650	0	0	2650	-1.2%	UK Film Council, BVA
Listen	Radio	0	522	657	1179	-1.8%	Ofcom
	Recorded music	1488	0	0	1488	-8.1%	IFPI
	Live	699	0	0	699	15.0%	WhatIf? estimate
Total	All	20443	9739	3272	33454	-0.7%	Calculated

(1) At constant prices over last five years
(2) Hand held + on line + wireless
(3) End user revs includes PPV, shopping channels, prog sales and sponsorship
(4) All sales to consumers
(5) Set to zero if negligible

We can see that:

- The sector generates revenues of just over £34 billion per year
- The sector is dominated, in terms of revenues, by TV, books, newspapers and magazines. In combination these categories account for well over 70% of entertainment revenues
- Games, DVDs, radio and recorded music all make a significant contribution to the sector, each generating more than £1 billion pa

[1] These revenues measure consumption but not production of entertainment. They exclude revenues from sale of electronic equipment, gambling and premium rate service telephony.

- 93% of advertising revenues is generated by TV, newspapers or magazines
- Overall entertainment sector revenues have shrunk by 0.7% pa when measured at constant prices. In the same period the economy as a whole grew at 2.2% pa
- Sales of recorded music have declined sharply - largely because of illegal copying and file sharing
- In contrast the live music segment of the sector is growing strongly. According to one report[2] revenue from the latter might overtake revenue from the former within a few years on current trends
- TV revenues are growing slowly while radio revenues are in decline
- The revenues generated by newspapers are declining - largely as a result of classified advertisers switching from traditional print media to the Internet
- The biggest growth areas within the entertainment sector - live music and games - are both participative and youth oriented.

To cross check the prediction that the entertainment sector is shrinking we have examined historic trends in household expenditure on entertainment. This produces contradictory evidence when and which suggests some growth in the sector over the last five years.

Figures A2 and A3 present our analysis for the periods 1994 to 1999 and 2001 to 2006 respectively. The two sets of figures are not directly comparable because the basis for categorising expenditure at the detailed level changed in 2001. But we can see that:

- Average household expenditure on entertainment (including spend on electronic equipment) grew by 4.5% pa in real terms in the earlier period and fell at 1% pa in the later period
- Much of this difference is due to the changes in spend on electronic equipment – which rose by 7%pa in the earlier period and fell by 5% pa in the later period
- If we exclude this spend, together with gambling, from our definition (as we do in Figure A1) then growth in entertainment spend is steadier at 2.4% pa in the late 1990s and 1.3% pa in the more recent period.

If we then add in the growth in households of 0.7% pa we get growth rates for spend on entertainment of 3.1% pa and 2.0% pa for the two periods.

Figure A2 Household expenditure on recreational activities in the 1990s

Spend per week (£) at 1998/99 prices	*94/95*	*98/99*	*% change*	*Cagr*
Entertainment - electronic equipment	5.88	7.70	31%	7.0%
Entertainment - digital services	2.96	3.60	22%	5.1%
Entertainment - other	10.30	11.50	12%	2.8%
Entertainment - total	19.14	22.80	19%	4.5%
Other recreational activities	38.82	46.90	21%	4.8%
Total	57.96	69.70	20%	4.7%

Source: ONS family expenditure survey

[2] *Live music revenues could exceed music sales*, Will Page, MCPS-PRS Alliance, November 2007

Figure A3 Household expenditure on recreational activities in the early 2000s

Spend per week (£) at 2006 prices	*2001/02*	*2006*	*% change*	*Cagr*
Entertainment - electronic equipment	9.28	7.60	-18%	-4.9%
Entertainment - digital services	5.25	5.80	10%	2.5%
Entertainment - other	17.99	17.90	-1%	-0.1%
Entertainment - total	32.52	31.30	-4%	-1.0%
Other recreational activities	26.15	27.90	7%	1.6%
Total	58.68	59.20	1%	0.2%

It is this 2.0% pa growth rate from the Household Expenditure survey that should be compared with industry statistics, where we must exclude advertising revenues for a like for like comparison. When we do this we only raise the growth rate based on industry statistics to 0% per annum.

Use of time

Another indicator of demand for entertainment is how much leisure time consumers enjoy. Currently the average consumer spends[3]:

- 3.6 hours per day on television. This has grown at 0.2% pa[4] over the past four years
- 2.6 hours per day on listening to the radio. This has declined at 0.5% per annum over the past four years
- 0.5 hours per day on reading books, magazines or newspapers. This figure may be declining as newspaper readership falls
- 0.12 hours per day playing games.

These numbers are not additive. Often a consumer is engaged in more than one of these activities at the same time.

To get any long term indicators of how time spent on entertainment has changed we must look to US longitudinal studies of leisure time. These indicate that:

- The amount of leisure time available to adults[5] grew from six hours in the 1960s to seven hours in the early 1990s [6]
- The amount of leisure time in the 1990s and early 2000s then remained constant as consumers chose to take increased productivity through higher income rather than more leisure time.

It is not clear whether UK leisure time followed the same patterns over the last 50 years. But UK studies[7] do suggest that UK leisure time has remained constant since 1994.

In combination these findings suggest that we should not expect any significant increase in time spent on entertainment over the next 20 years. But this conclusion omits three important facts:

[3] See *E-living survey*, University of Essex, 2002

[4] *The Communications Market 2007 – Television*, Ofcom, August 2007

[5] Which includes those retired or unemployed

[6] *Measuring trends in Leisure*, Agniar and Hurst, NBER Working Paper 12082, March 2006

[7] Eg *British Household Panel Survey 1994 to 2004*

- The proportion of old people will grow significantly. The UK population of over 65 is predicted to grow by 46% - from 9.7 million to 14.2 million - over the study period. This population has lots of leisure time, much of which is likely to be spent on entertainment[8]
- There is a significant and steady growth of obesity in the UK population which could increase the demand for passive entertainment services
- The development of entertainment services for mobile devices could expand the time available to consumers for entertainment services like TV to include time on the move and time while waiting.

A3 The platforms used for entertainment services

All of the research we have done indicates that technology will fundamentally change the mix of platforms which are used to deliver entertainment services over the next 20 years. Technology has already led to the digitalisation of nearly all entertainment media, making them suitable for delivery over a wide range of platforms. Now it is making it possible to deliver video, as well as text, still images data and voice, over interactive fixed and mobile communications platforms. We consider changes relating to platforms in this section.

These changes in platforms, in turn, affect the nature of the content and services which constitute entertainment, and the funding and business models used to deliver them. We consider these changes in subsequent sections of this paper.

The move from broadcast to Internet platforms for video

There is general agreement that:

- The delivery of video content for entertainment will shift from the traditional broadcast platforms to the Internet over the next 20 years
- Broadcast TV will not disappear over this period but will continue to serve a significant proportion of the population.

This is closely correlated with the move from the linear to non linear viewing of video content discussed in Section A4.

There is a range of views on the scale of the shift. Some broadcasters believe that Internet TV - the consumption of video entertainment using downloading and/or streaming from the Internet - will remain a niche platform, used mainly by the young. Others see the shift as much more fundamental, with most people using the Internet as the prime source of video content by 2028, and mainly the elderly using broadcast platforms as the prime source of video entertainment.

There is now considerable evidence to support this latter view. For example:

- We have already seen a move from family to individual TV viewing over the past 35 years[9]. We can expect this trend towards individual consumption of TV to continue

[8] The over 65's currently make up 15% of the population but represent 19% of TV audiences

[9] The average number of TV sets per household doubled to 2.07 between 1972 and 2007 (BARB) while the size of the average household declined by 15%. So the number of TV sets per household grew by 136%

- The take-up of broadband and PCs means that high-speed access to the Internet is already available to the majority of UK homes as illustrated in Figure A4. The statistics show no sign yet of the growth in take-up slowing significantly

Figure A4 Take up of broadband and PCs in UK households

Internet enablers	*value*	*date*	*value*	*date*	*% change*	*cagr*
% of homes with PC	25%	1996	63%	2006	152%	9.7%
% of homes with broadband	10%	2003	55%	2007	450%	18.6%
% of Internet users using Internet for						
playing or downloading music	20%	2002	35%	2006	75%	5.8%
reading or downloading on line news	31%	2002	35%	2006	13%	1.2%
listening to web radio/watching web TV	8%	2002	25%	2006	213%	12.1%
playing or downloading games	10%	2002	17%	2006	70%	5.4%

Source: Broadband and ICT access and use by households and individuals, OECD, December 2007

- The use of the Internet for entertainment applications is growing rapidly. Again Figure A4 illustrates. So too do the statistics on the amount of video carried on the Internet. According to Cisco, You Tube now generates more video traffic per month on the Internet worldwide than the entire US Internet backbone in 2000[10]. Cisco also predicts that video will account for 90% of consumer Internet traffic by 2012[11]
- There is growing demand for video-on-demand services. For example the i-Player has proved very popular, both for the BBC and Virgin Media, in offering catch-up TV from the Internet[12]. The ITV.com and 4OD services also demonstrated public appetite for on demand content[13]
- Demand for personal video recorders (PVRs), which allow consumers to time shift viewing, is strong. Enders Analysis estimates around 5 million households will use PVRs by the end of 2008 and that, by 2012, this will rise to 12 million[14]
- Content providers are starting to sell video content direct to end users and via general distribution platforms. The ABC channel in the US is already offering high-definition format content for download from its website while several Hollywood studios are using the Apple i-Tunes website to offer video content.

Research also suggests that the drivers to future full-scale Internet TV are strong:

- There is general agreement that next-generation broadband, offering download speeds of 50 Mbit/s or more will be deployed, using either fibre to the home or to the node, to well over 80% of the UK population by 2028. This will enable multi-streaming of high-definition TV to households
- Advertisers are showing a growing interest in targeting and measuring television adverts so as to make more effective use of their advertising spend. It is much easier to achieve such targeted advertising on the Internet than over the traditional broadcast TV platforms
- Considerable work is now going into developing software which will provide effective search for video content

[10] *Approaching the Zettabyte Era*, Cisco, June 2008

[11] *Approaching the Zettabyte Era*, Cisco, June 2008

[12] The original iPlayer was launched in December 2007; since then it has recorded over 100m requests for programmes, with 21.8m requests in May 2008 – an average of 700,000 per day. See *Digital TV: iPlayer's play for online eyes*, Independent, 14/7/08

[13] *BBC response to Ofcom's Second Public Service Broadcasting Review, Phase 1*, BBC July 2008

[14] *PVRs and Advertising Exposure*, London Business School, March 2007

- There is growing recognition that Internet TV will allow content providers, like the BBC, to exploit and make accessible their substantial archives of content to a much greater extent than broadcast platforms will allow
- The availability of simple-to-use devices and software for linking PCs (or other Internet devices) to television sets will bring Internet TV to the main TV set and improve usability. Come 2028 the consumer experience of Internet and broadcast TV could be indistinguishable.

Balancing these drivers towards Internet TV are a number of barriers. In particular:

- It is not clear what proportion of consumers wants to choose their own content and what proportion prefer aggregators, such as the BBC, ITV or Sky, to choose the content for them. If the latter proportion dominates then the progress towards Internet TV might be modest
- Video generates much larger traffic volumes than other digital media. This creates two potential problems:
  - It is not clear that the fixed and mobile networks will have the capacity to carry this traffic. This is something which we will consider at the start of the scenario development process
  - Suppliers are currently struggling to develop pricing models which reflect to consumers the cost of their actions in streaming and downloading video. Most of our interviewees believe this is a relatively short-term problem
- The growing importance of live events in attracting large audiences, discussed in relation to live sports events later in this annex, is more likely to support broadcast TV models than Internet TV models
- There are concerns about the extent to which Internet TV should be regulated. Broadcast TV provides an effective walled garden on the content available to children, with the 9pm watershed offering a simple way to allow a wider range of content to be shown while continuing to protect children from potentially harmful content. Internet TV does not offer these safeguards and it is, as yet, unclear what measures might be put in place. There is concern that any safeguards which are particularly onerous could slow the take-up of the Internet TV substantially.

The role of mobile entertainment services

The analysis of the previous section suggests that fixed broadband networks will play a central role in delivering Internet TV into the home – through both streamed and downloaded videos. But to what extent will the mobile device be used to deliver entertainment services in general and Internet TV in particular?

One interviewee, from a mobile operator, suggests that the bulk of entertainment services will be consumed via mobile devices by 2028, primarily through use of the mobile Internet. He argues that end-users will prefer to use their mobile device to access the Internet, not just when they are on-the-move, but when in the home and office as well. This might involve the use of large, fixed, high definition, screens connected wirelessly to the mobile terminal and used to project content stored on it.

There is some evidence to support these claim:

- The introduction of the i-Phone has led to a massive jump in the mobile Internet traffic generated by its owners, both in the US and in the UK. Much of the activity involves users in downloading music, software and videos from the Apple store

- Mobile devices enjoy big economy of scale advantages over fixed devices. 10 million mobile terminals are sold each month in India and China and the mobile Internet is the only option for Internet access in most of the developing world. Mobile terminals currently outsell PCs, TVs and cars combined
- Recent Nokia research[15], involving 9,000 16 to 35-year-olds, claims that the consumption of entertainment is moving rapidly from the home to the mobile device amongst this age group.

For such predictions to become a reality the mobile networks would need to massively expand their capacity to carry video traffic at low unit cost. Our research indicates that, to meet this challenge, the mobile operators propose to:

- Add network capacity - initially using 3G but moving to 4G (LTE) technology - as required. This will need high-capacity fibre backhaul
- Add WiFi capacity to devices and servers to minimise the mobile Internet traffic using the cellular radio access networks. This is already happening. For example O_2 has negotiated a commercial deal with BT and the Cloud to use their public WiFi hotspots plus home and office WiFi networks
- Use far more site sharing than at present (but not radio access network sharing)
- Look to consolidate networks through mergers - both with other mobile operators and with the major fixed operators.

In the past the mobile operators have attempted to offer access to the Internet and value-added services on a walled garden basis. Under this model the mobile operator takes complete ownership of the customer, bills the customer, and then gives the service provider a proportion of the value-added service revenues generated. The mobile operators now appear to recognize that many customers simply want to use them as "dumb pipes" to the Internet from which they will generate carriage fees. But they also plan to offer "smart pipe" services to generate additional revenues from at least a proportion of customers. Such services might include:

- A more secure environment for the protection of children from harmful content
- Location based and other value-added services
- Better support and maintenance.

Others take a more conservative view of the future role of mobile platforms in the consumption of entertainment. Some believe that broadcast television will continue to dominate video consumption. Others see Internet TV taking a central role, but with much of the video delivered over the Internet being downloaded via the fixed access networks and consumed in the living room on a big screen television set.

Overall there is considerable uncertainty about the extent to which Internet-based entertainment services will be consumed from mobile rather than fixed devices. The extent to which mobile devices will dominate in the delivery of entertainment will depend on:

- The scale of use of the Internet for video distribution in 2028
- The extent to which the behaviour and tastes of 16 to 35-year-olds change as they age. Does this behaviour regress to the norms of today's older generations and move the consumption of entertainment back into the living room?

[15] In the next episode… entertainment will be circular, Nokia, December 2007

- The capability of mobile devices. This is discussed in a parallel working paper
- The extent to which consumers value mobility when compared with the higher-quality viewing experience which is possible in the living room
- The way in which video is viewed on the move. This is discussed in the next section.

Video on the move

It is not yet clear how consumers will view video content on the move. There are a number of options which, in order of increasing unit costs, are as follows. Consumers might view video content on the move in one of four ways. The content might be:

- ***Pre-stored*** on the mobile device. Such an option makes sense for viewing content such as films, dramas and documentaries. By 2028 mobile devices might offer storage of between 1000 and 10,000 GBytes - enough to store 2,000 to 20,000 DVDs[16]. These devices might automatically download selected content from the home server using wireless links each night
- ***Broadcast*** over a dedicated mobile TV network, mostly using UHF spectrum. It is as yet unclear when such spectrum will become available in the UK. Availability will depend upon the results of the UHF auctions due in 2009[17]. Real-time but non-interactive content like sports and news is suited to this option, which could become important as consumers move away from printed newspapers as their main source of news
- ***Downloaded*** from the Internet over a cellular mobile network. Such an option is required for the development of mobile on-line gaming and will appeal to those with low price sensitivity who want instant access to a wide range of entertainment content from the Internet
- Real-time video content ***streamed*** to a mobile device over a cellular mobile network. This option has limited attractions. Broadcast mobile TV is likely to offer a significantly lower cost substitute for a lot of content.

The most likely outcome by 2028 is that we will see a mix of the first three options in use by different segments of the population and for different genre of video content.

The phasing out of traditional print media

The long term commercial outlook for traditional newspapers and magazines is poor. Revenue from classified advertising in the newspapers, magazines and directories is falling at around 5% per annum in real terms as advertisers switched to the Internet. In parallel display advertising revenue is falling at 2.5% per annum[18]. At the same time readership of newspapers is in long-term decline. Between 1975 and 2007 the number of paid for newspapers sold[19] declined from 11 billion to 7 billion pa while the

[16] Using MPEG4 in a format which matches the resolution of today's mobile TV screens

[17] Much of the spectrum auctioned then will not be available before 2013

[18] *Advertising Statistics Yearbook 2008*, Advertising Association, 2008

[19] There is also stable consumption of around 1.5 billion free newspapers each year

average cover price rose from 34 pence to 68 pence[20]. Figure A5 illustrates. On current trends sales will decline to 4 billion by 2028[21].

Newspaper publishing groups face a major challenge:

- The move of advertising spend from the traditional print media to on-line is likely to continue at current rates for some time to come
- The steady reduction in newspaper readership[22] makes newspapers less attractive places in which to advertise and so reinforces this move,

In response several of the largest newspaper groups are now putting significant effort into developing online sites and looking at new business models to ensure their survival. By 2028 we might expect that:

- The bulk of the population under 50 will get their news on-line, with news presented using a range of media including video, audio and print.
- Most will use mobile devices, perhaps with an e-reader[23] attached, to make reading easier, especially in challenging light conditions
- Newspapers will focus on the production of news items, editorial and news briefings
- Newspapers will generate the bulk of their revenue from online consumption - through advertising and subscription
- Newspapers might offer news content services which are personalised to reflect the consumer's location and interests. These could be offered wholesale (eg to mobile phone companies) or retail from the newspaper's online site
- Newspapers will continue to produce printed versions for a small, elderly, and declining percentage of the population.

This new business model could make it difficult for the main newspapers to retain their currently strong brand values. Newspaper groups are also worried about the rise of user generated content through bloggers. But most analysts believe that end-users will continue to want the authoritative reporting which newspapers deliver.

Many magazines are likely to suffer a similar fate. Glossy, feature rich, magazines such as Vogue may survive in the traditional print formats while listing-based and news-oriented magazines, such as motoring magazines, probably will not.

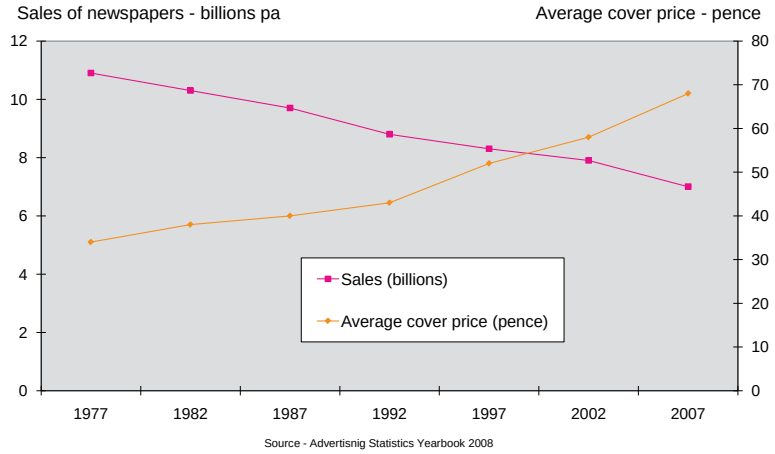
[20] At constant prices

[21] *Advertising Statistics Yearbook 2008*, Advertising Association, 2008

[22] The number of UK adults reading at least one national daily newspaper on an average day fell from 26.7 million in 1992 to 21.7 million last year. Guardian, December 2007

[23] Currently e-readers offer black and white images with a 0.5 second refresh rate on large, roll-up screens. By 2028 colour e-readers offering video should be available.

Figure A5 Long term trends in sales of paid for newspapers



The storage of content

By 2028 every home network and personal device will, on current trends, offer massive storage and a high proportion of this storage will be used for entertainment applications. Today a top end mobile phone might offer 80 GBytes of storage; in 2028 it might offer tens of thousands of Gbytes. Managing, backing up and synchronising this data between devices is a significant challenge. In particular where is the data to be kept?

Our interviewees identified three options, but gave little indication as to which will succeed:

- Option 1 - on the server of the home network. Under this option all downloaded and selected broadcast content is stored on the home server. Relevant subsets are then transferred to personal devices for subsequent consumption on a daily basis. This option is relatively cheap and simple but does not offer any obvious backup solutions
- Option 2 - on secure servers on the Internet. The consumer then uses fixed or mobile broadband connections to access the content. Such a solution is secure but generates higher costs than the first option and is not resilient to failures in broadband connections
- Option 3 - on local storage with the master copy residing on the Internet. The local and Internet versions are then synchronised at regular intervals. This option appears to combine the best features of Options 1 and 2.

Changes in radio platforms

Radio contributes less than 4% of entertainment sector revenues but occupies just under 40% of the leisure time spent on entertainment[24]. Listening hours are essentially constant. But the BBC is attracting audiences from the commercial, advertising funded, sector and national radio is growing at

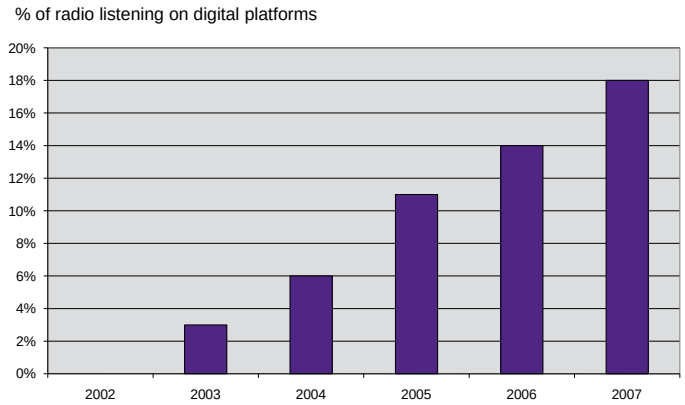
[24] This statistic needs to be interpreted with care. Radio listening is often carried out at the same time as other entertainment activities.

the expense of local radio. Advertising revenue is now in steady decline (at 2% per annum in real terms) following a period of strong growth in the 1990s. As a result commercial radio stations, and especially local stations, are struggling. 53% of stations launched since 1996 have yet to break even[25].

Radio is delivered over a wide variety of platforms. There is now a general trend, illustrated in Figure A6, away from analogue terrestrial broadcast using amplitude or frequency modulation to digital platforms such as DAB, digital terrestrial TV, satellite and the Internet. But there are a number of barriers to this migration. In particular:

- There are gaps in the geographic coverage offered by digital radio
- There is a limited range of portable DAB radios available
- There are virtually no digital radios in cars[26] where 20% of radio listening currently takes place
- It is unclear whether UK consumers will enjoy cheap digital radios in future. Digital radio has not been as successful elsewhere in the EU as it has in the UK. So manufacturers are reluctant to commit to the regional or global production which creates large economies of scale. In particular mobile phones currently incorporate analogue FM radios rather than digital radios.

Figure A6 The shift to digital radio



Source: Ofcom and Rajar

Set against this background, our research indicates that we might expect the following developments in the delivery of radio. In the period to 2028 we might see:

- Strong growth in listening in digital mode. For example Ofcom has predicted that 90% of listeners will use digital radio by 2020[27]

[25] *The Future of Radio*, Ofcom, November 2006

[26] 150,000 out of 34 million according to the Digital Radio Working Group's *Interim report to the Secretary of Stat for Culture Media and Sport*, June 2008

[27] *The Future of Radio*, Ofcom, November 2006

- A shift from broadcast to Internet radio. Much of the discussion on shifts in the distribution and nature of video content applies to audio content as well
- The emergence of personal radio channels like those already provided by LastFM
- Declining revenues to fund commercial radio as advertising revenues continued to move online
- Consolidation within the industry and relaxation of regulations on requirements for local content in response to this shrinking revenue base
- Integration of digital radio into mobile terminals, perhaps allowing click through to the mobile Internet to get more information on music being played or to purchase a music track[28]
- The switch off of analogue radio broadcasts by 2020. This proposal, made by the Digital Radio Working Group would:
  - release spectrum for other uses and
  - lower the costs of the radio stations who would no longer have to simulcast in both analogue and digital formats.

  Switch off will depend, inter alia, on how successful digital radio is in other countries and when car manufacturers switch to digital radios.

Platforms and business models for recorded music

Though the long-term outlook for the consumption of recorded music is positive, the future commercial models for the sector are less certain. Consumption of recorded music has held up over recent years due to the increasing diversity of music devices and services and falling prices. However, music industry revenues are declining due to the effects of large scale illegal copying and Internet distribution by consumers.

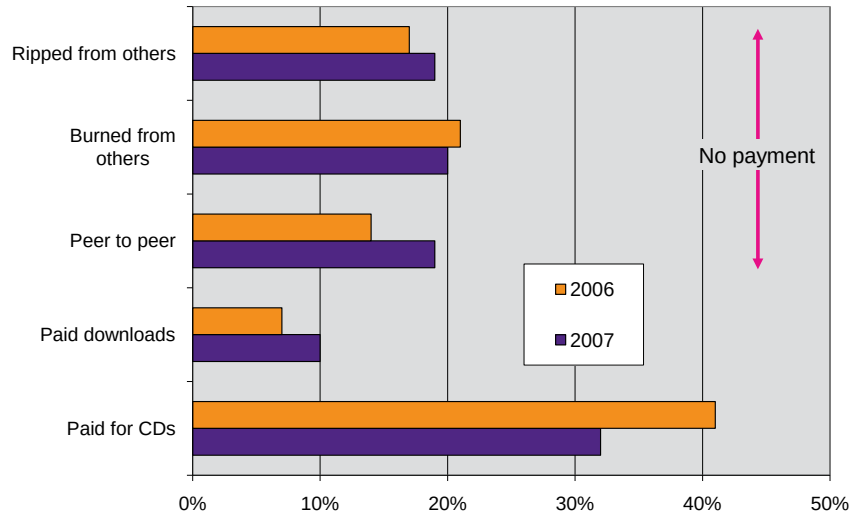
Sales of hard copy single music tracks (singles) have decreased dramatically, from 66 million in 2000 to 21 million in 2005 as these were most readily substituted by on-line activity. By 2007, 90% of single sales were digital.[29] In contrast, physical album sales increased from 217 million in 2000 to 246 million in 2005, mainly because retail competition drove down prices.

Consumption of recorded music on the Internet and mobile devices is increasing. Paid downloads of music in the UK reached 77.6 million tracks in 2007, growing at an annual rate of 47%. Illegal online activity is more difficult to measure, though consumer surveys in the US suggest that the volume of music acquired without paying exceeds the amount paid-for. Figure A7 illustrates.

[28] See for example *The iPod generation*, Ofcom, July 2004

[29] Source: IFPI

Figure A7 Volume of music acquired by method in the US



Source: NPD Group survey of US Internet users 13+

While the volume of music acquired by consumers is growing strongly, sales are in steep decline. The growth in paid downloads on-line has not compensated for the decline in physical sales, leading to a decrease in music industry revenue from £1,907m in 2002 to £1,488m in 2007, a nominal cagr of -4.8%[30] and a cagr at constant prices of -7.2%. This decline in physical sales and growth in on-line sales is likely to continue. Sales of music track through Apple's iTunes site, for use on iPods and PCs, are growing strongly. Globally they reached 5 million tracks daily in 2006. At the same time sales of digital music on mobile devices accounted for 29% of the total digital music market in the first half of 2007.

The challenge for the music industry now is to monetise the consumption of recorded music online. Unlike other content (e.g. video) standalone music tracks are not well suited to advertising, leaving end user payments as the main option. Growing this revenue stream will depend on developing more effective DRM, enforcing copyright law more forcefully online or persuading consumers to pay for content voluntarily.

The prospects are not especially good and many in the industry are predicting that music companies might use the Internet mainly as a marketing medium in future, with revenues generated elsewhere (e.g. live performances, advertising in radio-like services).

Platforms and devices for games

Revenues from the UK video game market are expected to increase from £1.5 billion in 2006 to £1.8 billion in 2011 – a cagr of 5%. Increasing uptake of the latest generation of consoles (Xbox 360,

[30] Source: IFPI

Nintendo Wii & Playstation 3) will drive short term growth while the extension of games to new demographics will contribute to longer-term growth.

The growth of games usage among new demographics (e.g. older people) has been stimulated recently by developments such as:

- the Nintendo Wii and Wii Fit consoles which have successfully attracted 'casual gamers' to the console games market
- the Dr. Kawashima's Brain Training game on Nintendo DS (handheld device).

Games publishers are taking advantage of the casual games opportunity by releasing franchises including Guitar Hero and Rock Band. The ageing of current gamers and the introduction of games to new demographics creates potential for continued revenue growth over the next 20 years.

The distribution of games over the Internet, as with other entertainment content, is increasing. The online games segment, comprising massively multiplayer online games or MMOGs and casual games[31], is growing strongly. It is expected to increase from £77m in 2006 to £281m in 2011. There is also the potential to distribute PC and console games (played mainly off-line) over the Internet in their entirety or as a series of levels that users download one at a time.

Games are also becoming more connected. Multiplayer games and virtual worlds require connectivity. The streaming of content live into games that are otherwise played offline could also make use of connectivity on games devices in future.

The increasing connectivity of games will enable the development of new business models. In-game advertising will become more widespread as advertisers are able to insert their advertising or sponsorship into games in a controlled and timely manner. Similarly, games publishers will be able to unbundle games into a series of levels that are sold as several small purchases rather than one large one. Virtual world games such as Second Life support a broader set of business models including transactions (e.g. users purchasing virtual goods and services).

The devices on which games are played will also diversify. The increasing penetration of new mobile handsets with better gaming capabilities and Internet access capabilities will continue to drive the wireless games market, where revenues are expected to grow from £197 million in 2006 to £321 million in 2011 - a cagr of 13%.

There is a trend towards seamless gaming experiences across multiple devices, as shown by Microsoft's Live Anywhere Initiative, which emphasizes access across a wide range of devices. So users may continue to enjoy their console gaming experience outside the home via other devices.

Peripherals devices such as controllers and displays will also develop in the games market. For example, sensors in clothing could be used as a games controllers, and wearable headsets as displays.

Overall we expect a strong growth in the use of the Internet to support the distribution of games software. Whether there will be heavy use of the Internet, fixed or mobile, for on-line games is less certain. On-line games are currently growing fast, but from a small base, and it is not clear if current growth rates will be sustained long term.

[31] For example card games

A4 The nature of entertainment services

A move from broadcast platforms to the use of two-way fixed and mobile broadband platforms will enable changes in the form of entertainment services and the type of content which is consumed. In this section we describe the likely nature of these changes.

The type of content consumed

Our research suggests that the entertainment content consumed in a broadband, Internet-oriented, world might change in at least five ways:

- Consumption of video content moves from linear to non-linear formats
- Content becomes more interactive
- User generated content becomes a substantial proportion of the content consumed
- Entertainment content is more varied in its country of origin
- Location-based entertainment services become significant.

We also expect to see live sports events becoming more important as a form of video entertainment, regardless of the scale of the shift to Internet TV.

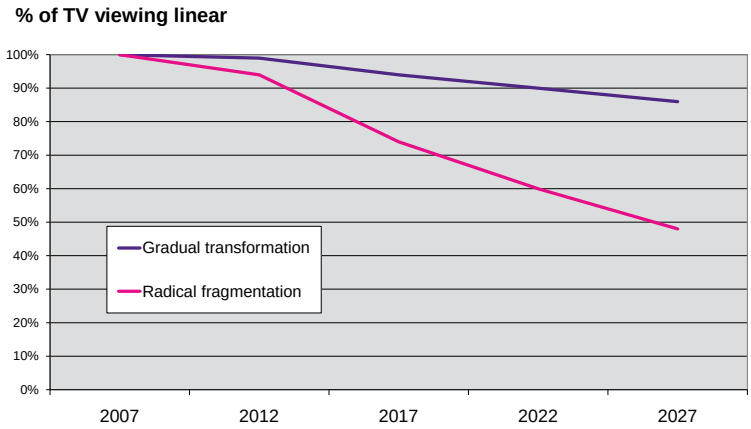
Non-linear viewing of video content

Traditionally the viewer sits down, switches on the TV set and selects a channel for viewing. This is linear viewing.

There is already a move from linear to non-linear consumption of video content, with the take-up of VCRs and PVRs offering time shifted viewing of broadcast content, and with the take-up of on-demand services. A move to Internet TV would accelerate this trend. Figure A8 provides projections of how quickly non-linear viewing might grow (in which time shifted broadcast TV is counted as linear TV). It is based on Ofcom scenarios, developed for the second Public Service Broadcasting Review. We have selected the two most extreme scenarios for presentation - the *radical fragmentation* and the *gradual transformation* scenarios and have extrapolated the projections from 2020, where they currently stop, to 2028.

Non-linear viewing and the uptake of Internet TV are closely correlated but they are not the same thing. Non-linear viewing includes viewing over traditional broadcast platforms using time shifting devices. It also includes viewing over IPTV networks - where a fixed operator, typically the incumbent, provides dedicated servers on its network to store the video content. The IPTV supplier can then engineer the network to provide a guaranteed quality of service for streamed video and a walled garden of content to the end user. This gives it strong ownership of the customers for the service. BT Vision is an IPTV service with dedicated bandwidth and guaranteed quality of service while the iPlayer offers Internet TV. So far the latter appears to be generating much greater demand than the former.

Figure A8 The move from linear to non linear viewing – Ofcom projections



Source: Ofcom PSB Review, April 2008

A move to non-linear viewing of video content does not necessarily mean a shift away from video with a strong linear narrative. Many of our respondents, including proponents of the Internet TV position, made the point that there is strong end-user demand for compelling linear narrative which will not disappear in an Internet TV world. Rather they argue that linear programmes offering such narrative will be viewed when and where the viewer chooses rather than at the time of broadcast.

A move to non linear viewing of content from the Internet should:

- Make it easier for content providers, like the BBC, Disney and others, to exploit their archives of video content. Such content providers might use a combination of Internet search, micro-payments and DRM mechanisms to provide a "long tail" of video archive material to consumers on a global basis
- Allow content providers, free from the demands of the TV schedule, to make videos in innovative formats and of much more variable length.

More interactive content

Several respondents suggested that entertainment will become more interactive and participative so as to engage the consumer more. In particular they point to the development of conversational viewing, in which consumers discuss their reaction to content as they view it with distant friends. In other words traditional linear viewing is combined with telecommunications to produce a new form of entertainment. Such conversational viewing is seen as a natural by-product of social networking sites. There is also scope for development of interactive contextual content around the video content. For example, viewers could be shown a range of Internet links relating to a programme, giving them a continuous set of options to bookmark or browse.

Others are more sceptical about such changes. They point to the lack of participation in entertainment services beyond programmes which use tele-voting or telephone based competitions. They also point to the failure of interactive broadcast TV to take off since the first services were offered 10 years ago.

User generated content

Opinions are also divided on the importance of user generated content (UGC). Some believe that UGC is a fashion which will pass. They argue that:

- Lots of people consume UGC but few produce it
- Those which do are gradually becoming professional producers as UGC sites like YouTube share advertising revenue with them and they start to gain a viable income from their efforts. According to the Guardian[32] Web 2.0 content follows a 1% rule - 1% of consumers are regular content creators and content creators are not typical users.

Others argue that UGC will fundamentally change entertainment. According to one mobile device supplier UGC could account for up to 50% of entertainment consumption by 2028. This group argues that UGC is already having a fundamental effect on entertainment through sites like YouTube which, in January 2007 alone, posted over 3 billion video views made by 79 million different users[33]. They claim that the relevance and immediacy of UGC more than compensates for lower production values for many consumers. They also point to the development of collaborative UGC in which attendees at an event pool their content (captured using their mobile phones) and edit it online into a final record for distribution to friends. The rapidly improving quality of mobile phone cameras is fuelling this trend. By the end of 2008 manufacturers will begin shipping mobile phones equipped with high-definition cameras for example.

Finally they point out that the current generation of broadband inhibits UGC. The low uplink speeds available from consumer fixed broadband, typically less than 0.5 Mbit/s, make uploading of UGC time-consuming. With the roll-out of next-generation broadband consumers can expect a 20 to 50 fold increase in uplink speeds which could stimulate UGC significantly.

If UGC does become a major source of entertainment then this could displace professionally generated content and the associated revenues. It is possible that the best UGC will carry adverts, as YouTube does already, and become commercialised. But it is also possible that both the consumers and producers of UGC will find the commercialisation of their content unpalatable and will act to minimise it.

A move to global content supply

A move to Internet TV should make the supply of video content more global. There are three main effects:

- We can expect to see a greater proportion of commercial English-language content becoming readily available from outside the UK. At the moment it is the broadcasters who decide what proportion of non-UK content is used on TV. If content providers sell direct to end users, on sites like Amazon and the Apple store, then it will be the consumer who decides this proportion and regulatory quotas on content become meaningless
- Equally we might see demand for UK content from overseas markets, and the revenues to the UK from such exports, increase. Good UK video content available over the Internet should have substantial and readily accessible markets across the English-speaking world
- We can expect that the needs of ethnic minorities, for video content in their own language and reflecting their own culture of origin, will be better met. Such minorities might visit websites of content providers in their own country of origin, or use services offered by specialist aggregators who assemble a range of such video material for storage and access in the UK.

[32] The Guardian, 20th of July 2006

[33] *You Tube looks for the money clip*, Yen, Accessed, March 2007

Location-based content

Mobile terminals may soon have GPS installed as standard. This will enable the development of new, location-based, entertainment applications. For example:

- A walker might send a favourite walk, with waypoints, photos and points of interest to friends or post the walk on a website of shared walks
- A local community organisation might create a "blue plaque tour" around its town, pointing out locations of historic or current interest so as to promote tourism.

The importance of live sports events

Live video of the major sports events, such as Formula One or the World Cup, will become more important as a way of attracting large audiences in a world where viewing is becoming increasingly fragmented. The value of sports rights[34] and the value of the sponsorship of sporting events[35] continues to grow. Such events have the greatest impact when viewed in high-definition format, in real-time, on a large screen. As such they fit better with traditional TV broadcasting than in the Internet TV world – which is better suited to downloads than high-quality video streaming. But it is also possible that sports rights holders might want to sell content direct to end-users in future via the Internet.

Conclusions

It is impossible to predict with certainty what kinds of entertainment content will be popular in 2028. But it is clear from the analysis above that, in an Internet TV world:

- There will be substantially more non-linear video viewing
- The variety of entertainment services available will grow substantially
- User generated content could, with the development of higher broadband uplink speeds, become a significant source of entertainment. This in turn could reduce the funding available to the entertainment industry.

We also expect to see live sports events becoming more important as a form of video entertainment.

The distribution of content

With a move to Internet TV we can expect to see a change in the way video content is distributed. In particular we might see content providers selling their premium content direct to end users on a pay-per-view basis. Such an approach cuts down significantly on distribution costs. More importantly it increases the opportunity for the content provider to discriminate in the price at which it sells the same content to different market segments, so increasing its ability to extract the full willingness to pay from the market. Such an approach has implications for the entertainment value chain. Currently providers of premium content distribute via aggregators like Sky and Virgin Media. If they go direct to the end user then this will tend to undermine the aggregator's business model. Consumers will be able to purchase only the content they want on a pay-per-view basis, rather than pay a substantial monthly subscription for a package which might contain a high proportion of unwanted content.

[34] The three year TV rights to the English Premier Football League are now worth £1.7 billion – with £1.3 billion from Sky and £0.4 billion from Setanta

[35] Visa recently paid a record $866 million to sponsor the Olympics

Discovering content

Opinion is divided on the scale of the shift to Internet TV; it is divided in a similar way on how consumers will discover the entertainment content they consume in future.

One set of respondents, clustered around the traditional broadcasters, argue that:

- A high proportion of people are time poor. They want to sit back in front of the television and be entertained
- These people start their viewing by browsing the five main UK channels or switching on for a favourite scheduled programme
- The mass audience channels will continue to use the time between programmes to promote future major programmes and series and so retain their audiences
- People will continue to trust TV channel brands, like the BBC, ITV, Sky and Disney, and rely on them for recommendations on what to watch.

Another set of respondents, clustered around the telecommunications operators, software vendors and mobile equipment suppliers, believe that a new mix of discovery methods will develop which will enable Internet TV to flourish. This mix includes the following mechanisms:

- Aggregators might sell personalised channels, assembled from the wide range of video material available on TV websites, to those who want passive entertainment. This is a new role within the entertainment value chain
- Social networks might become an important source of recommendations on what to watch eg through conversational viewing
- Content providers might make their content available for purchase on the site of companies like Amazon or Apple - making these obvious places for consumers to search for entertainment content
- End-users might use video search software to recommend content that they might want to watch. Companies like Blinkx are developing software which will recommend content to viewers based on such factors as viewing habits, device used, time of day and the individual's community context
- Content providers who sell content direct to end users might use various new ways to promote it. These might involve both direct and viral marketing. For example social networks might provide a mechanism for the viral marketing of new TV series which content providers could exploit.

In an Internet TV world we are likely to see a mix of these discovery mechanisms used, with different market segments favouring different discovery mechanisms. We are also likely to see a shift in brand values. Traditionally consumers have seen the TV channels as brands. In future, and especially in an Internet TV world, it is the programmes, such as Friends, Big Brother or the Sopranos, to which brand value will attach.

The cost of content production/distribution for broadcast TV

In looking at how entertainment business models might change we need to consider both how funding might change (see A5 below) and how the costs of production and distribution might change. A

parallel working paper is looking at how changing production methods might affect demand for spectrum. Here we provide a brief assessment of how the overall costs of traditional broadcast TV, where production and distribution costs are highest within the entertainment sector, might change.

These costs have three main components:

- The cost of production equipment and staff
- The cost of spectrum and other resources for distributing the programmes
- The cost of attracting star talent.

It is clear that the unit costs of production are falling as technology enables productivity increases. In its assessment of the recent BBC licence fee settlement[36] for example, Indepen estimated the likely fall in unit costs at 2% to 4% per annum in real terms. Changes in the price of scarce resources like spectrum and talent are much harder to predict.

The price of spectrum to the broadcasters is likely to increase in the short term. At the moment broadcasters pay nothing for their spectrum. But there are proposals to introduce administered incentive pricing to reflect the opportunity cost of the UHF spectrum they use. Long-term forces are also likely to raise spectrum prices for TV distribution. We might argue that, in an Internet TV world, there is less reliance on broadcast spectrum for distribution of TV content and that the price of spectrum will fall. But this argument ignores the fact that video distribution over cellular mobile networks, which makes substantial demands on spectrum (ideally at UHF), may to be an important component of Internet TV.

The price of talent is also difficult to predict. There are a number of factors to consider here:

- Stars attract audiences and reduce the risk that a new programme series might fail. So they command high talent fees in a profitable industry
- If profits fall then talent fees tend to fall as well, unless the star is recognized in a global marketplace, in which case he or she can go elsewhere to maintain high fees
- If demand for talent oriented TV genres increases then so too will talent fees
- In future TV companies might gradually replace stars with avatars. For example some futurologist[37] are predicting that, by 2015, 25% of TV celebrities will be synthetic. Such developments should help constrain talent fees, even if the avatar creators demand some of the rent.

In many ways talent fees act to limit changes in the profits of TV production companies. We can reasonably ignore global market effects. Ofcom's finding that UK audiences want UK based TV content[38]. With this assumption if profits rise, talent fees rise to capture these additional profits and, if profits fall, then talent fees fall as well.

Overall our analysis suggests that, while the cost of TV production are difficult to predict:

- Content which is talent light may have relatively stable production and distribution costs, with increases in spectrum costs offset by reductions in production costs

[36] *Appraising the proposed BBC licence fee increase*, Indepen, May 2006

[37] *BT Technology Timeline*, Neild and Pearson, BT, 2005

[38] *The Audiences view on the future of Public Service Broadcasting*, Ipsos MORI, April 2008

- Content where talent is a significant input may also have relatively stable costs. The mechanisms by which talent fees are set is likely to stabilise the profits of TV production companies and so enable a steady flow of UK oriented TV content.

A5 Funding of entertainment services

In this section we look at how the three main sources of entertainment funding might change. These are:

- Advertising revenues
- Public service broadcast funding
- End-user spend on subscriptions, pay per view and outright purchase.

We also consider briefly a potential source of future funding - commissions on e-commerce transactions.

Advertising

Overall spend on advertising

Spend on advertising in the UK (excluding direct mail) has fallen as a proportion of GDP over the past 20 years - from 1.31% in 1987 to 1.15% in 2007. UK advertising spend is also significantly higher, by about 25%, than the average EU member state[39]. Together these facts suggest that UK advertising spend might grow more slowly than GDP over the next 20 years.

The mix of spend

Advertisers have the option to allocate their budgets to a number of different media. For the purposes of this study there are two main groups of media:

- Content associated media including press, television, radio, cinema and Internet (display). In these cases advertising appears alongside content and helps to fund entertainment
- Standalone media including outdoor, transport, direct mail and Internet (search and classifieds). Advertising spend on these media does not help fund entertainment.

Figure A9 plots the advertising spend of these two groups at constant prices for the past 20 years. We can see that spend on the latter group has grown much more strongly than spend on the first group. Indeed in the last seven years spent on advertising associated with content has actually fallen at 1.5% per annum.

The primary reason for this fall is a switch to spend on Internet advertising as shown in Figure A10. This plot suggests that the rapid growth in spend on Internet advertising (mainly paid search and classifieds) has substituted largely for press advertising and direct mail. TV, radio and cinema advertising has so far held up better as display, the online substitute, is has developed less quickly.

[39] See *Advertising Statistics Yearbook 2008*, Advertising Association, 2008

Figure A9 UK advertising spend by context - 1987 to 2007

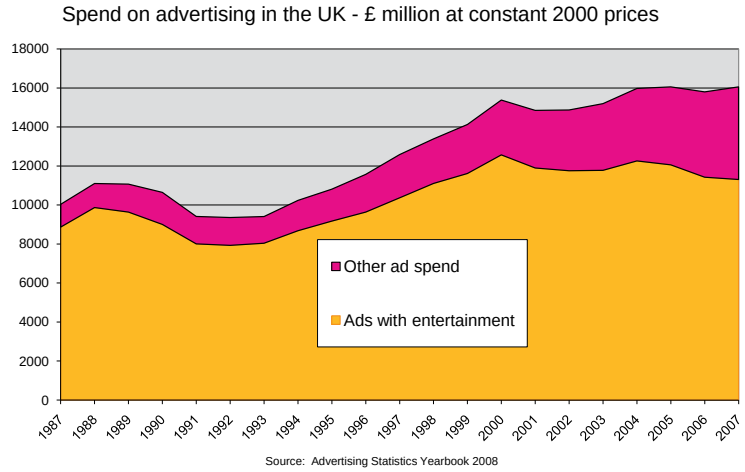
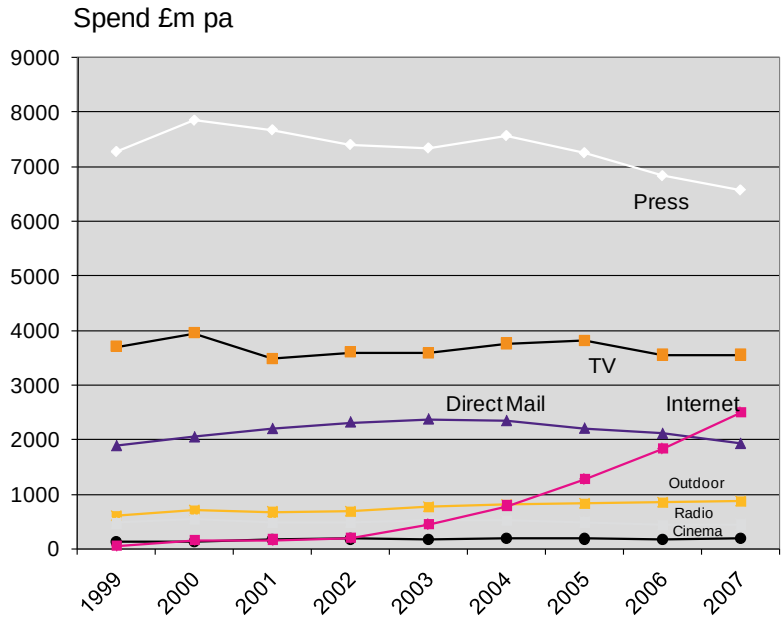


Figure A10 UK advertising spend by channel - 1987 to 2007



Future prospects

Analysis of these historic trends and the opinion of stakeholders suggests that:

- Press advertising revenue will almost certainly continue to decline as Internet paid search, classifieds and display advertising substitute for it
- Broadcast TV advertising will substitute less quickly to the Internet. As several respondents have pointed out, TV and radio advertising still provides the best way to deliver mass audiences for

campaigns aimed at launching products and building brands (e.g. FMCG advertising). Only as Internet TV achieves scale, and the ability to deliver mass audiences, will it take significant share away from broadcast TV

- Internet advertising will continue to grow strongly. In the longer term there is significant potential for display formats (e.g. video pre-rolls) to drive growth.

Less certain are the prospects for advertising in games and user-generated content, which could affect the overall advertising picture:

- Advertising in games is negligible in scale at the moment. Global revenue was estimated at $78m in 2006[40]. But many observers believe it could be much more substantial in future. The development of in-game advertising will depend on developing appropriate advertising formats and measurement systems
- It is unlikely that advertising in games will come to dominate advertising associated with entertainment over the next two decades. If we assume that games revenues continue to grow at 7% pa for the next 10 years and that advertising generates 20% of games revenues by 2028[41] then games might generate £620 million in advertising revenues in 2028 i.e. around 6% of the advertising revenues associated with entertainment
- If user-generated content grows to represent a significant proportion of entertainment content consumed then the extent to which it attracts advertising becomes a significant issue. To-date UGC has had difficultly in attracting advertising due to concerns over advertisers becoming associated with inappropriate content.

Future prospects for TV advertising revenues

As well as changes in the overall spend on TV advertising we can expect the distribution of this revenue between platforms to change significantly over the next 20 years.

Already we have seen the share of advertising revenue allocated to the three main commercial public service broadcasting channels (ITV, Channel 4 and Five) decline as advertising spend has shifted to the specialist multi-channels. Some commentators believe that this trend will continue; others argue that the fragmentation of TV advertising spend is now coming to an end.

In addition a shift from broadcast to Internet TV would mean that advertising revenue would move away from the traditional broadcast channels. But this does not mean that the commercial broadcasting companies will necessarily lose all the associated advertising revenue. If these companies can make a successful transition from broadcast to Internet TV they can retain at least a proportion of these revenues.

Potential changes in the advertising value chain

As advertisers seek more efficient and effective ways of reaching consumers, they are increasingly interested in:

- Targeted advertising – addressing specific groups in an appropriate context
- Measurement – accurate measurement of campaigns and their results
- Response – the ability for consumers to take action in response to advertising.

[40] Source: Yankee Group, 2007

[41] Compared with 30% for TV and 25% for cinema in 2006)

Internet advertising can deliver on these requirements, and Internet advertising companies are rapidly developing new services to offer advertisers better targeting. There are also opportunities for traditional media to improve their offerings to advertisers. For example broadcast television could become more targeted and measurable through the implementation of set-top box technology. It remains to be seen whether broadcasters, platforms and advertisers will co-operate to make this happen.

The development of targeted advertising online (and on other platforms) could shift some value add from content providers and aggregators to the platforms that provide the technology and customer data to support targeting. Options here include the following:

- The platform operators may be able to provide customer profiling information services to the advertisers, aggregators or content providers. Mobile operators are better placed here than fixed operators. They supply services to individuals while fixed operators typically supply services which are used by various members of a household
- A content provider or aggregator might run its own customer profiling service
- Specialist customer profiling information providers may enter the market. A specialist might collect and collate information from a variety of sources to enable more powerful targeting and then sell this service wholesale.

There is also the possibility that privacy concerns will limit the scale of targeted advertising. For example, there has been considerable opposition to BT's trials with Phorm in which the customer usage data of its ISP was used to deliver targeted Internet advertising.

Public service broadcast funding

The current situation

The concept of public service broadcasting is well established in the UK. It has four main objectives:

- To inform our understanding of the world (e.g. through impartial news)
- To stimulate knowledge and learning
- To reflect UK cultural identity
- To represent cultural diversity.

Public service broadcasters are subject to PSB obligations which include the need for compliance with various content quotas, impartiality in news reporting, and wide accessibility. There are five public service broadcasters:

- The BBC which runs eight TV channels and a series of local and national radio stations. The BBC is primarily funded through a licence fee levied on every household having a TV receiver. This licence fee, which generated £3.2 billion of revenue in 2006, represents 75% of the BBC's income. Roughly 80% of it is spent on TV and 20% on radio. The fee is scheduled to rise by 3% pa[42] to 2008 and then at 2% pa through to 2013, when a new licence fee regime is scheduled

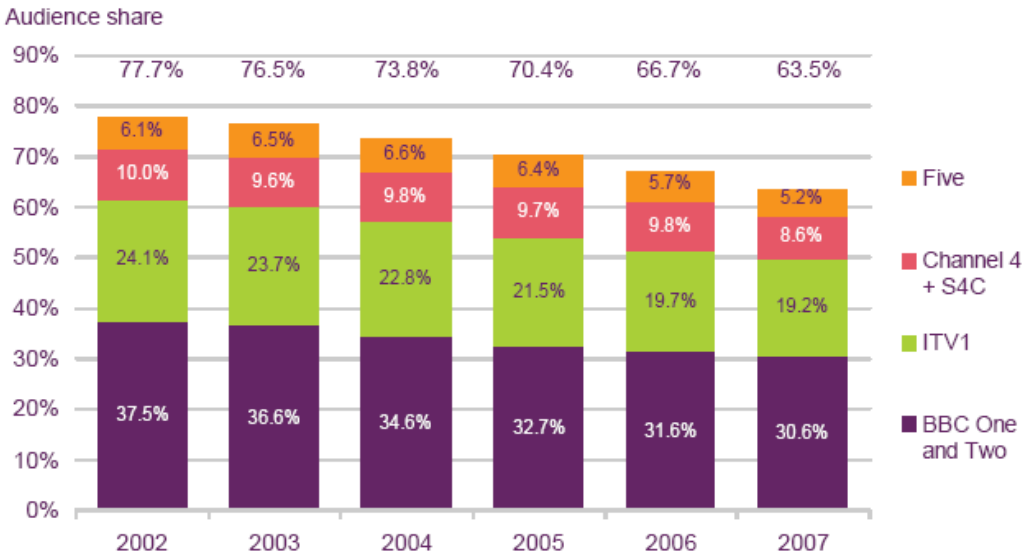
[42] At out turn prices

- Four commercial TV channels - ITV, Channel 4, S4C and Five, which are funded through advertising revenues and, indirectly, through the allocation of UHF spectrum for which there is no charge.

Over the past 20 years the hours of TV viewing have remained virtually constant but the proportion of audiences watching public service broadcasters has fallen significantly as the availability of specialist digital multi-channels has grown and attracted audiences[43]. In 1990 the public service broadcasters had a near 100% audience share. By 2006 this had fallen to 67% and could, on current trends, fall below 50% by 2012. See Figure A12.

This audience fragmentation has started to affect the commercial public service broadcasters advertising revenues. TV advertising revenue have remained constant in real terms over the last 5 years but the proportion going to the public service broadcasters has fallen – from 83% in 2002 to 70% in 2006. Ofcom expects this decline to continue[44].

Figure A12 The audience share of the main public service broadcast channels



Source: Ofcom Communications Market 2008

Likely developments

Based on discussions with stakeholders we have identified four likely developments in PSB funding of entertainment services over the next 20 years.

Development 1: PSB funding will remain at a level approaching its current scale.

Some respondents have argued that it is increasingly hard to get audiences to watch challenging public service content when there is such a massive, and growing, choice of TV to watch. If no one watches such content, why should it be publicly funded?

[43] In 2002 there were 236 of these multi-channels; by 2006 there were 433.
See *Communications Market 2007*, Ofcom

[44] See Paragraph 1.24, *Public Service Broadcaster Review, Phase 1*, Ofcom, April 2008

Others questioned whether PSB funding will be required in 2028 on its current scale. In an Internet TV world the range of content available should be much greater than today, with the needs of minority groups well met. So the role of PSB funding could be much reduced.

Yet others argue that:

- There is currently strong public and political support for PSB funding
- The need for public service content will grow if the UK is to preserve its national identity while its cultural and ethnic diversity continues to expand through immigration
- There are industrial policy reasons for preserving PSB funding, which provides core funding to help the UK's creative industries compete in global markets.

On balance the arguments suggest to us that PSB funding will continue to exist in 2028 but perhaps on a smaller scale.

Development 2: the BBC will continue to exist but will be less dependent on PSB funding than it is today.

There is currently very strong public and political support for the BBC. Even those who do not watch it believe it is "a good thing" which should be preserved. By the time of the next Charter review, which starts in 2012, two years before the current charter runs out:

- PSB funding could be increasingly concentrated on the BBC. In 2003 Ofcom estimated that 80% of PSB funding went to the BBC. On current trends of audience fragmentation this would rise to 90% by 2012[45]
- Audience fragmentation could also affect future BBC licence fee settlements. At the last Charter review BBC1 and BBC2 had a combined audience share of 35%. On current trends that share will fall to 25% by 2012. Again see Figure A12. At such audience levels it could be politically difficult to sustain licence fee increases.

At the same time there are opportunities for the BBC to become less reliant on its licence fee revenues:

- There are new opportunities to the BBC to exploit its content archives[46] on a global basis via the Internet
- BBC Worldwide's revenues continue to grow strongly. In the 12 months to April 2008 they grew by 13% for example[47]
- The BBC has a substantial stake in some of the more successful multi-channels such as UKTV and Dave.

Development 3: the TV licence fee will be replaced by PSB funding from other sources

In an Internet TV world a high portion of the content might be downloaded from the Internet for storage and subsequent viewing on a multiplicity of devices. Only a small proportion might be viewed on a conventional television receiver from broadcast signals. In these circumstances it would become increasingly difficult politically to sustain a tax based on ownership of TV receivers. This development is linked to the speed with which Internet TV might replace traditional broadcast TV.

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[45] Paragraph 1.24 of *Public Service Broadcasting Review Phase 1*, Ofcom, April 2008

[46] The second biggest in the world after Disney according to one stakeholder

[47] Annual Report of the BBC, for 2007/08

Development 4: funding of commercial public service broadcasters will move from advertising alone to a mix of advertising and direct public funding

With the erosion of advertising revenues through audience fragmentation, the commercial public service broadcasters face increasing difficulty in meeting their PSB obligations. At the same time there is a political desire to maintain a plurality of public service broadcasters and not to rely on the BBC alone. Resolving this issue would require some kind of public funding of the commercial public service broadcasters. This might take one of several forms. It might:

- Involve the commercial public service broadcasters and the BBC in competitive bidding for funds as Ofcom suggests in its ***Model 4*** for PSB funding[48]
- It might involve, as the BBC argues[49], providing the commercial public service broadcasters with spectrum at below market prices
- It might involve other sources of funding such as the National Lottery or direct taxation.

End user spend

Current trends

Trends in the end user spend on entertainment vary by activity:

- End user spend on ***games*** is growing strongly at 7% pa in real terms (see Figure A1)
- End-user payments for ***newspapers and consumer magazines*** were close to static between 1998 and 2007, rising from £4555 million to £4791 million[50] at constant 2000 prices
- End-user spend on ***TV*** has grown steadily over the last five years at 7.6% per annum in real terms. This growth in spend, largely on subscriptions to Virgin Media and Sky services, contrasts with near static advertising revenues and a 2.5% growth in the BBC licence fee. Figure A13 illustrates
- End-user spend on ***DVDs*** has grown at 5% per annum over the past five years. Historical growth has been driven by decreasing price points on DVDs and an increasing installed base of DVD players. Looking ahead, there is the potential for Internet pay-per-view (or P2P file sharing) to substitute for purchases of physical product
- There is virtually no end-user spend on ***radio*** which is funded primarily by the BBC licence fee and advertising
- End-user spend on ***music*** is changing rapidly. Spend on CDs is declining quickly as consumers switch to MP3 downloads from the Internet, with a high proportion using illegal (and free) point-to-point file transfers. In contrast spend on live performance is growing at a speed which goes a substantial way towards compensating for the decline in sales of recorded music. This suggests that it is the music publishers rather than the musicians who are suffering from these changes.

[48] *Public Service Broadcaster Review, Phase 1*, Ofcom, April 2008

[49] *BBC response to Ofcom's second Public Service Broadcast Review, Phase 1,* BBC, July 2008

[50] *Advertising Statistics Yearbook 2008*, Advertising Association, 2008

Figure A13 TV funding – End user spend vs other sources – 2007 prices with revenues in £m

	2002	2007	cagr
TV net advertsing spend	3745	3544	-1.1%
BBC licence fee	2637	2615	-0.2%
Subscriptions	3431	4288	4.6%
Other (1)	774	775	0.0%
Total	12588	13229	1.0%

(1) PPV, programme sales, sponsorship and TV shopping

Source: Communications Market 2008, Ofcom

Future developments

We have identified two possible major changes in end-user spend on entertainment over the next 20 years

Development 1: the recent 7% pa growth in TV subscriptions will stop and revenues will begin to decline.

Many of the consumers who took out subscriptions to CATV or satellite TV packages did so because, at the time, this was the only way to get access to multi-channel TV. As Freeview becomes well established, and its geographic coverage moves towards 100%, a proportion of these customers might switch from subscription services to Freeview. This might slow or reverse the current growth in spend on subscriptions. The statistics for 2005 and 2006 in Ofcom's *Communications Market 2007* suggest that this may already be happening – with growth in subscription revenues down to 1% pa in real terms in this period.

In addition there are reasonable prospects (see below) for pay-per-view to generate a far greater proportion of TV revenues than it does now. Such revenues would, almost certainly, substitute for subscription revenues.

Development 2: pay-per-view services will generate a significant proportion of end-user spend on entertainment in general and TV in particular.

In theory a pay-per-view model makes excellent sense in an Internet TV world. It allows content providers to extract more of the willingness to pay by end users through direct sales, and it allows end users to buy only the content which they want.

Such developments are already taking place on a limited scale. In the US for example the Apple iTunes store rents films at $3 each and sells them for $10. It also sells videos of more than 20,000 TV shows.

But many content providers are still concerned that they might run into the same problems as the music industry has over the past few years with illegal copying. During this period the sales of recorded music, primarily on CD, have slumped because of illegal copying of MP3 music files[51]. Illegal copying of music has always been widespread. But the success of the Internet and the MP3 player has led to a new form of illegal copying - with sharing of copies using peer-to-peer file transfer over the Internet - on a much greater scale than before. The early commercial sites involved in such file sharing were close down by the courts but the practice is still widespread amongst young

[51] According to one stakeholder recorded music sales have fallen by 30 to 50% over the past 10 years

consumers. Largely as a result of such developments, revenues from recorded music sales have been falling at 6% to 8% per annum in the UK over the past few years.

The music publishing companies have tried using digital rights management (DRM) techniques on their CDs to prevent the copying. But they abandoned these efforts in January 2007 when EMI was the last music publisher to stop using DRM on CDs. Some online music stores, such as Napster, Wal-Mart and Sony used DRM in their offerings. But end-users complain about difficulties in playing this music, often because of interoperability problems with different music players. As a result some music stores, like Apple, have abandoned DRM and others, such as Amazon, simply do not use it.

In July 2008 the UK music industry tried a fresh approach. It reached agreement with the UK's five leading Internet Service Providers for them to monitor their customers' use of the Internet and threaten them with disconnection if they persisted in distributing illegal copies of music tracks. At the same time the industry hopes that the proliferation of easy-to-use online stores will help restore recorded music sales.

In contrast the film industry is pushing ahead with a variety of DRM technology based on the concept of a broadcast flag. This requires consumer recording devices to obey a streamed specification detailing whether or not the stream can be recorded[52]. For example ETSI expects to receive a specification for such a standard (DVB-CPCM) in 2008.

Several of the stakeholders interviewed believed that DRM holds out false promise. They point out that:

- All commercial DRM systems introduced so far has been broken
- The analogue hole[53] means that DRM can never prevent copying.

They believe that video distributed over the Internet will need to rely on a business model based on advertising or sponsorship rather than end user payments.

Others argue that DRM only needs to be good enough to deter mass illegal copying. So, providing it can be repaired once broken, it can fulfil its function of allowing a viable business model to develop around digital distribution on the Internet[54]. This group believes that illegal copying will not stand in the way of pay-per-view models for the entertainment sector. They argue that the music industry has so far fought to defend old business models rather putting its effort into exploiting the new models which the Internet makes possible. They also argue that there are fundamental differences between the incentives to share video and music content via the Internet. While people collect music and listen to it repeatedly, with familiarity enhancing the experience, the same is not true of video (and especially films). In this case most people just view once. So the incentives to collect content through swapping copies are weaker with video than with music.

The analysis set out above suggests that:

- There is potential for pay-per-view models to become a much more significant source of revenue for entertainment content in an Internet TV world
- If successful this model might displace subscription revenues

[52] Such a mechanism is designed to protect streamed rather than downloaded content

[53] All digital material must be converted into analogue form for viewing and/or listening. At this point it can be copied

[54] Or any other appropriate digital media

- Successful pay-per-view requires the players involved to develop business models which keeps the loss of revenue through illegal copying to reasonable levels
- This is more likely with video than music content because the incentives to copy videos are weaker
- If successful a pay-per-view model shifts market power away from aggregators and channel providers and towards content providers
- But if pay-per-view fails this would boost advertising revenue. Content providers and aggregators using the Internet for content distribution would switch to advertising and sponsorship models. It might also slow growth in use of the Internet for video distribution.

Payment systems

Several respondents mentioned the importance of reliable payment mechanisms for the success of a pay-per-view model and pointed to the difficulties which suppliers face in developing low-cost, secure, micro-payment mechanisms. Our research suggests that:

- There are substantial difficulties in developing micro-payment systems which make it commercially viable to sell items (such as a page of information) for a penny but that
- There are a number of payment systems which already provide trusted, high-volume, mechanisms for payment on items priced at 50 pence or more. For example the current PayPal system, which has an excellent reputation, charges $0.05 plus 5% per transaction. On a 50 pence (100 cents) item this represents a 10% commission.

Annex B End user behaviour and preferences

B1 Introduction

It is important to understand consumer behaviour in developing scenarios for the consumption of entertainment in future. End-user behaviour will determine how (if at all) new technologies and services will be taken up and used, and which business models will succeed. This paper looks at three aspects of consumer behaviour:

- Amount of time and money spent on entertainment activities;
- Uptake of enabling technologies and services;
- Usage patterns of entertainment services and content.

Approach to end user research

In each area there is an account of recent trends and developments and a discussion of drivers that are likely to influence future market development. The findings are based on a synthesis of existing research data and the results of consumer research commissioned for this study (see box below for an explanation of the methodology used).

Qualitative research methodology

We conducted qualitative consumer research for this paper focused on answering four questions about areas of consumer behaviour where uncertainty is greatest, and where research can usefully add value.

- Extent of on-demand and time-shifted viewing of video content
- Degree of mobility in consumers' entertainment consumption
- Quality of the viewing experience for video content
- Willingness to pay for entertainment

The research programme was designed to understand consumers' current behaviour and the core needs that will affect the evolution of their behaviour in response to new technologies and services. The research was conducted in three stages:

- Diary keeping – consumers kept diaries over the course of a week, noting their entertainment consumption and the reasons for it (usage occasion, motivations). 20 consumers took part
- Groups – consumers took part in structured sessions which probed the four questions through activities (e.g. placing cards representing different kinds of content into 'on-demand' and 'live' labeled areas) and discussion. 33 consumers took part
- Home visits (to come) – in-depth interviews with consumers in their homes. 5 households

We recruited a balanced mix of gender, age, income, living status, ethnic background and rural/urban/suburban location. However, given the small size of the sample the results of this research are indicative and do not provide a statistically robust representation of the population as a whole.

All of the research work was conducted by ?What If!

Given that today's consumers will be 20 years older in 2018, Section 7 also discusses how consumers' behaviour might change as they age: the cohort effect.

Definition of entertainment

We define what we mean by entertainment in the box below.

Within the definition	Outside the definition
Watching TV and films	Working
Attending live events	Learning
Reading for pleasure	Active recreation
Playing games (but not sport)	Sleeping eating shopping and cooking
Listening to music or talk radio	Personal and child care
Creating entertainment content (non work)	Socialisation
	Gardening and other hobbies
	Civic or religious activities

The definition of entertainment is becoming increasingly blurred as it becomes increasingly closely integrated with communications activity. Often consumers do not make a distinction between the two. This behaviour ranged from people talking on the telephone about a television programming that they are watching to the use of social media services to discuss and recommend programming. As social media sites offer content as well as communications services (e.g. MySpaceTV) consumers often view these sites as a type of entertainment as well as socialisation. The link between entertainment and communication is particularly strong in multiplayer immersive games. We discovered that some individuals were communicating with their (real world) friends within games such as World of Warcraft (PC) and Call of Duty (X-Box).

B2 Time use

The amount of free time that people have presents an ultimate limit to the time available for entertainment consumption as a primary activity. It also affects the way in which people consume entertainment; the rich use entertainment in a very different way to the poor. The distribution of entertainment consumption across the day is also significant in the context of this study e.g. peaks in consumption creating maxima in demand for spectrum.

Obtaining detailed and accurate information about time use by activity is difficult. The main challenges are:

- Lack of consistent and comparable measurement across different media e.g. television viewing data is gathered by BARB and internet usage by companies including Nielsen Netratings, but no organization provides a comprehensive view of users' time use across different media.
- Definition of time use – people often multi-task, consuming entertainment at the same time as doing other activities (e.g. driving and listening to the radio) or consuming two forms of entertainment simultaneously (e.g. television and internet).

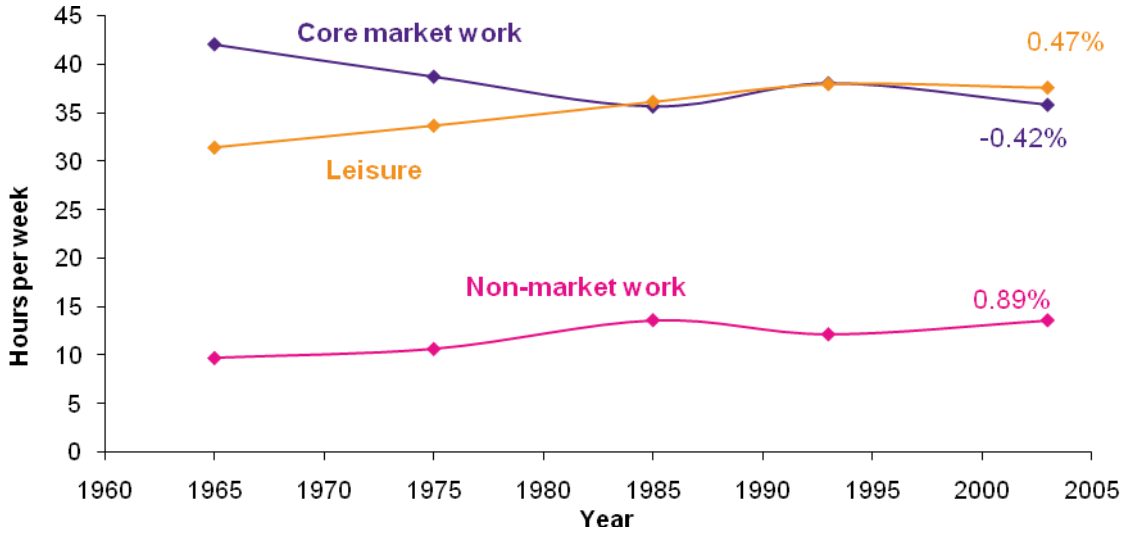
This section makes the best use of available data and where appropriate draws attention to any shortcomings or ambiguities.

Trends in leisure time

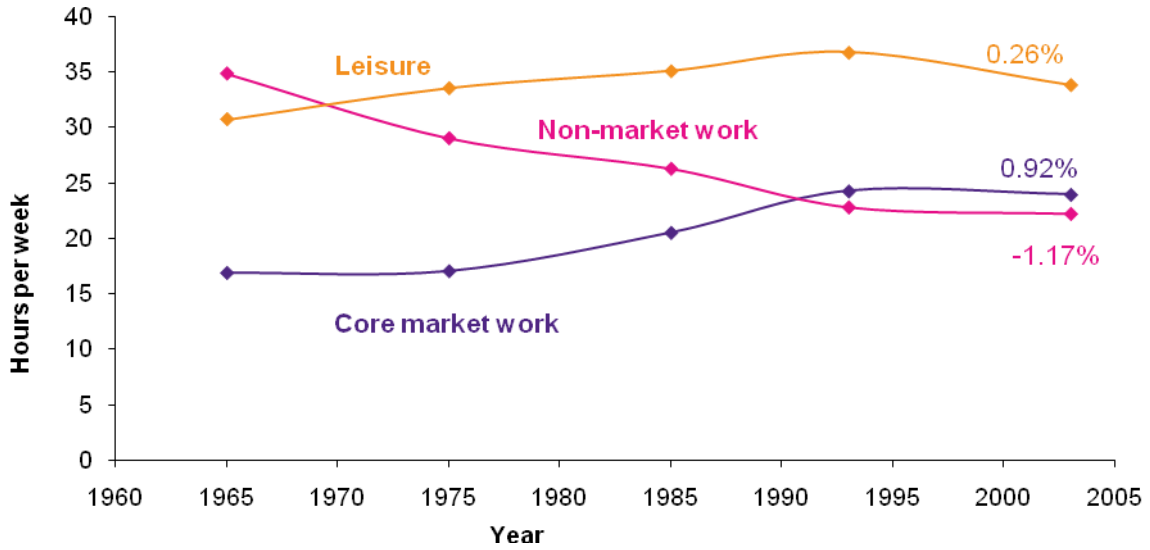
Over the long term there has been a trend towards increasing leisure time, though over recent years this trend has slowed. The key driver for the long-term trend has been a decrease in time spent on

domestic work, particularly among women. Longitudinal data from the US best illustrates this trend (as available data for the UK is more limited):

Hours per week spent on work and non-work activities in the US - men



Hours per week spent on work and non-work activities in the US - women



Source: Measuring trends in leisure: the allocation of time over five decades, National Bureau of Economic Research, March 2006. http://www.nber.org/papers/w12082

Notes: 'Leisure' includes socializing, passive leisure, active leisure, volunteering, pet care, gardening and recreational child care. 'Core market work' includes all time spent working on all jobs for pay (excludes travel). 'Non-market work' includes non-market work includes food preparation, indoor household chores, shopping, obtaining goods and services, vehicle repair, household management, outdoor chores, and outdoor maintenance.

In the UK, leisure time has been relatively flat in the decade to 2003 with only minor changes in different activities.

Estimated time use in the UK, 1994 and 2004

(Minutes per day)	1994	2004	CAGR
Men			
Paid work/study/travel	315	304	**-0.35%**
Domestic work	131	135	**0.30%**
Passive leisure	266	274	**0.30%**
Social leisure	154	149	**-0.33%**
Women			
Paid work/study/travel	201	203	0.10%
Domestic work	216	203	**-0.62%**
Passive leisure	253	260	0.27%
Social leisure	161	160	**-0.06%**

Source: Analysis of the British Household Panel Survey presented in Infusing Time Diary Evidence into Panel Data, Institute for Social and Economic Research, University of Essex, 2006.

Notes: Passive leisure = watching video, reading books and magazines etc; Social leisure = meeting friends, playing sports, going to the cinema etc;

Looking ahead, the amount of leisure time is likely to be determined by a combination of economic factors and lifestyle choices. Consumers will trade off income against leisure time.

Leisure time is considerably greater for the over 65s than for those of working age, and consequently time spent consuming entertainment by this group is correspondingly higher. Over the period to 2028 a large growth in the over 65s population is likely to result in an increase in time spent on entertainment.

Currently there are significant differences in leisure time between different social groups and age groups. Our research shows that 20-30 year-olds and 30-45 year-olds were most time poor due to long working hours and child care commitments respectively.

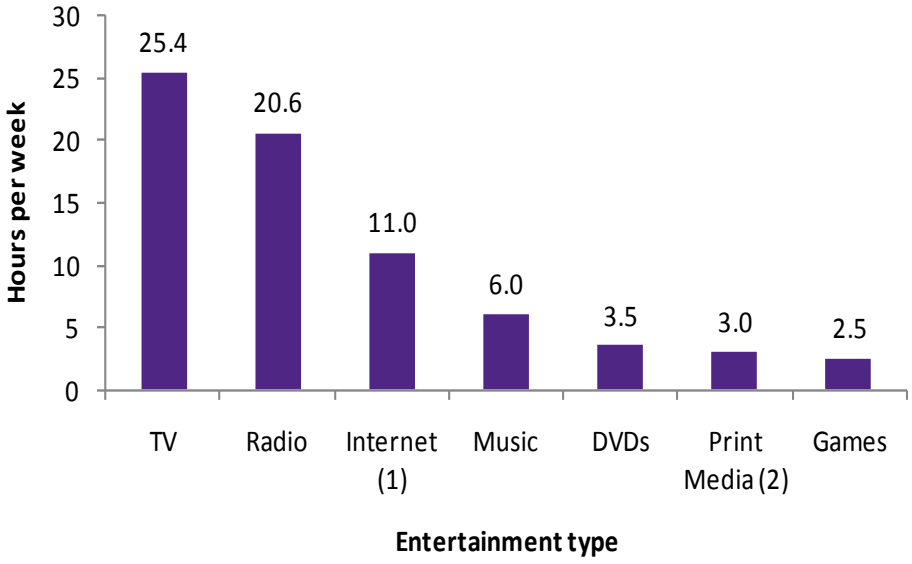
Though leisure time is a useful indicator of time available for entertainment, the increasing pervasiveness of entertainment means that entertainment can also be consumed as a secondary activity at most times (e.g. listening to internet radio in the office).

Time spent on entertainment

We believe that consumers need a regular dose of entertainment to fulfill a core need for light relief, stimulation, something to fill free time etc. Current entertainment usage behaviour reflects one way of meeting this need, which may well change. Consumers could meet the same need in less time or with a different mix of activities than currently seen.

Entertainment currently takes up a significant proportion of people's leisure time, the rest being spent on other activities including socializing and communications. Entertainment time is current distributed across a mix of different activities. The present balance is as follows:

Average weekly time spent on entertainment in the UK, 2007:



* **Notes**: (1) Internet usage time excludes school and work use (additional 7 hours per week) as this is mainly not entertainment activity. Home use is likely to include non-entertainment activities e.g. communication, shopping and banking. (2) 'Print media' includes newspapers and magazines.

Sources: Ofcom, OxIS, ONS, Onepoll

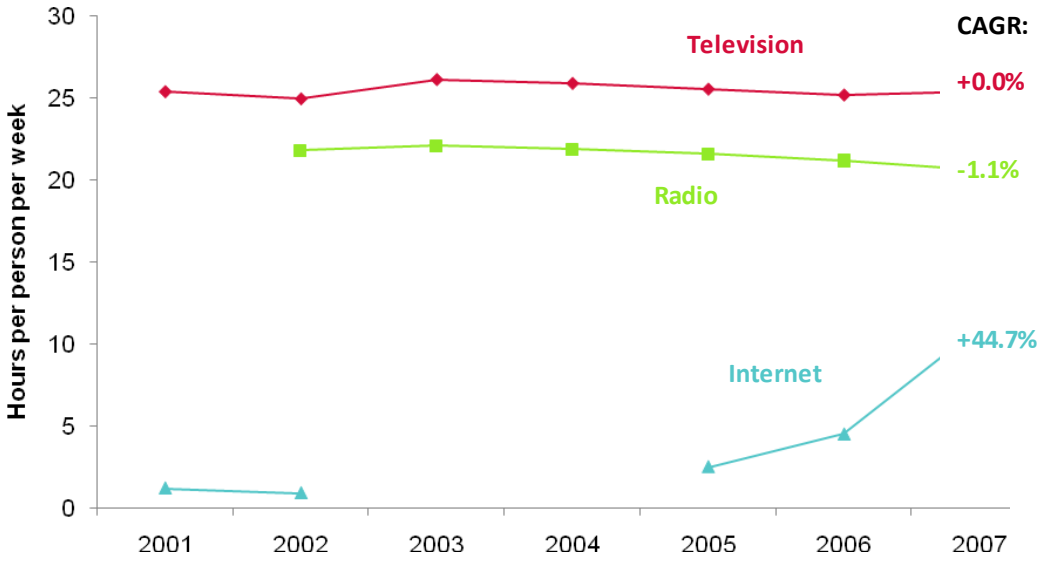
The growth of the internet is causing a redistribution of time spend

The pattern of consumption has remained relatively stable until recently, when the internet began to attract significant time use. However, the impact on traditional media is relatively small at an average level.

Television viewing time was flat over the period 2001 to 2007. However, more recently viewing hours have decreased: from 2003 to 2007 viewing decreased by 3% from 224 minutes per person per day to 218.[55] Given fluctuation in weather conditions, quality of programming and magnitude of news events, and the cyclical nature of the sports calendar it is unclear whether this represents a longer-term trend relating to internet substitution. Over the same period 2001 to 2007, radio listening hours decreased by an average 1.1% annually.

There is limited up-to-date analysis of video gaming time use in the UK. Anecdotal evidence of the growth in the overall market and the proliferation of platforms and devices available for gaming indicate that more people are playing video games, and total games time is increasing. Quantitative research[56] suggests that there is some substitution from gaming to internet and mobile use. However, consumers also play games on these platforms, so at a net level games time is likely to be holding up.

Average time spent on entertainment in the UK, 2001 – 2007



Notes: (1) The BARB measurement panel chaged in 2003 leading to a potential discontinuity. (2) Internet use in 2007 excludes school and work use. (3) Internet time use data not available for 2003 and 2004

Sources: Ofcom Communications Market Reports, BARB/Thinkbox, Rajar, OxIS

Though use of the internet does not appear to have significantly substituted for radio and television time at an average level (the growth in internet time is larger than the decrease in television and radio time), there are some marked effects among younger people. For example, radio listening hours among 4-24 year-olds decreased by 7.8% between 2006 and 2007 compared to a decrease of 0.6%

[55] Ofcom Communications Market Report 2008, link

[56] Ofcom Communications Market Report, 2008

among 45-54 year olds[57]. This is likely to relate to the popularity of iPods/MP3 players, especially in situations where the radio might previously have been used.

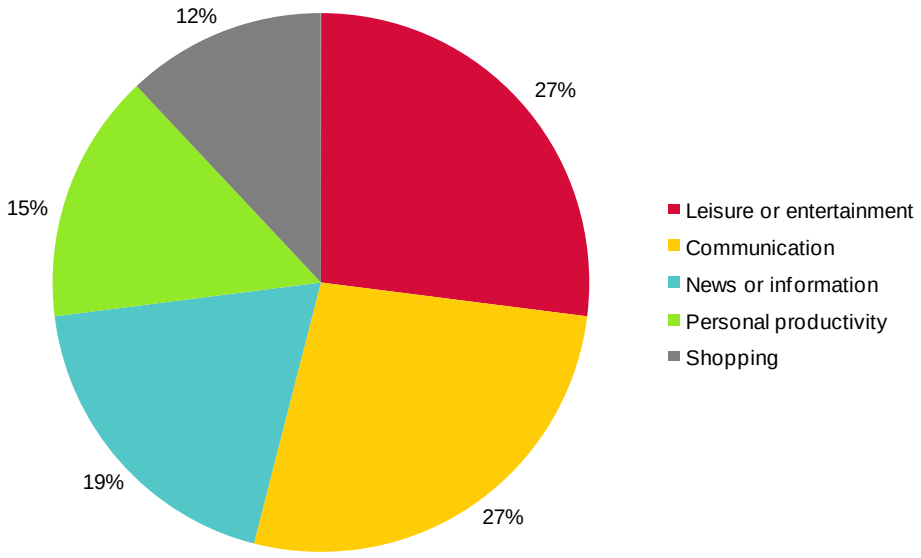
"I used to listen to radio but can't find a station that's right for me. I've gone off the radio, now I have an iPod I can create my own playlist"

Chantelle, 32, textiles assistant – uses iPod at home and outside home

There is some uncertainty over the amount of time spent on internet entertainment

One potential reason for the limited substitution effect is that only about a quarter of internet time is entertainment. Commerce, communication and other activities account for the rest and potentially substitute for their physical counterparts (e.g. high street shopping) rather than traditional media time. Figures for the US show that 27% of internet time was spent on leisure or entertainment activities in 2006. It is likely that entertainment share of internet time is growing due to the growth of internet video services (e.g. BBC iPlayer).

Allocation of time spent online in the US, 2006



Note: Base = 4190 **Source:** Netpop 2006

There is some uncertainty in this data due to definitional issues (e.g. whether social networking is classed as communication or entertainment) and the accuracy of self reported time spent in surveys. However, this data is supported by analysis of leading web sites by time spend which indicates that entertainment-focused sites take a moderate share of internet time, though much less than social networks, portals and general web properties. However the latter include an entertainment component (e.g. video content on MySpace, listed as Fox Interactive Media on the chart below).

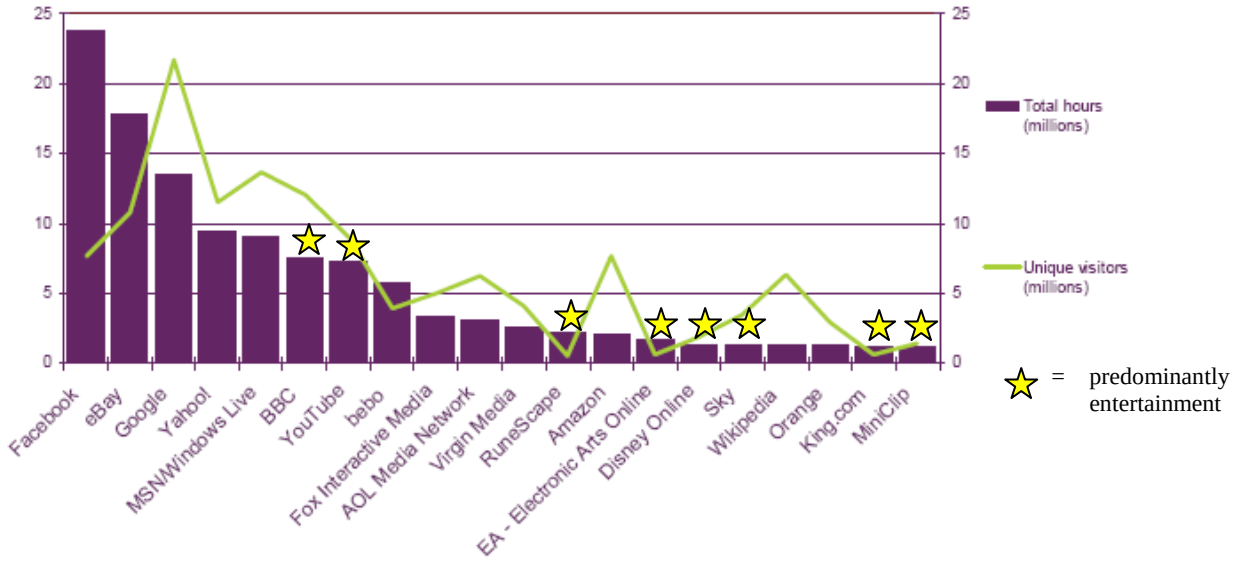
[57] Ofcom Communications Market Report 2008, link

Consumers have clear routines which create spikes in consumption

Our research found that some elements of consumers' routines is embedded in their lifestyles and creates inertia to change. However, other parts of current routines are more flexible. Any inertia is significant as it will affect the rate of any change that requires a major shift in behaviour (rather than less disruptive substitution changes).

This is reflected in current television and radio consumption by day part: radio consumption peaks in the morning and tails off later in the day, while television consumption peaks between 7pm and 10pm.

Audiences, and time spent, on websites with the highest unique audiences, April 2006



Note: Fox Interactive Media includes MySpace

Source: Nielsen Online, April 2006

Increasing incidence of media stacking behaviour

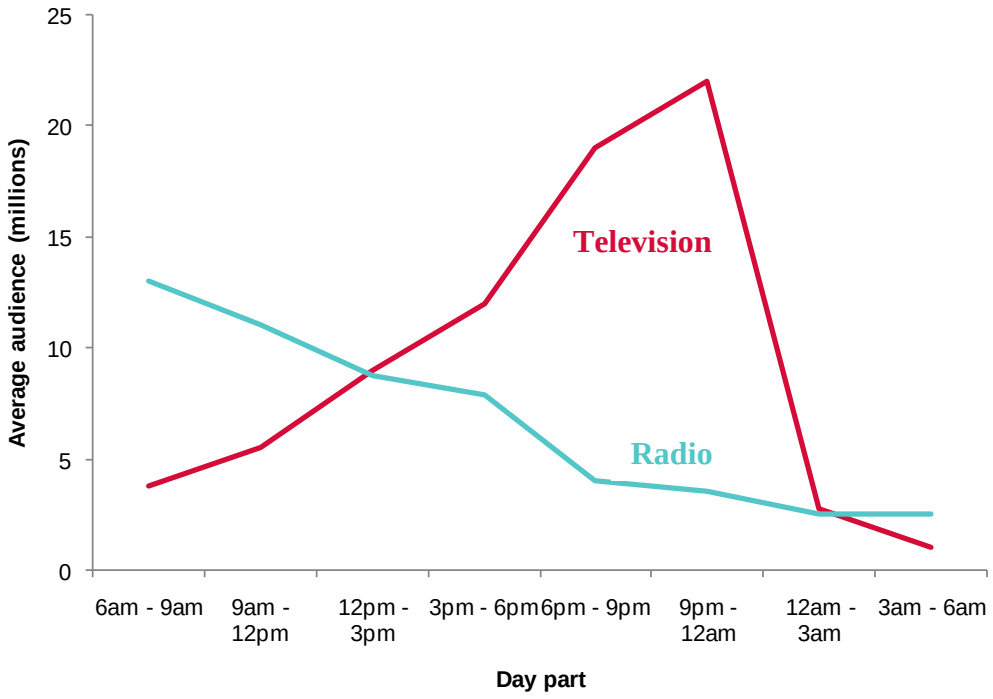
A new generation of consumers is emerging who are less attentive and engaged with media due to the use of multiple media simultaneously. Currently, there is a significant incidence of consumers using multiple media at the same time, in particular using the internet while watching television. This behaviour is most common among the young, peaking among 16-19 year-olds and 25-34 year olds. Older people tend to give media more attention: our diary research found examples of older consumers planning their viewing in advance and giving television full attention while watching.

This result suggests that younger consumers may be more able to engage in multiple entertainment activities simultaneously, and that they will consequently demand 'everything at once'.

"I just use TV as background noise most of the time when I'm on the internet – a lot of the time I'll find myself muting the TV so I can watch a YouTube video"

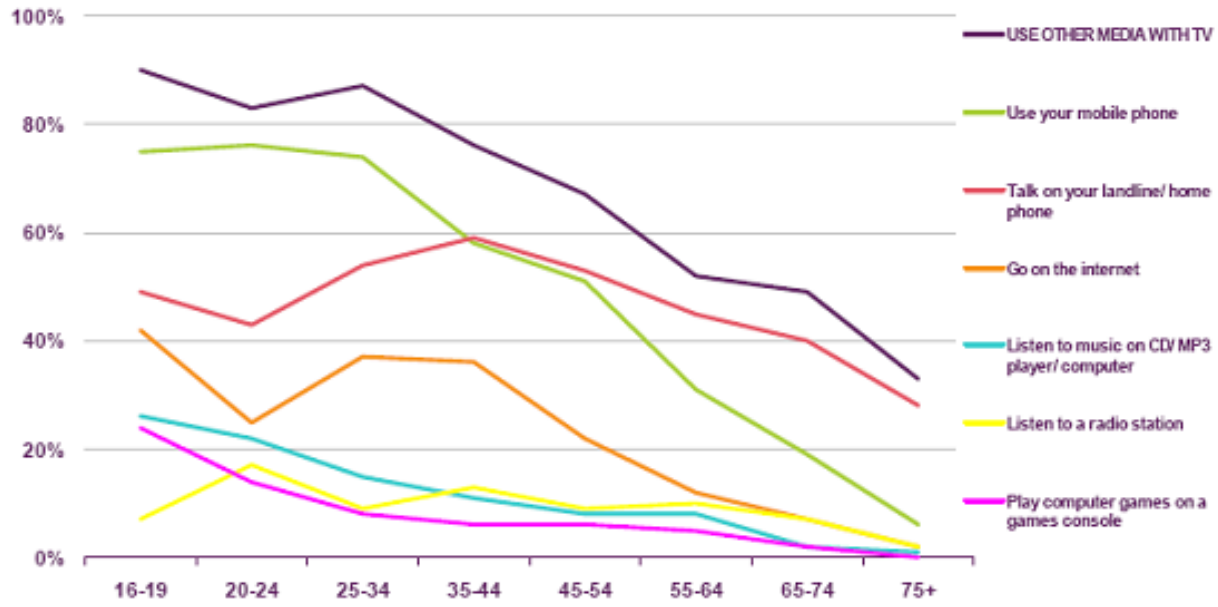
Jordan, 22, hotel reservations manager

Consumption of television and radio by day part, 2007



Sources: Ofcom Communications Market Report 2008, ?What If! analysis

Frequency of using other media while watching TV, by age



Notes: Base = Adults aged 16+ with any TVs (2887 aged 16+, 203 aged 16-19, 205 aged 20-24, 471 aged 25-34, 657 aged 35-44, 488 aged 45-54, 336 aged 55-64, 355 aged 65-74, 167 aged 75+) **Source:** Ofcom research

B3 Consumer spending and willingness to pay

Our research shows that though most consumers express a reluctance to pay for entertainment, when pressed they admit a willingness to pay if there is a clear benefit such as exclusivity, quality, experience, convenience, lack of advertising or ownership. An equilibrium is reached between consumption of paid and free (advertising-funded) content that depends on supply and on consumers' needs and means. However, the increased supply of free 'premium' content on the internet is disrupting this equilibrium; the results of this change remain to be seen (at least for video content).

This section looks at trends in consumers' ability to pay (e.g. disposable income) and discusses consumers' willingness to pay for entertainment in the light of the internet.

Consumers' ability to pay is increasing with disposable incomes

Between 1994/95 and 1998/99, household spending on recreational activities grew significantly, at 4.7% pa in real terms. This growth slowed between 2001/02 and 2006, to an average of 0.2% pa in real terms. For both periods, household spending on entertainment grew at a lower rate, by 4.5% pa between 1994/95 to 1998/99, and by -1.0% pa between 2001/02 to 2006, in real terms.

Household expenditure on recreational activities in the 1990s

Spend per week (£) at 1998/99 prices	*94/95*	*98/99*	*% change*	*Cagr*
Entertainment - electronic equipment	5.88	7.70	31%	7.0%
Entertainment - digital services	2.96	3.60	22%	5.1%
Entertainment - other	10.30	11.50	12%	2.8%
Entertainment - total	19.14	22.80	19%	4.5%
Other recreational activities	38.82	46.90	21%	4.8%
Total	57.96	69.70	20%	4.7%

Source: ONS family expenditure survey

Household expenditure on recreational activities in the early 2000s

Spend per week (£) at 2006 prices	*2001/02*	*2006*	*% change*	*Cagr*
Entertainment - electronic equipment	9.28	7.60	-18%	-4.9%
Entertainment - digital services	5.25	5.80	10%	2.5%
Entertainment - other	17.99	17.90	-1%	-0.1%
Entertainment - total	32.52	31.30	-4%	-1.0%
Other recreational activities	26.15	27.90	7%	1.6%
Total	58.68	59.20	1%	0.2%

The main difference between the two periods is the change in spending on electronic equipment. During the period of 1994/95 to 1998/99 household spending on electronic equipment increased at an average rate of 7.0% pa in real terms. Between 2001/02 it declined in real terms by 4.9% pa. If we exclude spending on electronic equipment, growth in spending on entertainment averaged 2.4% pa between 1994/95 to 1998/99, and 1.3% during the latter period. Spending on digital services expanded at a rate of 2.5% pa during the latter period - this growth was driven by spending on items such as DVDs, but was still lower than the 5.1% pa growth in spending on digital services between 1994/5 and 1998/99.

Trends in spending vary considerably by medium

Consumers allocate the highest proportion of spend to television, newspapers and DVDs. Strong growth has been seen over the 5 years to 2006 in games (7% CAGR in real terms) and live music. Recorded music has seen a steep decline (8%) due to the popularity of illegal copying and file sharing. Television has seen strong growth, while cinema revenues have been in slow decline.

Revenues from the UK entertainment sector in 2007[58]

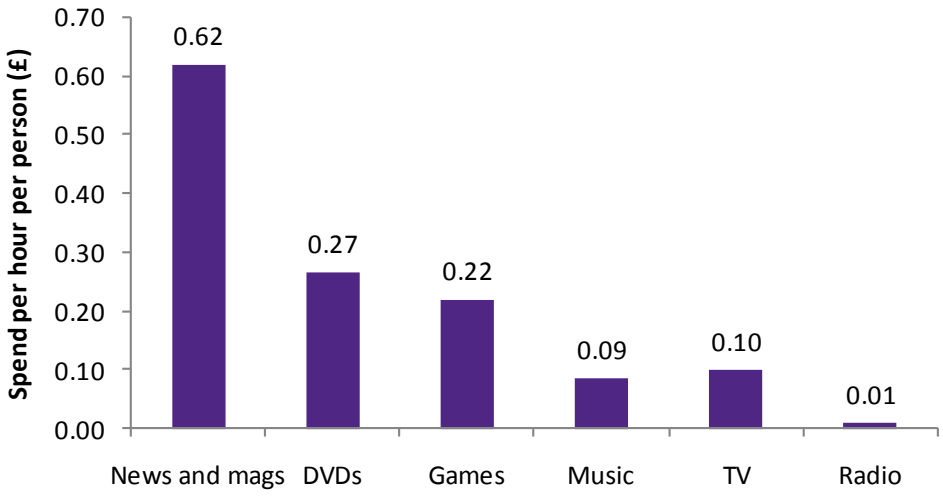
		End user revs (£m 2007)					
Activity	*Category*	*End user*	*Adverts (5)*	*PSB fund*	*total*	*cagr (1)*	*Source*
Play	Games - all (2)	1754	0	0	1754	7.0%	Screen Digest
Read	Books (4)	2578	0	0	2578	0.0%	The Publishers Association
	Consumer mags	2182	791	0	2972	-1.8%	Advertising Yearbook
	Newspapers	3208	4675	0	7884	-2.8%	Advertising Yearbook
Watch	TV (3)	5063	3544	2615	11222	1.2%	Ofcom
	Cinema	821	207	0	1028	-1.6%	Advertising Yearbook, UK Film Council
	DVDs and VHS	2650	0	0	2650	-1.2%	UK Film Council, BVA
Listen	Radio	0	522	657	1179	-1.8%	Ofcom
	Recorded music	1488	0	0	1488	-8.1%	IFPI
	Live	699	0	0	699	15.0%	WhatIf? estimate
Total	All	20443	9739	3272	33454	-0.7%	Calculated

(1) At constant prices over last five years
(2) Hand held + on line + wireless
(3) End user revs includes PPV, shopping channels, prog sales and sponsorship
(4) All sales to consumers
(5) Set to zero if negligible

When consumer spending is compared to time spend, it is striking that consumers are paying considerably more per hour of consumption for newspapers and magazines than television or radio.

[58] These revenues measure consumption but not production of entertainment. They exclude revenues from sale of electronic equipment, gambling and premium rate service telephony.

Consumer spending per hour of media consumption[59]



Source: ?What If! calculations

Consumers have developed perceptions of value based on current models

Consumers have developed perceptions of the value of entertainment based on current / recent charging models (e.g. paying for DVDs, CDs and live music, and exclusive services marketed as premium) and subjective judgments on the value of quality content.

We found that consumers attach value to exclusivity e.g. sport and film content.

"I would pay for sports events but not the ones I currently get for free."

Gordon, 58, musician

"I would pay for privilege and exclusivity – Dark Knight but not Borat."

James, 26, English teacher

They also value the quality of the viewing experience e.g. high-definition or free of advertising.

"I hate ads; I might pay to miss them."

Nisha, 30, lawyer

"I pay for the resolution of HD as I had invested money in the HD screen. I wouldn't pay a premium for ad-free TV as I can use Sky+ to fast forward through them"

Gavin, 42, bank manager

The perception of quality and the value attached to it is very much a personal judgment. Some consumers saw uncommon value in educational content (e.g. 'blue chip' television documentaries).

[59] Including spend on TV licence fees as well as direct spend

Others valued big formatted programmes such as the X-Factor to the extent that they would pay for them if the programmes were charged for. Overall, very little value was ascribed to 'everyday' programming.

"I would pay for the Blue Planet as it's a one off … educational, fascinating"

Carol, 59, retired

The internet is disrupting the balance of paid and free content

Large amounts of 'premium' content (e.g. films, television series and music) are available for free on the internet, legitimately or otherwise. Our research found that consumers, particularly the young, are actively seeking it out.

"There are always ways to get things for free on the internet"

Sharene, 22, office manager

We also found that consumers are willing to sacrifice quality in order to watch this free content for some genres / types of content.

"The quality [of surfthechannel.com] is OK for TV but not for film, some films have people walking across the screen"

James, 26, English teacher

Given this erosion of exclusivity, we found that it is increasingly the experience that counts in encouraging consumers to pay rather than the content.

"I can get so much for free online that I'm only willing to pay for something extra like the cinema or a box set"

James, 26, English teacher

For some consumers playing by the rules / legality is important. However, we found that some of the younger consumers did not perceive use of illegitimate services as wrong since they are not 'keeping' anything.

"I do not feel guilty about it [watching programmes on surfthechannel.com] as it is streamed"

James, 26, English teacher

The potential end-point of this behaviour is a significant reduction in the ability of service providers to monetize (non-live) video content that currently relies on exclusivity to secure payment.

Consumers expect ownership of any digital content that they do pay for

Consumers commonly expect some level of ownership of digital content that they pay for, either on a temporary or permanent basis. This process of ownership is in some senses what people are 'paying' for rather than the content itself.

"I would want to keep it if I had paid: on a DVD or hard disk"

Eleanor, 18, student

Consumers prefer convenient and flexible payment models

Talking about pay-television we found that some consumers expressed a preference for more flexible payment models as opposed to large bundles.

"Sky has the most choice but it's expensive … if they rearranged the package I'd sign up to it"

Mark, 21, Student

"I pay for films when I want them on Virgin – you select the film you want and they add the payment to your monthly bill, it's really easy"

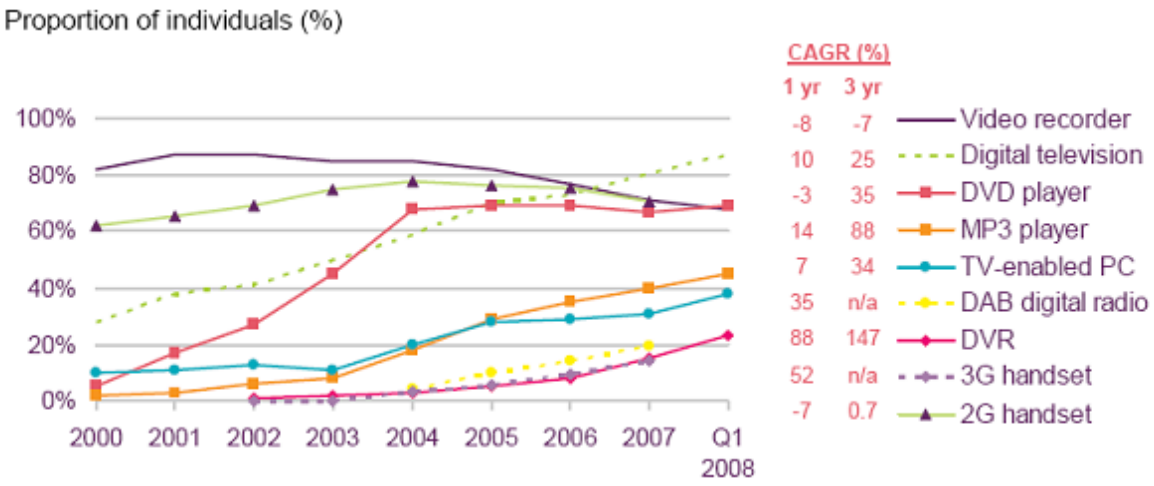
Rozeena, 31, HR

The success of the iTunes store, compared to cheaper or free alternatives, suggests that consumers also value convenience and ease of use (the key differentiators of the service).

B4 Technology and service uptake

The uptake of all digital entertainment devices and services is increasing, with digital television, broadband and mobile telephones all now reaching a majority of the population.

Penetration of audio-visual devices, 2000 – 2008



Note: CAGRs are calculated against the full 2007 year base (i.e. not using Q1 2008)

Source: Ofcom Communications Market Report 2008

New technologies are being taken up quickly

New technologies are being adopted at an increasingly fast pace. It took Apple 18 months to sell its first million iPods[60] but only 5 years 5 months to sell 100 million[61]; 74 days to sell its first million iPhones and 3 days to sell its first million 3G iPhones[62].

On the demand side, the drivers for faster adoption include:

- Demand for fashion accessories and status symbols (e.g. the large television set or iPhone)
- Increasing demand for digital devices due to the increasing range of services that they support (e.g. retail, financial services, health as well as entertainment)

On the supply side subsidized prices (e.g. mobile handsets and digital pay-television set-top boxes provided by service providers) and short upgrade cycles on mobile handsets due to short mobile contracts are key drivers. It is uncertain how the demand side drivers will change in future. It is quite possible that consumers will respond to environmental concerns by upgrading technology less frequently and buying less 'disposable' technology.

Some technologies are reaching the market by 'stealth'

There is also an increasing phenomenon of passive uptake of technology. Whereas in the past consumers bought specific devices for a specific purpose (e.g. the Walkman to listen to music on the move), now they often find that they have acquired functionality that has been thrown in as an add-on. For example MP3 players reached 45%[63] by 2007 as these are provided as an add-on to many mobile

[60] Ezilon, January 2006, link

[61] Apple, April 2007, link

[62] TechCrunch, July 2008, link

[63] Ofcom Communications Market Report 2008, link

handsets. 32.1 million MP3 players were sold in 2007, of which 75% were MP3-enabled mobile phones. 90% of phones sold in the past year could play MP3 files[64].

Similarly, digital radio is an add-on to digital television services. In neither case is this functionality the primary reason for consumers' buying the device. The implication is that the uptake of technologies will exceed demand in many cases.

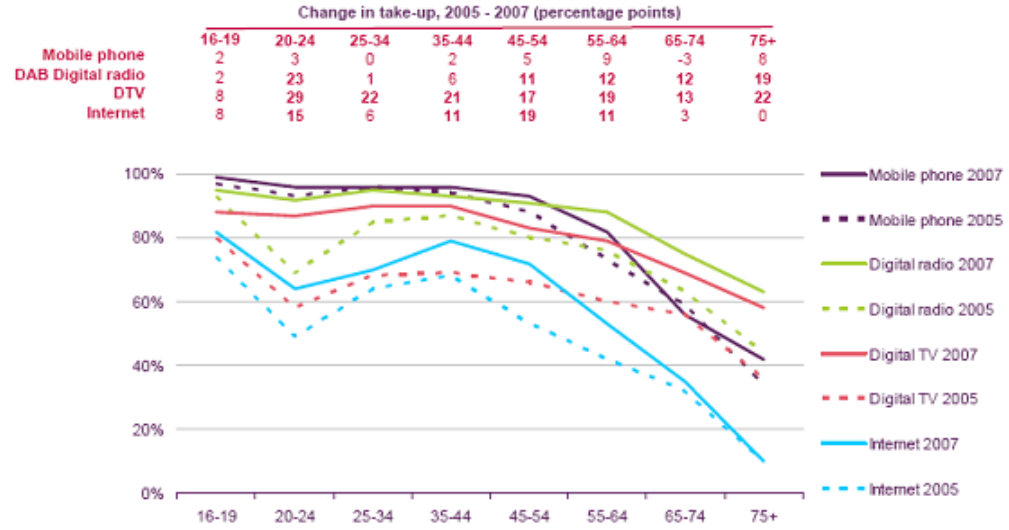
There is also an increasing overlap of ownership of digital devices and services. Individuals have access to an increasing range of digital entertainment technologies and services at home and on the move.

Digital exclusion

The increase in penetration of entertainment technology and services is not, however, true of the whole population. There is currently a significant portion of the population who are 'digitally excluded', without access to digital television, mobile phones or the internet.

Digital exclusion, or involuntary non-ownership of digital technologies, can affect the disabled, those with low incomes and those living rurally / remotely with poor availability or access to digital services. However it primarily affects older people, amongst whom uptake of digital technologies is currently low.

Penetration of digital technologies by age, 2005-2007



Notes: Base = All adults aged 16+ (206 aged 16-19, 207 aged 20-24, 473 aged 25-34, 661 aged 35-44, 489 aged 45-54, 341 aged 55-64, 356 aged 65-74, 167 aged 75+)

Source: Ofcom Communications Market Report 2008

The low uptake is due to low perceived need among other issues: 58% of the over 75s who do not use the internet felt that they had no need or interest for the internet, 33% felt that they lacked the confidence or knowledge to use the internet and 7% felt that the cost was too high[65]. However take-up and usage of the internet by older people is increasing and the trend in "no need" as a reason for not

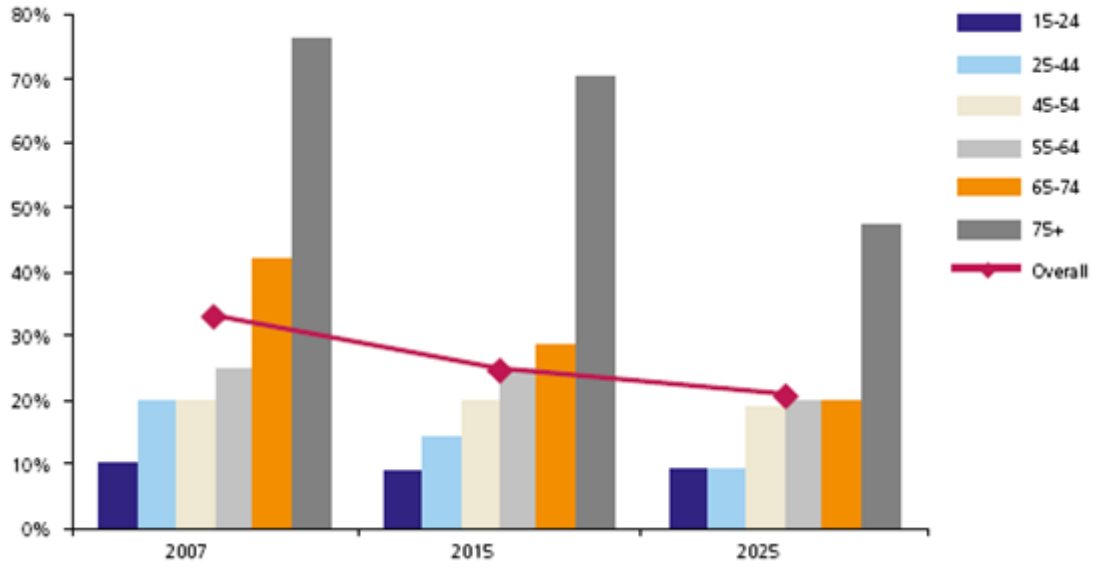
[64] Guardian, November 2008, link

[65] ONS, Focus on the Digital Age, 2007, link

using the internet is falling, from around 50% in April 2003 to around 40% in January 2006[66], suggesting that digital exclusion will continue to fall.

Poor skills, however, could lead to fear and a rejection of the internet. “A significant proportion of the population still lack general IT skills in terms of using a PC as well as using the internet. A lack of skills leads to a lack of confidence, which in turn leads to a lack of trust of technologies. Credit card protection is the main concern for internet security and there is a correlation between lack of confidence and reluctance to use personal information over the internet”[67].

Projections for the number of non-users of the internet in 2015 and 2025



Source: Department for Communities and Local Government

These forecasts are consistent with the migration of the present uptake curve forwards by just under 20 years.

Exclusion from digital television will be remedied more readily. The switch-off of the analogue TV signal in 2012, and accompanying assistance scheme will drive take-up among older people.

However it is likely that disability, age and low income will mean that there will continue to be a significant minority of the population who do not have no access to the internet or more limited access than the rest of the population.

B5 Consumer behaviour

We found that entertainment is an important part of people’s lives. Some consumers are truly passionate about it, whether their interest lies in music, books or television. Others see entertainment as a valuable way of filling time. The importance that consumers attach to different types of entertainment does not necessarily reflect the way they spend their time: consumers spend a large

[66] Department for Communities and Local Government, Understanding Digital Exclusion, October 2008. Note that figures are approximate because source data is not provided.

[67] DTI, Improving ICT skills and trust among disadvantaged groups is an important element of digital inclusion, 2007

amount of time watching television though some reflected that it was less important to them than music or books.

This section looks at four areas of consumer behaviour:

- Mobility of entertainment consumption
- Use of on-demand and time shifted video services
- Quality of the viewing experience
- User-generated content

The first three sets of findings are based on the qualitative research conducted for this study, the fourth on desk research only.

Mobility of entertainment consumption

We found that there is demand for entertainment on the move, and that music and reading are what consumers most want. There is less demand for mobile video due to inherent environmental and practical factors that will persist.

'Mobility' includes a range of different occasions

There are a number of situations in which a consumer is mobile: from moving around the home or office to commuting to work or travelling long distance. The main distinction is between indoor mobility that could be supported by WiFi within the home and outdoor mobility that requires cellular (or other) mobile connectivity. Each situation is also different from the perspective of people's environment, activity and attention.

Different types of mobility

The amount of travel is relatively constant

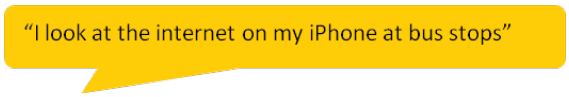
Regardless of changes in lifestyle (e.g. home working – between spring 1997 and spring 2005 the number of home workers increased from 2.3 million to 3.1 million[68)], people are maintaining a similar levels of travel: on average, individuals have spent around 60 minutes per day travelling since records began[69].

“People appear to have a need to travel, not only to work and shop but also to socialise - travel is important to maintaining our social networks with family, friends and workmates, and most people would feel frustrated if they travelled less. Nevertheless, personal travel patterns have changed substantially over the past 50 years as people have become better off and switched to the use of cars in preference to bus, coach and rail travel”[70].

Modes of transport differ between urban and rural settings. Currently in the UK 71% of people travel to work by road, 8% by bus, 7% by train and 11% on foot, but in London this situation is reversed: 69% travel to work by train and 9% by road[71].

Entertainment competes with other activities for mobile time

People increasingly have a choice when they are mobile: to consume entertainment or engage in another activity (e.g. communicate, socialize or simply do nothing / engage with the surroundings). Our research found that mobile occasions that were previously ‘owned’ by entertainment (e.g. on a bus - reading the newspaper or listening to music) are now shared with other activities (e.g. reading emails). People with advanced mobile devices such as the iPhone often choose communications use over entertainment.



Lisa, 25, buyer

Current mobile entertainment usage is mainly music and reading

Our research showed that consumers most like to listen to music or read when they are mobile. This is backed up by quantitative research: 44% of people always carry a book if they are likely to be travelling on public transport, and 35% find journeys give them a chance to read or learn about things they don't otherwise get a chance to[72]. 31% of respondents felt that listening to their music MP3s is the best way to get though the journey to work[73].

[68] ONS, Home-based working using communication technologies, October 2005, link

[69] Department for Trade and Industry. “Intelligent infrastructure futures: Project overview”. January 2006

[70] Transport Scenarios Development Study, Ofcom 2008

[71] Transport Scenarios Development Study, Ofcom 2008

[72] CBS Outdoor / Future foundation – Britain on the move, link

[73] Silicon.com, February 2008, link

Music is the most widely used – the iPod etc:

"Music is everything to me, music works for me in the background… now I have an iPod I can create my own playlist, going to the gym without an iPod is horrible – I'd have to turn back. I link my iPod to the car stereo"

Chantelle, 32, textiles assistant

"I need music to reinvigorate; I miss my iPod when I don't have it on public transport as can hear voices otherwise"

Derek, 45, sports development manager

"My iPhone is like having a walking laptop. I read so much less now that I have music on the move"

Laxmi, 30, estate agent

"I always have the iPod on as I really hate just not doing anything"

Andrew, 21, student

Books, magazines and newspapers are still widely used on sit-down occasions:

"I love books! If I pick up a book I have to finish it that day, reading helps me wind down. I like the Sunday papers for the random stuff – it opens my mind, lasts me the whole week"

Kenza, 34, PA

"I take a book if I know I'm going to be travelling"

Kershika, 21, HR

"The tube is my time to read a book"

"

Pamela, 42, housewife

Radio owns the car:

"I listen a lot to radio in the car as I drive an awful lot – I don't listen to radio so much at home"

Carol, 59, retired

"I listen to Radio 5 all the time in the car"

Gordon, 58, musician

Use of and enthusiasm for mobile video and games was more limited:

"I can't be faffing around with my mobile on a train"

Rozeena, 31, HR

"You have to ask yourself is TV that great that you'd want to carry it around with you?"

Carol, 59, retired

"I have the capability to watch things on my phone but I do not use it, I would only use it to watch goal highlights – short and sharp"

Derek, 45, sports development manager

"I have never watched stuff while travelling; I want to be at home on a big sofa"

Ben, 18, student

These findings are also true of in-home mobility. Consumers like to be able to take their music with them, but are happy to keep television fixed.

"I plug the iPod in to a stereo/dock in the kitchen, and I have a portable iPod stereo/dock for other rooms. The ideal would be to have one thing to take everywhere"

Chantelle, 32, textiles assistant

Much of this behaviour is driven by a need to create personal space or to fill time

We found that a lot of people like to consume entertainment on the move as it helps them create a personal space / cocoon:

"I take my iPod absolutely everywhere with me, if I leave the house without it I go back for it. I lost it one time and still wore the earphones on the tube"

Derek, 45, sports development manager

The type of entertainment consumed on particular occasions in order to create personal space is determined by factors including:

- environment: ambient light and noise
- social context: who people are with, privacy, fear of crime
- physical / practical factors: walking, driving, sitting down
- available time: long period vs. snacking moment

For example, there is some resistance to the use of mobile entertainment due to fear of crime:

"I don't like to use an iPod at night or on a bus [due to fear of crime]"

Carmella, 21, graduate

"I don't think I'd watch anything on the iPhone as you have to hold it, fear of crime."

Anish, 19, student

Currently penetration of mobile video services is very low

Penetration of mobile video services in the UK is currently low: in 2007 only 1.3% of all UK mobile subscribers used their phones to watch commercial video / TV[74]. This is consistent with the failure of Virgin Mobile's mobile video service in early 2007, less than a year after launch. Virgin cited poor take-up of the service, despite spending £2.5m on an advertising campaign[75].

Our research indicated low demand for mobile video except for the time poor

Many people are not excited about having video on the move (except for live sport) for reasons of need and environment not technology:

"I wouldn't have the stamina and attention span on the small screen"

Gavin, 42, bank manager

"You have to ask yourself is TV that great that you'd want to carry it around with you. Soaps are just to fill time at home. The quality of TV is so awful: reality programmes, repeats of rubbish, there aren't new things coming out"

Carol, 59, retired

"If there's something that you really want to watch would it matter if you missed it? Watching on the phone, how sad is that? It doesn't matter to my life that I miss something. TV is just escapism"

Carol, 50, runs property company

Even consumers who owned iPhones showed limited enthusiasm for mobile video:

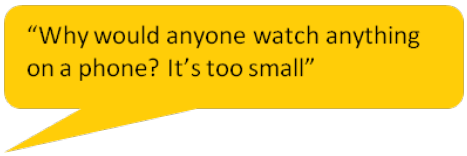
"Everything is on there, I use it for email and music, I don't watch anything on it"

Pamela, 42, housewife

Mobile is a less than ideal medium to watch video, in particular, small screen size is often cited as a major barrier.

[74] M:Metrics

[75] http://www.guardian.co.uk/media/2007/jul/26/citynews.broadcasting



Sharene, 22, office manager

The most interest in mobile video services came from the time poor (e.g. 20-30 year olds with busy lifestyles).

Mobile video trials to some extent contradict our findings

Our results differed from the higher levels of interest in mobile video measured by some trials.

- Mobile operator O2 and transmission group Arqiva conducted a mobile television trial in Oxford in 2006: 83% of triallists said they were happy with the 16-channel service, and 76% wanted to take it up if offered over the next year [76]
- The trial suggested that users were viewing around 3 hours a week of mobile TV on average [77]
- Another Arqiva mobile TV trial in Cambridge concluded that over 85% of triallists were pleased with the service, 72% would take up the service within 12 months and that 40% of them watched more TV in total – an average of 44 minutes of extra TV viewing per week.[78]

Some reasons for the difference in findings might include:

- The prominence of the mobile video functionality / service in trials, which may have encouraged people to use it.
- The lack of well-developed alternative applications – mobile video was the exciting thing to do on the handset for triallists.
- Novelty effect – it is well know that there is a 'new toy' effect which means that service usage is highest in the first days of using a device before tailing off.

Future outlook

In future, new mobile video devices and services will no doubt launch and improve (e.g. better quality video, bigger displays, wearable displays) making them more attractive consumer propositions, and usage may well increase. However, other mobile applications (e.g. productivity and communications) will also improve, countering this effect. For example, on a 'super iPhone' of the future consumers might choose to use their travel time for email and Facebook applications rather than entertainment.

Regardless of technology change, some of the key features of mobile usage occasions will remain. Technology is unlikely to solve the problem that consumers find it difficult to walk and watch video simultaneously or that they fear crime.

[76] http://www.dtg.org.uk/news/news.php?id=1414)

[77] http://www.ebu.ch/en/technical/trev/trev_306-mason.pdf

Use of on-demand and time shifted services

Linear broadcast television provides viewers with limited options: they can watch only (one of) the programmes shown on broadcast channels at the particular time that they are watching. In the on-demand environment, whether PVR, IPTV or internet-based, viewers are given significantly more **choice** of content and **flexibility** of viewing time. We sought to understand the drivers that affect the extent of choice and flexibility exercised, now and in future. We also looked for new types of behaviour that are emerging as a result of the on-demand and time-shifted viewing.

Our findings on PVR usage support and add detail to the findings of other research in this area. This work has, however, uncovered new insights into consumers' need for the television schedule and it has identified new forms of internet video consumption behaviour.

Consumers can use a range of technologies and services to free their viewing

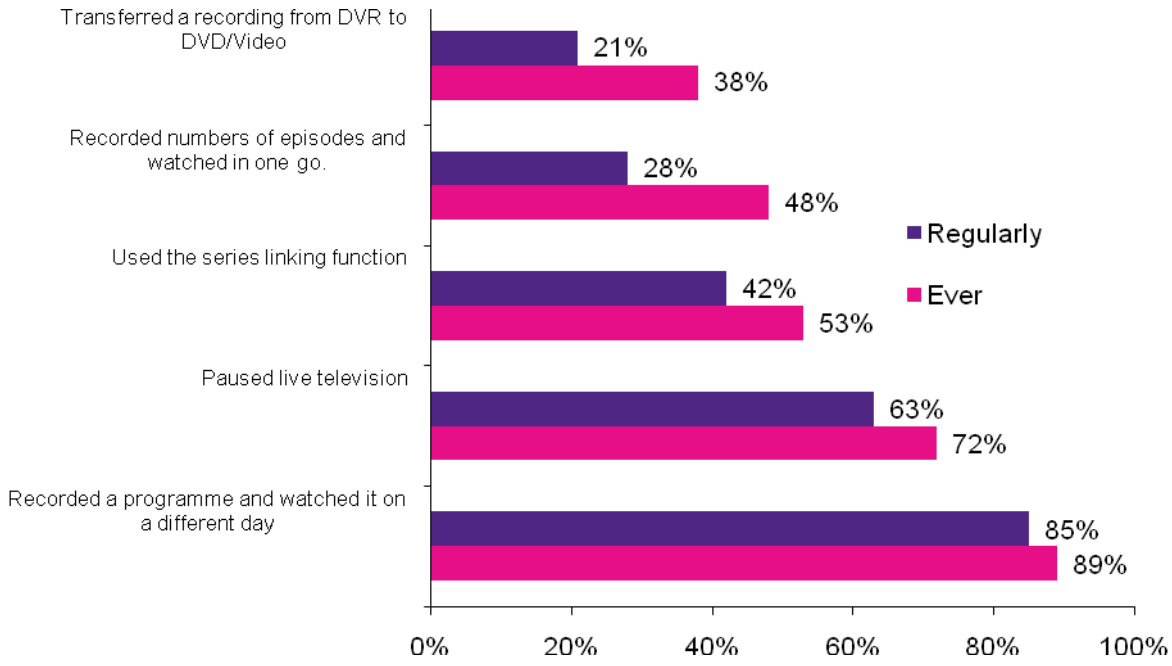
Currently, viewers are able to exercise choice and flexibility through the following technologies and services:

- PVR (e.g. Sky+) – enables users to record programming and watch at a time of their choosing. Features such as 'series link' help users to plan their recording. Playback features on some devices include fast-forward and skip 30-seconds which enable ad-skipping.
- IPTV (e.g. Homechoice) – enable users to watch on-demand any programme offered by the service provider.
- Internet (e.g. BBC iPlayer, YouTube) – a range of services exists to enable viewers to stream or download programmes (mainly catch-up at present e.g. 7-day window on BBC iPlayer).

Usage of these services has reached high levels among those equipped

Despite being relatively new, all of these services have reached relatively high levels of usage among enabled users. Of the 23% of the population with a PVR at home in Q1 2008:

Frequency of using DVR functions:



Source: Ofcom research, Feb/Mar 2008.

Ethnographic research conducted in 2006[79] found that 30% of commercial impacts (advertisements seen) on PVR enabled television sets were viewed time shifted, indicating that a similar proportion of viewing is time shifted.

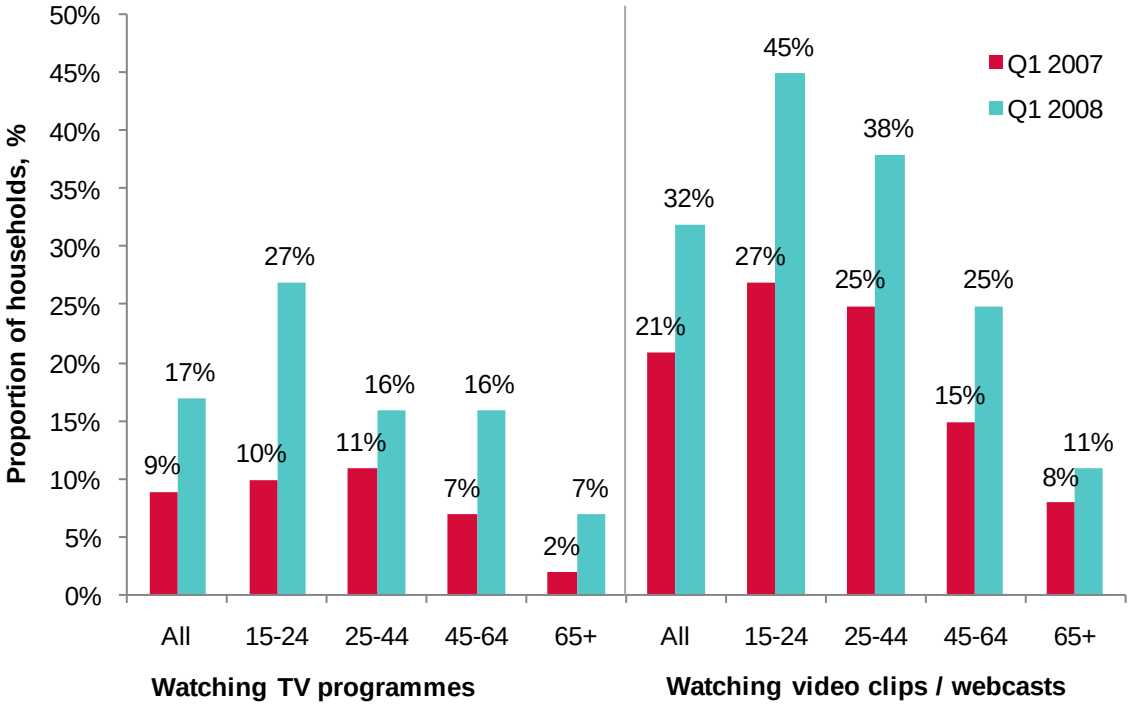
The penetration of usage of internet video services is also relatively high.

- 64% of broadband users watched online video in the past week, for an average of 3 hours (self reported)
- 45% had done so in the past few days[80]

[79] PVRs and Advertising Exposure: A Video Ethnographic Study. Actual Customer Behaviour and London Business School, September 2006.

[80] Thinkbox Touchpoints 2 survey, 2008

Proportion of online households viewing video content on the internet, 2007 and 2008



Source: Ofcom research, Jan-Mar 2008.

Base: All adults who have the internet at home.

The BBC's iPlayer was used by an average of 1.4m people per week in April 2008, and the total number of requests for downloads and streams of BBC programmes in April was 21m, rising from 17.2m in March and 11.2m in January. There are slightly more users in the 35-54-year-old category (43%) than the 16-34 category (37%), with over-55s making up the remainder[81].

Evolutionary and revolutionary viewing behaviour is emerging

The usage behaviours that our research uncovered for PVRs, on-demand services and television-like internet services (e.g. BBC iPlayer) are essentially new and better ways of watching the same television content – this is evolutionary behaviour. However, the usage behaviour associated with other internet services (e.g. file sharing) are new, and can be thought of as revolutionary.

Evolutionary behaviour on PVRs, on-demand services and internet catch-up

We found that the main motivations for watching on-demand or time shifted were convenience and freedom. People like to watch some of their programming at a time of their choosing, instead of planning their lives around the television schedule. On the PVR this means recording for later viewing, while on the internet the usage occasion is mainly 'catch up' – watching missed programmes.

We found that consumers often use the PVR to avoid family disputes over what to watch on television. The device gives the opportunity to record one of the two clashing programmes. However, we found

[81] Brand Republic, May 2008, link

that in some families with particularly divisive viewing preferences (e.g. sport, soaps) viewing would take place in separate rooms to avoid conflict.

"Sky+ avoids dispute with my wife"

Gavin, 42, bank manager

"Life is hectic at uni so I have to watch TV on the internet"

Eleanor, 18, student

"I'm no longer bound by the schedule, I used to come home early from dinners to watch a programme"

Julie, 24, administrator

"I didn't have TV for the first 4 months of uni so used iPlayer to watch TV on the internet"

Andrew, 21, student

"Why organize yourself around a TV schedule when you can free yourself from it?"

Phillip, 65, retired

"I have on-demand but I don't use it much – sometimes I can get carried away with it"

Janet, 62, retired

"We have a Freeview+ PVR – it's a wonderful piece of technology – recommended by a friend, brilliantly designed, one of the few pieces of technology that I can't fault"

Phillip, 65, retired

"If you're in then watch the schedule, if you're out then record it"

Carol, 50, runs property company

"I love iPlayer. It's beautifully organised. I tend to use it more for radio. I'm looking forward to series linking and improvements in quality"

Phillip, 65, retired

"I would have wanted to watch more of the Olympics on-demand"

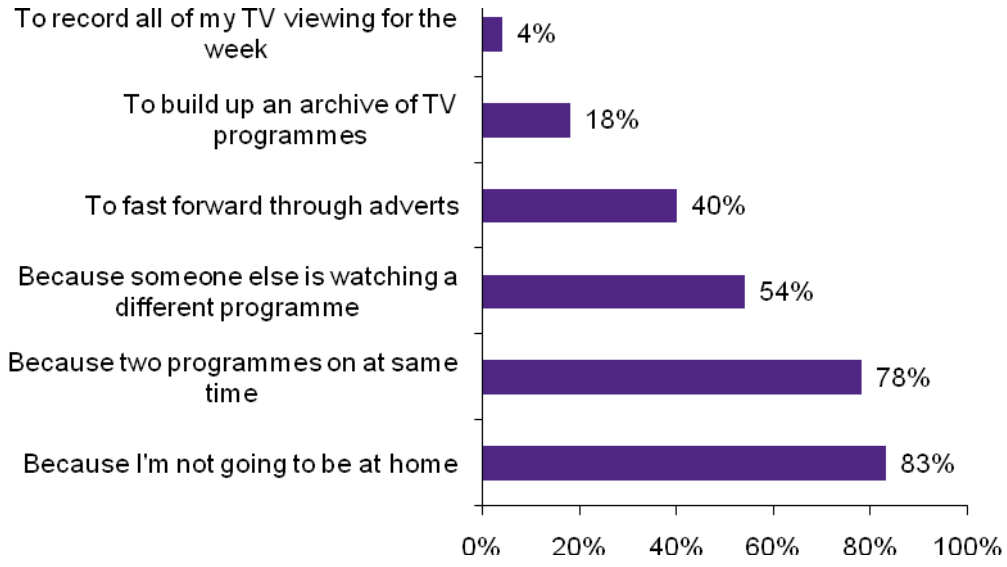
Michael, 20, student

"My partner watches 4 hours of Indian soaps every night – I had to get another Sky box to watch things other than Indian soaps"

Julian, 55, estate agent

These findings are consistent with the results recent quantitative research.

Reasons for recording a programme on a DVR



Source: Ofcom Communications Market Report 2008

We found that demand for flexibility of viewing time is related to life stage and lifestyle: unsurprisingly those with busy lives are most likely to need to watch time shifted or on-demand.

Narrowing rather than expanding selection of programming viewed

Though these services give people increased choice by allowing them to see programmes that they would otherwise have missed, consumers in our groups did not stress improved choice (e.g. the chance to see new programmes) as a key perceived benefit. On the whole consumers saw these services as new ways to watch programmes that they were already familiar with. In fact, in some cases consumers saw these services as a way of watching more quality television and less of the rest, thereby narrowing their range of programming. This is particularly the case with 'wallpaper TV' that is scheduled at non-peak times.

"*Richard & Judy* should be scheduled as I would not sit down in the evening to watch it"

Gavin, 42, bank manager

"I can't imagine having the munchies in the evening and turning on *Richard & Judy*"

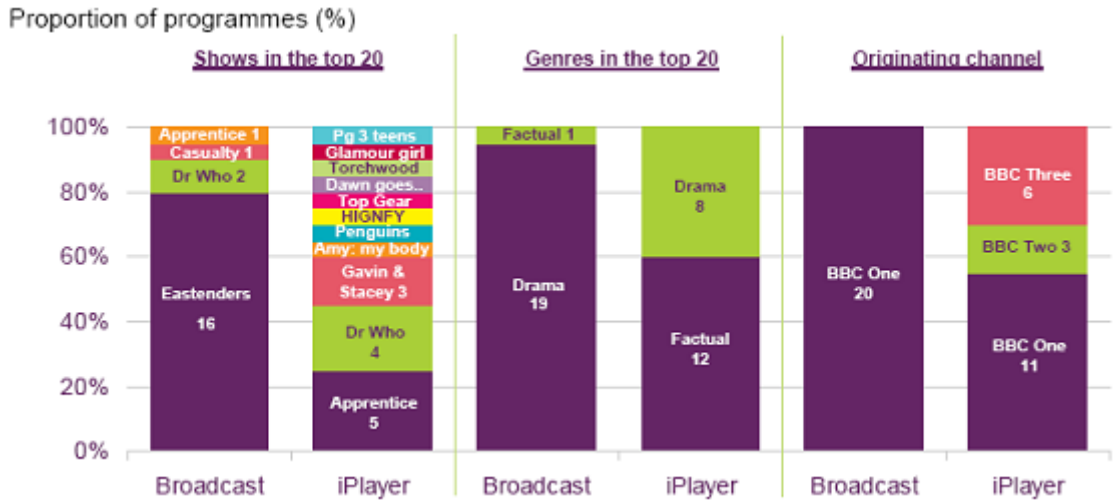
Chantelle, 32, textiles assistant

We asked consumers to list the programmes that they would prefer to watch on-demand. Most frequently mentioned were major long-running series (e.g. Lost, Heroes, 24) and films.

Data from the BBC shows that the mix of programmes viewed on iPlayer is more diverse than those watched on the main channels. However, this may reflect the difference in demographic between the

platforms and the increased privacy offered by the PC, rather than a significant new breadth of viewing stimulated by the new platform.

The 20 most-viewed BBC programmes, April 2008



Source: Ofcom analysis based on a BBC press release

PVR bingeing behaviour

Another evolutionary behaviour we observed is 'PVR bingeing', in which consumers spend an evening watching recorded programmes back-to-back. For example, one consumer who completed our diaries used a PVR to record programmes then binged on a Sunday afternoon by watching several episodes of a series (e.g. Dexter) back-to-back.

To some extent this behaviour mirrors consumers' consumption of DVD box sets. For example:

> "My family bought the 24 box set. We watched several in a row, then we started watching independently in competition"

Anya, 17, student

Our findings are consistent with quantitative research[82] which showed that 58% of users 'always' and 30% 'sometimes' check what is on live television before watching a recorded programme: 'bingeing' occurs when there is 'nothing on'. The same research also showed that 48% 'had ever; and 28% 'regularly' watch several episodes at the same time – the equivalent of bingeing.

Overall, this suggests that consumers are attracted to quality programming, and when they find it they like to consume in excess.

[82] *Ofcom research, February/March 2008. Question: "How often, if at all, do you check what is on TV before watching a recorded programme?" Base: 237 DVR users.*

The impact of time shifted viewing on advertising

The effect of time shifting on the way that consumers engage with spot advertising is an important consideration given the reliance of commercial broadcasters' business models on advertising. The consumer research commissioned for this study did not seek to address this question. However, ethnographic research conducted in 2006[83] showed that:

- 30% of total 'opportunities to see (OTS) commercial impacts were time shifted on television sets with PVRs
- Of these, 68% were fast forwarded and 32% played back at normal speed
- Users of the PVR were often fully attentive whilst fast forwarding time-shifted commercials such that the advertisers could be recognised

More recent quantitative research showed that 88% of PVR users claim to always or almost always fast-forward through advertising[84]. However, claimed behaviour often does not correspond with the (more accurate) results of ethnographic studies.

In summary, these results indicate among most consumers an inherent desire to avoid advertising, but a degree of exposure to advertising during time-shifted viewing nevertheless. However, these findings relate to the use of current PVR technologies: users need to use fast-forward or 30-second skip buttons to avoid adverts. In future, PVRs may well enable complete and automatic ad skipping.

New types of viewing behaviour are emerging on the internet

The internet has led to the emergence of more active and engaged kinds of viewing behaviour, including:

- Getting ahead of the schedule – using file sharing or other services to watch episodes of series that have not yet been screened on broadcast television. This is particularly the case with long-running US series that are launched in the US before coming to the UK
- Discovery and exploration – using services such as YouTube to browse nostalgia or other archive content (e.g. old music videos); following links and connections to find new programmes
- Quality checking - one group member used the internet to watch overseas versions of formatted UK shows not yet launched in the UK to check whether these would be any good. Other consumers use online recommendations for this purpose
- Snacking – consumption of short-form programming, whether user-generated (e.g. YouTube material) or professionally produced

[83] PVRs and Advertising Exposure: A Video Ethnographic Study. Actual Customer Behaviour and London Business School, September 2006.

[84] *Ofcom research, February/March 2008. Question: "When you watch recordings you have made with your DVR, how often, if at all, do you fast forward through the adverts". Base: 237 DVR users.*

We found this behaviour is most prevalent among younger people.

"I use the internet to watch shows that are not out in the UK yet"

Sharene, 22, nursery nurse

"I use surfthechannel.com. I can watch The Wire streamed while my girlfriend watches BBC drama. I do not have to wait for the next episode"

James, 26, English teacher

"I use the internet to watch shows that are not out in the UK yet"

Leah, 21, student

We found a real need for the schedule and live programming

Our research shows that scheduled television addresses real needs among some consumers for:

- Routine
- Something to look forward to
- Something to talk about
- A companion

These needs were mentioned by people of all ages, though the young and time poor were generally less attached to the schedule.

"My wife has got into the routine of watching at particular times"

Gordon, 58, musician

"The schedule motivates me to go home and watch television"

Rozeena, 31, HR

"I used to look forward to 24 on a Sunday night"

Pamela, 42, housewife

"I look forward to the Apprentice on Wednesday"

Gavin, 42, bank manager

"X-Factor and Strictly Come Dancing are what scheduled TV is all about"

Gordon, 58, musician

"It's nice to have the anticipation of something in the evening"

Ben, 18, student

"Friends talk about programmes afterwards"

Kenza, 34, PA

"I phone my mother to share the experience of the X-Factor"

Chantelle, 32, textile assistant

Consumers also felt that some programming has to be seen at the time of broadcast: news (due to currency) and sport and reality programming (due to risk of spoilers).

"I would never record football, it has to be live – I once tried it but a friend texted the result to me so I deleted the recording"

Ish, 25, web designer

"It is important for the X-Factor and the Apprentice to be live. People spoiling it would be an issue if I watched on demand. I wouldn't want to watch a week later when everyone is talking about it. Live experience is important"

Eleanor, 18, student

"Putting a whole series on-demand would spoil it for those who are behind"

Anesh, 20, student

Future outlook

These results show a clear consumer demand driver for increased flexibility of viewing time, particularly among those with busy lifestyles. Demand for an increasingly wide selection of content is less clear from this research, though there is clearly strong demand for quality content, especially major series and sport.

There is also a strong need for live programming and a schedule. What this research does not show, however, is any preference for broadcast delivery of scheduled programming. It would be possible for internet delivered content to replicate the feel of the schedule. Programmes available in on-demand services have a time of first release, which could serve as an equivalent of broadcast time were a schedule-like interface to be built. Therefore, the demand of consumers for a schedule does not mean a demand for broadcast television.

Together, these findings suggest demand for a balanced mix of on-demand / time shifted viewing and scheduled and live viewing.

Quality of viewing experience

The quality of entertainment experience (e.g. screen size and definition) that consumers demand is important as it will have a significant influence on bandwidth requirements. Our research showed that on most occasions consumers prefer to watch video content on a large, high quality screen. However, people are sometimes in the position of making trade offs between quality of experience and convenience, cost or privacy.

People like the comfort of their living rooms, and watching on a large screen with good audio. Consumers thought that some content demanded the high quality screen:

"You couldn't watch something like Lord of the Rings on your phone or iPod because the quality wouldn't be good enough"

Niall, 29, customer banking services

"The quality of TV is so good now it's getting nearer cinema"

Phillip, 65, retired

We found that several consumers had recently invested in new LCD television sets for the improved quality that it would give them. There was some appreciation of high definition television, though some consumers were unable to tell the difference between HD and regular services or did not fully understand the current service provision.

Consumers who used the a PC or laptop to view video content generally did so for the advantage of watching for free, getting ahead of the schedule or watching at a convenient time or while out of the home. These benefits outweighed the lower quality compared to a television set.

"I can't get my head around watching on a laptop, I have a big telly so why would I watch on a small screen? It depends on the setting – I would do it [watch on laptop] on a train journey but not at home"

Chantelle, 32, textile assistant

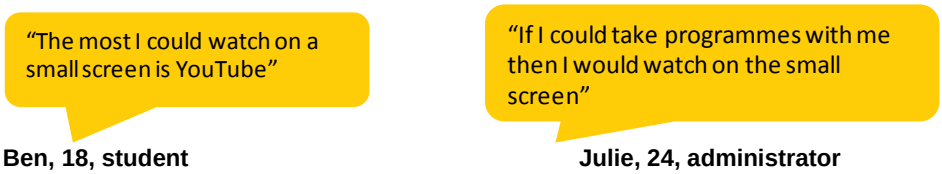
The mobile screen was acceptable to people only for short-form and user-generated content to watch on the move. However, these views were based on recent experiences of mobile video technology (e.g. few had tried higher quality mobile screens such as the iPhone).

"I'd watch X-Factor snippets [on a mobile screen], but not the whole show, 2 mins max"

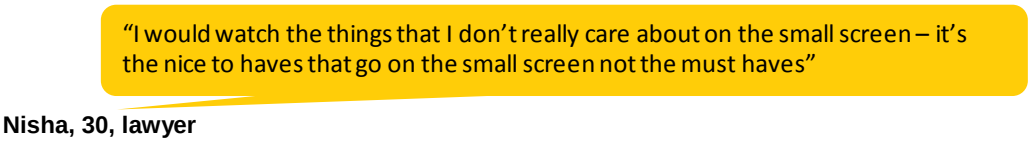
Chantelle, 32, textile assistant

"Why would anyone watch anything on a phone? It's too small. I'm not out for long enough"

Sharene, 22, office manager



In all of the PC and mobile viewing scenarios there is an inherent contradiction. The content that people are most interested in (e.g. major series), sufficient to motivate them to watch it on the move is the programming that they really want to watch in comfort on a large high quality screen.



User-generated content

User generated content (UGC) is one of the most complex and uncertain areas of evolving consumer behaviour. The term user-generated content is used to describe user creation of content forms such as blogs, photos, videos and reviews, and the consumption of this material. To confuse matters, a great deal of professionally produced content is shared and consumed on the same web sites that started out as user-generated content sites. User-generated content involves the following sequence of activities:

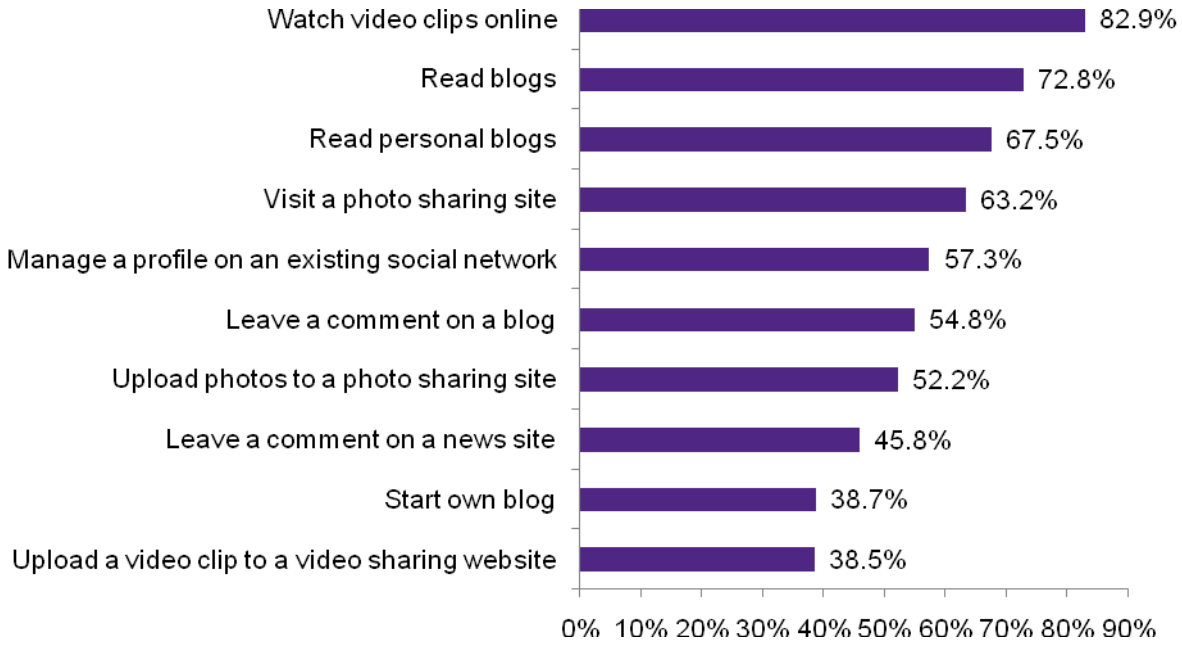
- Creation
- Uploading
- Sharing – on closed communities and open web sites (e.g. YouTube)
- Consuming
- Commenting, reviewing, amending/editing

Examples of web sites that currently cover these activities include

- YouTube – videos
- MySpace – user profiles
- Flickr – photo sharing

Viewing user-generated videos, blogs and personal pages are the most popular activities

Use of different social media functions, March 2008



Note: Base = Active internet users
Source: Universal McCann, Power to the people – Social Media Tracker Wave 3 (March 2008)

In the UK, 12.3% of the population were writing blogs, 23.8% uploading photos and 15.6% uploading videos in March 2008.[85]

Currently many more consumers are consuming UGC than creating it

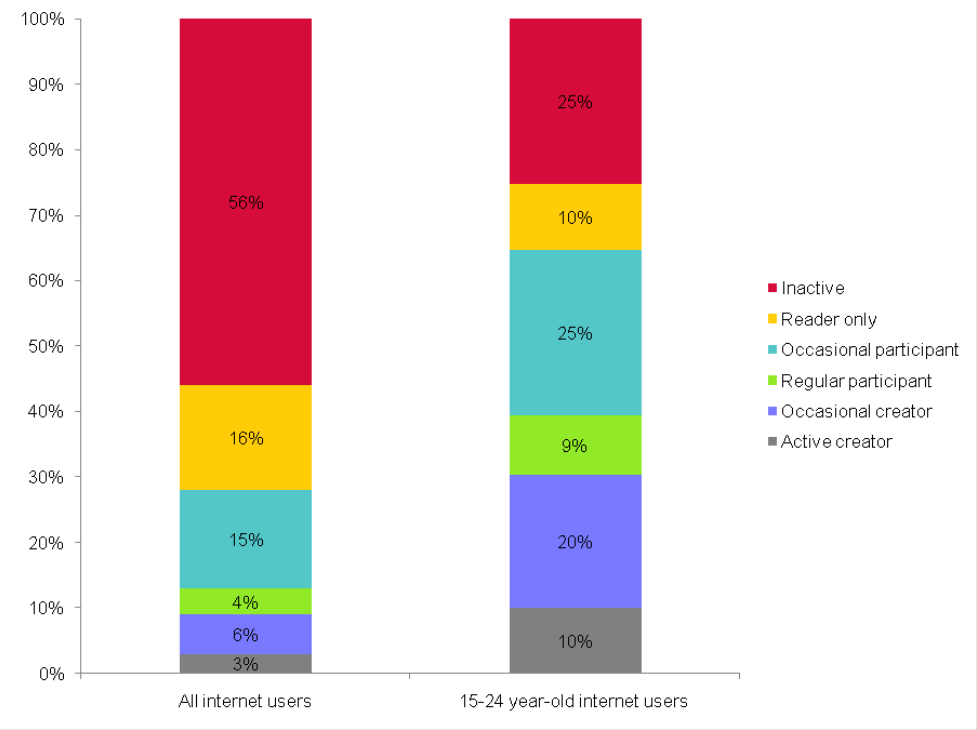
Though participation / content consumption within user-generated content communities is a mainstream behaviour for online users, particularly the young, creation is still a niche activity. Participation follows a power law distribution, where the vast majority of content is produced or shared by a very small proportion of users – the vast majority of users rarely contribute or do so only occasionally. Thus users are divided into a variety of roles. This is true of a variety of user-generated content communities including Amazon, Slideshare and Digg.[86] In the US, only 0.18% of visits to YouTube were to upload videos, the rest being consumption.[87]

[85] Universal McCann, Power to the people – Social media tracker wave 3 (March 2008)

[86] Source: Quantitative Analysis of User-Generated Content on the Web, http://journal.webscience.org/34/1/WebEvolve2008-03.pdf

[87] Hitwise US Research Note – Measuring Web 2.0 Consumer Participation, June 2007

Level of participation in user-generated content services



Source: IDATE, Use-IT survey, 2007

UK data shows that consumption of user-generated video content is similarly higher among households containing young people: of households that watch video content on the internet 87% of those with 15-24 year olds, 83% with 25-44 year-olds and 58% with 45-64 year olds watched user-generated content.[88]

It is uncertain how the level of content creation will evolve

The level of participation in content creation and uploading is influenced by

- The ease of creating and uploading content
- The dynamics of online communities (e.g. credibility, recognition)
- Potential financial or professional gain

A recent study of user-generated web content found that the consumption-creation imbalance holds true across sites / features of different complexity and ease of creation / contribution[89]. However, an alternative hypothesis is that in future pervasive easy-to-use content capture devices (e.g. cameras built in to clothing, stick-on disposable cameras) with all-day recording will significantly increase the volume of content capture and lead to a rise in the creation of user-generated content. Currently, slow upload speeds on broadband and mobile networks are a barrier to contribution of user-generated video content.

[88] Source: Ofcom research, Feb-Mar 2008: "Which of the following types of video clips or programmes do you or members of your household watch over the internet?"

[89] Source: Quantitative Analysis of User-Generated Content on the Web, http://journal.webscience.org/34/1/WebEvolve2008-03.pdf

In a study of prolific Wikipedia contributors, researchers at The Georgia Institute of Technology[90] showed that within a small community of heavy contributors there is a complex system of incentives to contribution. The desire to contribute is driven by a desire for credibility within that small community of contributors. The same participation inequality is found within publications that bind scientific communities – a very few authors publish the vast majority of content – and that though the barriers to entry are very different in nature both the system of incentives and level of participation inequality are similar. This desire for credibility seems to be scalable in user-generated content communities, so that within a group of friends somebody can seek to be seen as the most popular by having the most friends or photos posted on a social network, and a blogger can gain credibility by having the most people follow their site.

The most prolific and popular contributors to user-generated content communities are likely to be 'prosumers' who are seeking financial or professional gain. These are the bloggers who go on to secure contracts with major book publishers, or the YouTube contributors who seek a share of advertising revenues.

The way that the interplay between these three factors will evolve in future is uncertain.

Professionally produced content is being consumed heavily on UGC sites

A large proportion of consumption on UGC sites appears to be of professionally produced content. Nine out of the top ten videos by viewing on YouTube in 2008 are professional content, the majority of them are professionally produced music videos from major music publishers.[91] This was supported by our research:

> "I use YouTube to listen to music – nostalgia, I like to go back in time. I go back to an artist then go off in different directions and save things as favourites – Marvin Gaye, Frank Sinatra"

Julian, 55, estate agent

This questions the extent to which user-generated content will substitute for professionally produced material, suggesting that consumers have an enduring need for professionally produced content.

The future outlook for user-generated content is highly uncertain

The consumer needs driving end user behaviour in relation to UGC are not new to 'Web 2.0'; they are the same needs that have driven the historic popularity of content and communication forums such as letters pages in newspapers, talking about TV shows with colleagues, Usenet groups in the 1980s and Geocities communities in the late 1990s. The mode of sharing content has changed, but the desire for it is not new.

It is likely that roles will further crystallize and differentiate within user-generated content communities. Additionally, as professional content becomes more important within the business models of user-generated content communities, these communities may become more focused on user distribution

[90] Source: Why Do People Write for Wikipedia? Incentives to Contribute to Open-Content Publishing

[91] Source: http://www.readwriteweb.com/archives/top_10_youtube_videos_of_all_time_2008.php

than production. This appears likely since end user behaviours are currently creating a more significant shift in how content is distributed than what content is produced or consumed by end users.

In conclusion, some of the key uncertainties about the evolution of consumer behaviour with respect to UGC are:

- The extent of substitution of UGC for professionally produced content
- The degree of participation in creating and uploading content
- The forms of UGC created and consumed (e.g. short-form vs. long-form video)

Games playing behaviour

Games are one of the fastest growing and fastest changing areas of consumer entertainment. User demographics and behaviour are evolving fast in response to the supply of new games devices and content, and externalities such as the growth on social networking.

The consumer needs that games address are fundamentally different from other entertainment types. Games players are often seeking a challenge, social interaction, engagement of the mind, excitement, action and a lean-forward experience. Escapism is also an attraction, though this is shared with other entertainment formats. Another benefit to consumers is that, due to repeated play / long periods of play, games content is relatively good value for money.

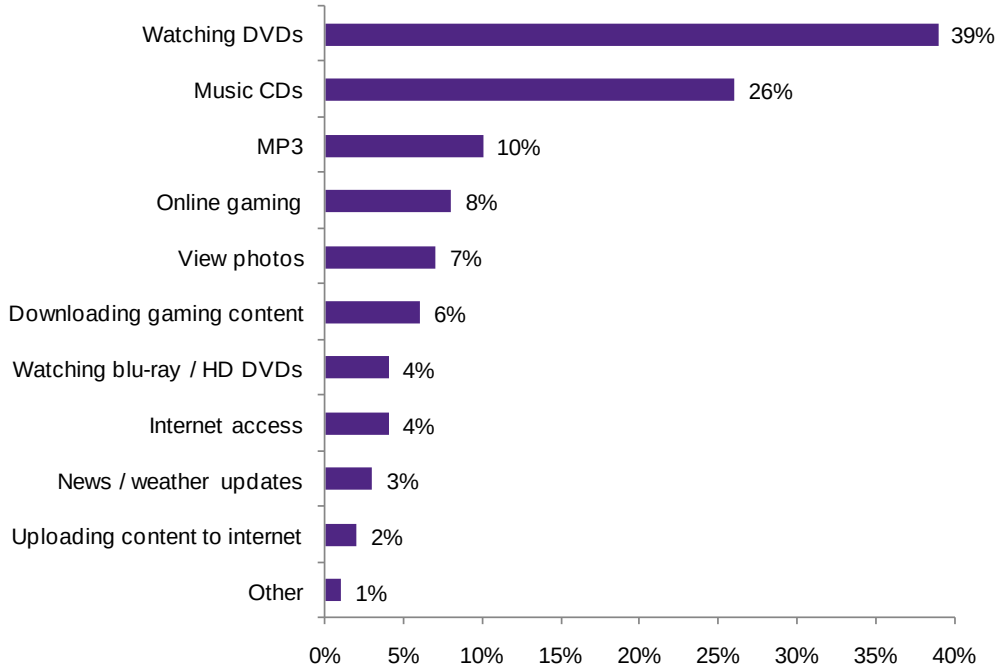
Current games devices and content types

Consumers are playing a range of different types of games on various platforms and devices. Currently, the main gaming devices are:

- Consoles - including the latest, so-called, next-generation console platforms - Microsoft's Xbox 360, Sony's Playstation 3 and the Nintendo Wii
- Dedicated handheld devices - such as the Sony PSP, Nintendo DS (and its variants) and the Apple iPod Touch.
- Mobile handsets – almost all handsets have some basic games installed, for example Snake. High-end smartphones, such as the new Apple iPhone or Nokia handsets installed with the N-Gage software platform, have advanced game-playing capabilities that rival those of the dedicated handhelds and previous generation consoles.
- Personal computers – traditionally associated with hard-core game players but recently proving massively popular for the playing of online games.

The high-end console devices are increasingly becoming central to users' home entertainment experiences, all-round devices used to support activities including watching DVDs, listening to music and viewing photographs.

Activities undertaken in addition to games by consumers using games consoles



Notes: Base: All adults who use games consoles (351)
Source: Ofcom research, Feb / March 2008

There are three distinct categories of game types, all of which can be played on different platforms:

Category*	Platforms	Example Game Titles	Typical game length	Business Model / Distribution Channel	Distribution Means
Casual / Online	Consoles, Handheld, PC, Mobile	Tetris, Bejewelled 2, Snake, Minesweeper, Blackjack	Minutes to hours	Ad-funded, subscription, try-before-you-buy or DTO	Online Over-the-Air (OTA) Pre-installed
Immersive	Console, handheld, PC	GTA IV, Halo 3, Call of Duty IV	Hours to hundreds of hours	Software purchase, rental or download-to-own (DTO)	Retail Download Online
Virtual Worlds / Massively Multiplayer Online Games (MMOGs)	Consoles, PC	World of Warcraft, Second Life, Habbo Hotel	Hundreds of hours+	Software purchase & ongoing subscription or Ad-funded	Retail Download Online

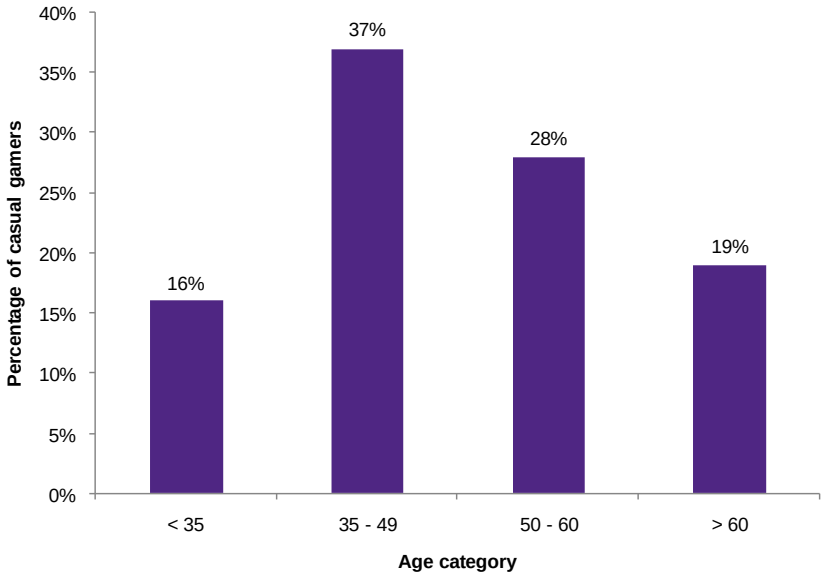
Note: The boundaries of these games are not fixed and are constantly being redefined – for example Habbo Hotel could be classified as a casual MMOG

Casual games are widening the demographic spread of games users

The Nintendo Wii console and DS handheld have both been enormously disruptive to the UK games industry. Games released on these platforms, such as Wii Fit and Dr. Kawashima's Brain Age, have skewed the typical male, 15 to 24 gaming demographic to one that as is older and more female. The games have proven popular with traditionally non-core gamers and with families. Other platforms are successfully emulating this success with the release of more socially-enabled casual games on their platforms, including title such as 'Guitar Hero' and 'Rock Band'.

Casual games are designed to be simple to play and appeal to a broad demographic. They are usually accessed online from websites including Pogo.com, King.com and Yahoo.com/games. Demographics differ from the traditional games player profile in that 75% of casual gamers are women and only 16% of players are under the age of 35[92].

Age profile of casual gamers, 2006



?What If! estimates that the casual gaming market will grow in value by 23% a year, with a concurrent increase in usage.

Mobile games use is increasing

17% of mobile users play mobile games on their handsets[93]. This figure is likely to rise as handset capabilities and functionality continue to improve and manufacturers increase marketing focus to capitalise on gaming popularity growth. The release of Nokia's N-Gage gaming platform and Apple's positioning of its iPhone (and iPod Touch) as a serious gaming machine and convenient over-the-air (OTA) payment and distribution enablers will continue to drive this trend for the foreseeable future. Mobile games are typically casual in nature and are designed with bandwidth and handset constraints in mind and are therefore small in file size.

[92] Casual Gaming Association, 2006

[93] Ofcom research, Feb-Mar 2008

Recent analysis by ?What If! shows that mobile gamers are typically evenly split between the sexes, but tend to be older than console gamers with about half being aged between 25 and 44. 50% of mobile gamers play at home, 36% whilst travelling and 16% in public places.

Console games are becoming more immersive and networked

The games industry has seen demand for online social networking services grow, and responded by developing multi-player games titles that include community features and user-generated content. Some examples include:

- Team Fortress – cartoon-style team war game with competitive and collaborative elements
- Animal Crossing – children's game on the Nintendo DS (WiFi connected). Players build villages, visit each others' villages and engage in text chat. Essentially it is a virtual world with occasions for players to interact with each other e.g. play hide and seek.
- Burnout – multiplayer racing game. Players set each other collaborative challenges within the game, which have become popular with users
- Little Big Planet – two dimensional platform game with extensive user-generated content capability (e.g. creating and uploading levels)

Virtual worlds and MMOGs are growing strongly

Massively multiplayer online games (MMOGs) are games that support a large number of players who interact with each other to accomplish quests or tasks in the game and build their characters (avatars). World of Warcraft is the largest game in this genre, and is growing strongly: subscriptions grew from about 8 million at end of 2006 to 10 million at the end of 2007[94].

Virtual worlds are web sites which allow consumers to take on a new identity, explore new (virtual) places, meet other players and engage in other activities such as playing games. Often there is an element of user-generated content: consumers can create their own characters and places within the world.

Currently, virtual worlds have been most popular among children. Of the top ten virtual worlds in terms of registered users, only two are targeted at adults.

[94] Mmogchart.com

Top ten virtual worlds sites by registered users, Q3 2008

Site	*Description*	*Number of registered accounts, Q3 2008*[95]
Habbo	Casual gaming, socialising and chat site for children and teenagers	100 million
Neopets	Casual gaming for children	45 million
Stardoll	Fashion and lifestyle world for teenagers	21 million
Poptropica	Virtual world for kids to travel, play games, compete in head-to-head competition, and communicate	20 million
IMVU	Socialising and chat world for children	20 million
Club Penguin	Casual gaming for children	19 million
Second Life	User generated content world for adults	15 million
Barbie Girls	Virtual world in which children create characters, design their own rooms, play games and chat	15 million
Gaia	Role play and fantasy world for teenagers	15 million
Meez	Social entertainment site combining avatars, web games and virtual worlds	7 million

Due to an explosion in supply of virtual online world services, consumer usage has grown strongly. However, analysis of the usage of one of the major sites suggests that the phenomenon is still relatively niche in the UK.

The best known adult virtual world is Second Life. The site had 16.2 million registered users globally in November 2008 (compared to 12 million in January 2008), but only 1.0 million (6.3%) had accessed the service during the last month[96]. UK users accounted for 6.8% of total Second Life usage hours in July 2008, suggesting that there were approximately 69,000 users active in the UK last month. These users appear to be highly engaged, spending an estimated 5.7 hours per week on the site.

Similarly in the children's, Club Penguin appears to have a relatively low UK use: it accounted for 0.83% of the UK social networking site market by traffic in June 2008[97].

Consumers' behaviour in virtual worlds is still relatively uncertain. However, virtual worlds appear to meet a need for escapism combined with entertainment and socialising.

Completely new games behaviours are emerging

New formats, devices and peripherals are enabling end-users to interact with games in different ways. Some examples of new developments include:

- Wireless peripherals - Emotiv has recently released a computer headset that allows people to control PC-based video games using only the power of their minds, by measuring electrical impulses in the head.
- Location-based games – incorporates the GPS-functionality in mobile handsets and satellite navigation systems as a component of the game-play

[95] www.kzero.co.uk

[96] Linden Labs - http://secondlife.com/whatis/economy_stats.php

[97] Hitwise UK Social Networking Update, July 2008

- Alternate Reality Games (ARG) – an interactive narrative that uses the real world as a platform, often involving multiple media and game elements, to tell a story that may be affected by participants' ideas or actions. These are currently very niche. An example is www.thelostring.com, a McDonalds sponsored ARG for the Beijing Olympics

It is currently uncertain how consumers will respond to and use these technologies.

Overall, the future of games behaviour is highly uncertain. This is an area that will likely see real innovation and unforeseen developments. Many of the significant developments in this market to-date (e.g. the Wii) have been largely unexpected.

Annex C Technology developments affecting platforms and devices

C1 Semiconductor devices

Processing power

Just as technological developments are key to understanding the evolution of the entertainment industry, so will the capabilities of semiconductor devices be key to enabling such technical developments.

In 1965, Gordon Moore published the paper containing his famous prediction concerning the growth in capability of semiconductor devices. As the number of devices fabricated on a silicon wafer increases, so the cost per device will tend to fall; this is offset, however, by the decreasing yield of good samples as density increases. There is, consequently, an economically optimum component density for integrated circuits, and Moore noted that this had increased by a factor of two per year between 1959 and 1965, and predicted that this growth would continue 'for at least ten years'.

Moore later revised the figure to a doubling in complexity every two years, and other versions of Moore's 'law' refer to a doubling in the number of transistors or performance every 18 months. Similar exponential trends have also been demonstrated in other areas such as hard disk storage, flash memory and display resolution.

A key result of this rapid improvement in processing capacity is that it has allowed a relaxation of the historical need to concentrate complexity at the transmission end of the broadcast chain. As an example, digital distribution of audio and video signals between studios and transmitters has been used for decades, but it was always necessary to convert these back to analogue form for broadcast transmission, as the decoders occupied many rack of equipment using the technology of the 1980s. As processing power is now very affordable, it is possible to adopt a more balanced approach to the design of the broadcast chain.

The 'International Technology Roadmap for Semiconductors' (ITRS) is a cooperative effort by semiconductor industries and manufacturers of semiconductor production equipment to understand the future technical possibilities in, and hence the requirements of, the semiconductor manufacturing sector. The roadmap sets out the timescales over which new production techniques are to be expected.

Current technology (as used for the production of Intel's Core2 processors) is based on the use of a 45nm process[98] , with UV light of 157nm wavelength used for lithography. This has evolved from 3µm (used in the 8088 CPU, 1979) via 800nm (486 CPU in 1989) and 180nm (Pentium III, 1999).

The ITRS suggests that 16nm processes will be in use by 2018, and this scale if often considered to represent the limits of current methods, due to quantum tunnelling, amongst other effects. Problems of heat dissipation will also become increasingly serious as densities increase. It currently seems possible, therefore, that the exponential growth associated with Moore's Law will reduce or cease in this timescale.

[98] The distance refers to the 'half-pitch, or half the distance between identical features on a semiconductor array

Depending on the doubling factor (i.e. every 2 years or every 18 months), an improvement in processing capacity of 32 to 100 fold will be achieved by 2018, the point at which Moore's law might flatten out. If techniques are found to overcome the foreseen fabrication limitations or if alternative processor technologies having long term potential are introduced, then improvements in processing capacity by 2028 could be 1,000 to 10,000 fold, assuming the same rate of improvement.

Memory

Of particular importance in the context of the current study is the availability of cheap and portable memory, particularly of the 'flash' type. Although the cost/capacity ratio is still higher than for hard-disk based storage, the mechanical ruggedness of such memory is a significant advantage.

Currently, flash memory is widely used as a hard-drive substitute in low cost laptop computers (e.g. the Asus Eee PC) and in portable devices such as the iPod range. The break point below which flash devices are used is currently around 10 GB, though solid state drives have been demonstrated with capacities beyond 100 GB. While hard disk drives still offer a greater capacity/price performance, the difference is shrinking (from 33x in 1995 to 19x in 1996[99]). Samsung claim that NAND[100] flash memory is currently following a trend of doubling in capacity every 12 months, and this appears to be the case given their release of a 32 Gb chip in 2006, a 64Gb chip in 2007 and the current availability of a device of 128 Gb capacity (albeit with a read speed reduction from 25ns to 50ns). If this trend is followed, it would imply the availability of 1Tb chips by 2011.

These advances in individual chip design have made possible the availability (2008) of 64 GB memory cards and sticks at prices around £100.

Flash memory will be constrained by the same quantum limitations noted above, but capacity can be increased by the use of 'Multi Level Cell' (MLC) techniques, in which more than one bit is stored in each element by the use of more than one charge threshold.

An alternative approach, being investigated by Nanosys[101] to addressing the problem is to replace the gate material in memory cells with metal 'nanocrystals' or 'quantum dots', allowing a smaller size cell for a given charge storage capacity.

Successful trials of a completely different technology have been reported (New Scientist, 19.7.08) in which elements of a metal alloy surface are driven between crystalline and disordered states by localised heating. As the different states have differing electrical resistances the elements can be read by a small current. Such Phase Change memory (PCM) cells have been demonstrated at scales of only 5nm, but the technology is still at a demonstrator stage.

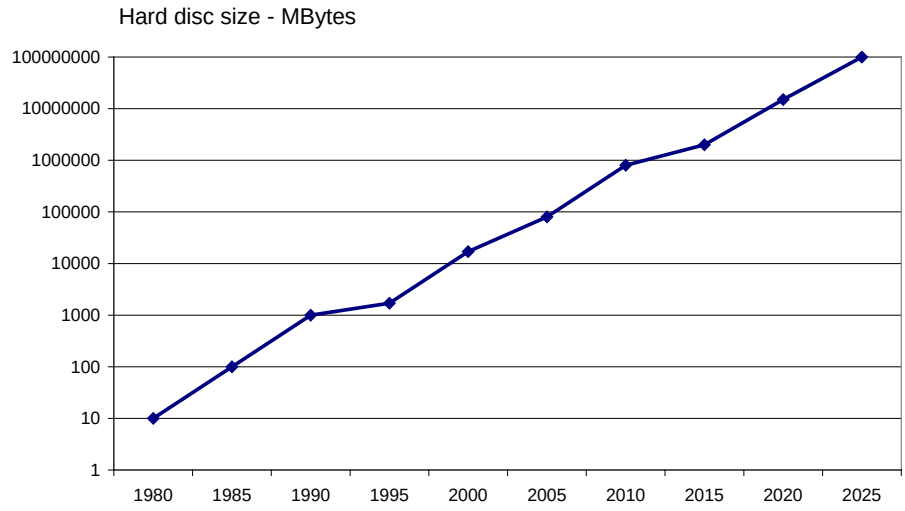
If these new technologies continue the Samsung trend of doubling capacity every year then the 1 Tb capacity noted above for 2011 would become some vast number (over 10,000 TB) by 2028. It is not known whether such a rate of improvement can be sustained over such a period and it is uncertain as to the point at which capacity improvement will flatten out as these new technologies are still in their infancy.

[99] Reported in The Guardian, 24.8.06

[100] The NAND structure gives page based access, particularly suitable for access of sequential data such as video and audio files. NOR flash is better suited for fast random access to data.

[101] www.nanosys.com (reported at http://www.technologyreview.com/Infotech/19074/page1/)

The rate of improvement in hard disk capacity (which is relevant to home network servers for example) has also been rapid, more than doubling every two years.



Source: *Wireless Communications: The future.* W Webb, 2007

It is arguable that the trend has picked up recently as 1 TB hard drives are widely available now and will probably be standard in a mid range PCs before 2010.

C2 Compression

Probably the single most important benefit of the adoption of digital broadcast technologies lies in the opportunity they provide for data compression. While limited opportunities existed in the analogue world for compression (such as the bandwidth reduction of the colour difference signals in PAL), digital methods allow for great flexibility in trading quality (however defined) for capacity.

To give an example of the benefits of compression, a raw 625-line colour picture, digitised so as to preserve all the original information with no additional coding, would require a data rate of 2 bytes x 13.5 MHz = 27 MB/sec = 216 Mbit/s. Using a typical MPEG-2 coder, this is reduced to around 5 Mbit/s for a good quality picture.

Newer coding algorithms can improve somewhat on his performance; thus an HDTV picture coded using MPEG-2 might require some 20 Mbit/s while MPEG-4 coding might reduce this to around 8 Mbit/s.

Coding methods

The most popular video coding methods are based on the use of the discrete cosine transform (DCT) to code small blocks of the image in spatial frequency terms. It is then simple to discard the higher frequency terms (representing the fine detail), thus implementing (lossy) compression. The set of coefficients can then be (losslessly) compressed using variable length coding.

In MPEG video coding[102], only a few frames (intra-pictures) of the picture are sent as described, with the remainder using 'motion vectors' to code the movement of bulk elements of the scene between frames (e.g. a moving car, or the effect of a panning camera), and thus interpolate between the reference frames.

If a constant bit rate transmission is required, buffering may be used, with feedback to steer the spatial filtering of the DCT depending on buffer fullness.

Current DVB-T transmissions (and DVDs) use the above methods, with the chrominance signal compressed by a factor of two both vertically and horizontally (4:2:0). MPEG-2 coding will reduce the raw bit rate of a digital TV signal sampled at 4:2:0 according to CCIR Recommendation 601, from 124 Mbit/s to between around 3-15 Mbit/s.

MPEG-4[103] video coding (Layer 10 or AVC) improves on the compression achieved in MPEG-2 by the use of enhancements of the techniques described, including variable block-size motion compensation, which allows more accurate isolation of moving elements of the scene and the ability to use neighbouring DCT blocks to improve spatial prediction. A more flexible use of previously encoded pictures for motion vector estimation is also possible.

The 'high' profile of MPEG-4 Layer 10 is used by the BBC and Sky for their satellite HD offerings, and will be used for the new terrestrial HD multiplex (MUX B). Bit rates are less than half those that would be achieved using MPEG-2 coding.

An alternative to the MPEG-4/H.264/AVC approach is that developed in the BBC open-technology 'DIRAC' project. This is a video Codec that is entirely free of licensing or patent restriction, and is intended to support the free and flexible distribution of public service programme content over multiple platforms, particularly via the internet. There does not appear to be a very significant difference between the compression rates achieved using Dirac, and those of MPEG-4 – the main distinguishing feature is the IPR issue.

Future trends and developments

The standards described above specify the format of the signal as transmitted, and the algorithmic operation of the decoders. The implementation of the encoding algorithms is not specified, and this allows a useful degree of flexibility; significant improvements in overall coder-decoder (codec) efficiency can be made with no upgrade required of the consumer equipment.

Thus, the efficiency of MPEG-2 coding has improved [1] by a factor of more than 2 since the mid-1990s due to improvements in coding algorithms. Historically, the rate of improvement of such coding algorithms declines exponentially, with MPEG-2 approaching an asymptote of efficiency by 2002, by which time MPEG-4 had been introduced.

Several workers, e.g. in [2], have pointed out that the incremental improvement in bit-rate reduction between MPEG-2 and MPEG-4 is lowest for HDTV, where coding artefacts are likely to be less tolerable to the viewer.

[102] In the Main profile.

[103] Technically identical to ITU-T Recommendation H.264

It is not, however, clear that any dramatic further developments are to be expected in this area using current coding architectures. One possibility for the future, using techniques taken from virtual reality computing, is that scenes may be decomposed as a series of simple geometrical elements (e.g. triangles) in vector form, with added data to provide textures and shading. This is further discussed below.

Scalable coding

As the number of broadcast distribution paths increases, involving an ever-expanding range of terminal devices, so the problem of providing appropriately formatted picture material becomes more problematic.

Part of the requirement is concerned with the need to 'repurpose' material to make it appropriate for display on screens ranging from mobile phones to HDTV displays; such repurposing may include the use of panning a small area within the main frame, and the re-formatting of graphics, and these topics are discussed elsewhere. It may also be the case that the same video content may need to be transmitted at different resolutions, and this may be achieved through the use of hierarchical or scalable coding.

The H.264/AVC standard an extension (Annex G, completed in 2007) for scalable video coding. This was based on a proposal from the Heinrich-Hertz-Institute (HHI).

For maximum end-to-end channel efficiency, such scalable coding should be linked to the transmission coding and modulation. Hierarchical coding, where the distance between constellation points is linked to the significance of the individual bits represented, has been investigated using the DVB standards, but is not currently employed.

Vector representation

MPEG-4 (Part 11) implements an object-based representation of a scene, similar to the Virtual Reality Modelling Language (VRML) in the form of the 'Binary Format for Scenes (BIFS). Tools available within the standard include methods for facial animation and (eventually) full body animation.

These techniques currently have application in composing scenes that may include avatars, computer-generated backgrounds or graphical elements, and in manipulating these appropriately for a range of formats.

Such elemental vector decomposition of scenes may, however, prove to be a useful basis for the compression of natural video scenes in a broadcast context. Currently, however, such methods appear to be primarily used where machine object recognition in surveillance or robotics is required.

Conclusion

It is difficult to generalise about improvements in compression as there are many variables involved and the output depends on the type of input (i.e. nature of content) and the degree of loss at the output (i.e. acceptability of artefacts). Suffice to say, the initial application of compression to a raw digital video stream achieved a relatively large improvement immediately (more than a factor of 10) because redundant information could immediately be stripped out through digital processing.

Improvements more recently have been more modest – factors of two over a number of years, as existing methods have been improved and then factors of two as new approaches are introduced. It is hard to see any dramatic improvements in existing techniques occurring in the future as most of the redundancy has already been stripped out. It may be the case that vector representation reduces content for transmission to the barest essentials potentially leaving the recipient with a significant processing / storage burden to recreate the original content. This is highly uncertain however.

C3 Display technologies

It is arguable that, until recently, available display devices constituted the main bottleneck in the pipe (to mix metaphors) from broadcaster to viewer. In most cases a better analogue signal could be conveyed over the 5.5 MHz channel than could be displayed on a shadow mask CRT. With the cheap availability of large, high definition, flat panel displays, this is no longer the case. But display technology will remain a major constraint on the use of mobile devices for video applications, though this may be a more fundamental mismatch between form factor and application.

Before examining the display technologies available, it is worthwhile to summarise some existing and proposed display formats.

Digital Standard	Pixels (H x V)	Notes
SHV	7680 x 4320	NHK 'super Hi-vision'
HD_{1080}	1920 x1080	Can be progressive or interlaced
HD_{720}	1280 x 720	Can be progressive or interlaced
SD	720 x 576	Analogue PAL 'equivalently' has 702 horizontal pixels
CIF / SIF	352 x 288	Applications in videoconferencing & coding
QCIF	176 x 144	Applications in videoconferencing & coding

While this section is primarily about display technologies, it can be seen from the above figures that as standards "improve" an increasing burden will be placed on distribution platforms. In comparison to standard definition television, and assuming no associated improvements in compression, high definition television requires up to 10 times as much data and the super Hi-vision 160 times as much data.

Current technologies

Cathode ray Tubes (CRT) have been used for the display of television pictures since the 1930's; although envisaged by some at that time as a stopgap solution; they are only now becoming obsolescent. The primary disadvantage of the CRT is its bulk; this was not a serious inconvenience when the remainder of the receiver electronics occupied a significant volume, but is now unacceptable for larger screen sizes. A further disadvantage is the need for the provision of very high voltage supplies within the receiver.

CRTs have now been superseded for most applications by plasma and LCD displays. While shipments of CRT and flat-panel displays were equal in the third quarter of 2007, by the end of 2008 CRTs will represent only 25% of the market [3]. An unscientific sample by the author showed that in July 2008, 100% of all sets sold in a large electrical retailer were flat screen types, with some 90% being LCD displays.

Plasma displays

Plasma displays incorporate a large number of cells containing inert gas, each of which can be individually addressed by a matrix of electrode strips. When sufficient voltage is applied across a particular cell, the gas ionises, and causes a phosphor coating at the back of a cell to fluoresce. Each image pixel is generated by a triad of cells with red, green and blue pixels, allowing the full colour spectrum to be represented. Plasma displays have tended to be restricted to larger formats, as the cell size is not readily scalable. Furthermore, colour fringing can be noticeable on fast-moving images due to the pulse-width modulation of individual cells. A contrast ratio of some 2000:1 is typically achievable.

LCD displays

LCD displays make use of the polarising properties of liquid crystals (LC) to pass or block light from a source behind the display. Individual LC cells are addressed via switching transistors[104] (necessary to avoid partial illumination of un-addressed cells in the same row or column). As for the plasma display, pixels are represented by triads of LC cells, with appropriate colour filters. Unlike plasma displays, the LC cells may be made extremely small, allowing the manufacture of such displays at a wide range of sizes.

As plasma screens use phosphor coatings to emit light, their colour rendition can be arranged to match that of CRT systems exactly. Greater problems are presented in matching the filtering in LCD devices to existing colour standards although it is claimed that the new colour rendering standard (xvYCC[105]) provides as big a difference in picture quality as moving from standard to high definition formats for end users.

Other frequently-cited drawbacks of LCD technology are the relatively poor response times, leading to blurring of motion, poor contrast ratios and restricted viewing angles.

Other and future display technologies

The first commercial TV based on organic LED (OLED) technology has recently been released by Sony in Japan. OLED screens have the significant advantage of not requiring a backlight, and had been increasing important as small display elements on consumer electrical devices such as shavers. Though compact (the Sony device is 3mm thick), and offering very good contrast ratios, they are currently less energy efficient than LCD displays and have a limited life (estimated at 5-6 years).

[104] Implemented as thin-film transistors, hence the name 'TFT-LCD'

[105] Extended-gamut YCC makes use of values in the colour space that have been released by the move from analogue to digital. It supports 1.8 times as many colours as the RGB colour space and allows for deeper reds, greens, blues and intermediate colours.

Projection and rear-projection methods have been used since the earliest days of TV[106], and are still employed for larger image sizes. A variety of technologies are employed, typically using arrays of micro-mirror devices to 'switch' the light from an appropriate source; both white light combined with spinning colour wheels[107] and laser sources have been used. The micro-mirror chip technology was developed by Texas Instruments in the 1980's and has been widely licences as Digital Light Processing (DLP). Contrast ratios of around 1000:1 have been reported with these displays, which are bulky compared with other 'flat' displays, at around 30-40cm.

Cold-cathode displays have been promoted since the 1990s, but new manufacturing processes based on carbon 'nanotubes' have re-invigorated the approach. This replaces the single electron gun of the CRT with an array of miniature electron source, each of which illuminates an individual phosphor pixel. The technology is also referred to as Field Emission Display (FED), and is initially being targeted at professional uses in the medical and broadcast production field.

3D displays

There has been interest in 3D displays since the earliest days of visual technologies, with stereoscopic photography being popular in Victorian times, and a mechanical 3D television system demonstrated in 1928. In the 1950's there was a mini-boom in 3D cinema using the simultaneous projection of frames shot in orthogonal linear polarisations and viewed using disposable spectacles with polarising filters. Disadvantages were the need to project the two sequences in perfect synchronisation, the relative small viewing angle (imposed by the need to use reflective rather than matt screens) and the need for the audience to keep their heads upright. The popularity of 3D films waned with the coming of Cinemascope.

Current 3D cinema techniques ('Real-D', or 'Disney Digital 3-D') use circularly polarised images (eliminating the head-tilt problem) and alternate projection (at 144 frames/second) of images from the two viewpoints.

For smaller scale displays (TVs, computers and even mobile phones) the 'parallax barrier' approach has generally been adopted. Such a barrier ensures that, for a correctly-positioned user, each eye sees only half the columns of pixels on a display. It is then possible to address the display to generate images for each eye, and to synthesis a 3D image. The main restrictions of the technology are the need for a user to be located in a specific position (or one of a number of specific positions), and the loss of resolution inherent (with respect to the raw resolution of the display device).

Philips have developed a 3D display based on the use of a sheet of lenses in front of the display screen as a parallax barrier. This 'multi-view lenticular' technology allows different images to be projected towards each eye of a viewer positioned at any of a number of discrete positions around the display. Data is stored as a 2D image with a separate depth map. An extension of the MPEG standard is used.

The EU seventh Framework programme is providing funding for the '3D4you' project (www.3d4you.eu), which is seeking to develop a practical 3D television system. Partners include BBC Research, Philips, Heinrich-Hertz-Institute and France Telecom. The work programme includes studies on content acquisition and on coding for compression and transmission.

[106] In some televisions of the 1930's the limitations of glassblowing technology were sidestepped by mounting the necessarily long CRTs vertically, and viewing then via mirrors.

[107] Reminiscent of the first, doomed, US colour TV system of the 1950s.

At face value a 3D transmission should at worst require twice the capacity. However, redundancy between stereoscopic images should allow for a significant reduction in the information transmitted. In effect, the Philips system does this by sending a 2D image with a depth map and this requires only 8 – 20% extra in terms of transmission capacity. While it would be reasonable to assume that 3D video using current techniques might be standard by the 2028 it is not foreseen that its possible successor, holographic video, will have entered the market on a widespread basis.

Rollable displays

A number of companies (e.g. Polymer Vision) have already produced flat, flexible displays that can be rolled up. The slow response times currently possible (0.5 second refresh) and black & white display have limited application to e-book readers.

Power consumption is low, as available light, rather than backlighting is used. This also makes the displays very usable in sunlight, in contrast to most current mobile displays. Colour video displays are foreseen in a 5-year timescale.

Ambient effects

Philips amBX is a scripting language with which room lighting, heating, etc can be controlled. Commands can be transmitted alongside image and sound content in order to provide a more immersive experience using senses other than sight and sound. Such commands are effectively telemetry, will require minimal transmission capacity and can be ignored as second order.

C4 Transmission technologies

Fibre and cable access

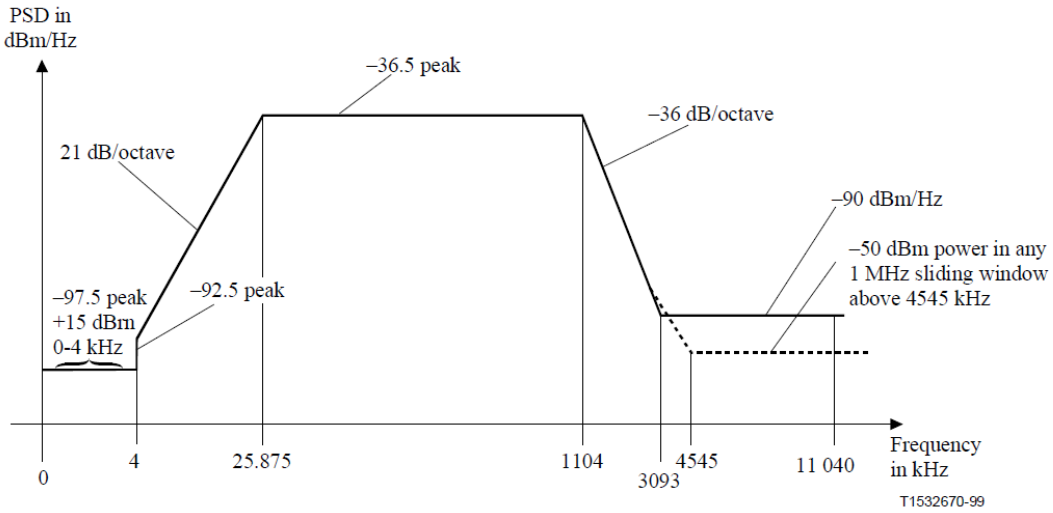
The use of dial-up modem connections to provide home internet access is now moribund, replaced by a 52% penetration[108] of broadband connectivity via either ADSL or cable.

ADSL (Asynchronous Digital Subscriber Line) makes use of the standard 'twisted-pair' (of copper wires) telephone line into the home to provide digital services that have a significantly higher capacity downstream than upstream.

The standard telephone line was required to provide a relatively flat response to analogue audio signals up to around 4 kHz. Over longer circuits, this is achieved by the use of equalisers, which, as a side-effect, impose a very sharp cut off above this frequency. The 'local-loop' between the exchange and home, however, is generally free of such equalisation, and therefore has a frequency response determined by the distributed impedance of the line. ADSL technology exploits this by frequency-division multiplexing the digital signal on a set of subcarriers spanning a frequency range from 26-138 kHz for the upstream data and from 138 kHz to 1.1 MHz for the downstream. The sub carriers are modulated using a QAM scheme; the order of modulation on each subcarrier is adaptive to the channel.

[108] From: http://www.ofcom.org.uk/consult/condocs/nga/summary/

Figure C1: Spectrum occupied by ADSL signals (From ITU-T G.992.1)



ADSL as specified in ITU-T Recommendation G.992.1 can support downstream data at rates in integer multiples of 32kbit/s up to a maximum of 6.144 Mbit/s, with upstream capacity at a maximum of 640 kbit/s. Typical copper pairs can support the full data rate out to around 3km from the exchange, though this figure is very dependent on cable condition and routeing.

ADSL2 is a development of ADSL technology defined in ITU-T G.992.3, and adds an additional degree of robustness to the coding, while somewhat improving the achievable data rates (a maximum of 12 Mbit/s downstream and 3.5 Mbit/s upstream). It occupies the same frequency space as ADSL.

ADSL2+, on the other hand, makes use of spectrum up to 2.2 MHz and is defined in ITU-T G.992.5. This provides a significant increase in data rates available on shorter lines, giving data rates around 20 Mbit/s on lines of around 1.5km.

The latest xDSL technology, 'Very high speed DSL', or VDSL, is standardised in ITU-T Recommendation G.993.1 and allows for symmetric or asymmetric transmission, with data rates of tens of Mbit/s. This is primarily achieved by extending the frequency range used for signalling to 12 MHz.

VDSL is further extended as VDSL2 (Recommendation G.993.2), and can make use of frequencies up to 30 MHz (though band plans for such use have not yet been finalised – a BT variant proposes the use of frequencies only up to 7.05 MHz). A VDSL2 network using the full bandwidth would offer downstream data rates of some 100 Mbit/s at around 0.5km from the exchange.

Access via traditional cable networks

The cable industry in the UK has historically been fragmented, leading to a lack of investment and a consequently minor role in the delivery of either television or internet access compared with some continental countries. At the end of 2006, cable accounted for only 23% of all broadband connections[109].

Over the last two decades, consolidation has occurred, with the result that one company (Virgin Media) now provide virtually all cable services in the UK. Services are provided to the home over a

[109] From: http://www.ofcom.org.uk/research/cm/cmr07/telecoms/

hybrid fibre / coaxial network using the DOCSIS standard[110]. Virgin are currently upgrading their network to support 20 Mbit/s data rates.

The most recent DOCSIS 3.0 specification allows for the 'bonding' of multiple RF channels over a bandwidth of some 100 MHz, to allow data rates of around 160 Mbit/s.

Optical fibre access networks

BT is trialling optical fibre networks based on ITU-T Recommendation G.984. This describes 'Gigabit Passive Optical Networks' which are, essentially point-multipoint networks supporting overall data rates of 2.4 Gbit/s. A wide range of possible network architectures is possible, including 'fibre to the home' (FTTH), 'fibre to the building' (FTTB) and 'fibre to the cabinet' (FTTC); in the last two options, the final distribution would be by xDSL or other methods

Within FTTH, there is a choice to be made between point-to-point fibre, with a dedicated fibre for each end-user, and GPON, where 32 or 64 end-users share the split ends of a single fibre. Thus far, fixed incumbent operators which are considering FTTH roll-out have nearly all indicated that they prefer GPON. In contrast, most local government-funded networks have used point-to-point fibre. In either case, there is an opportunity to increase the bandwidth available over the fibre by one to two orders of magnitude using wave division multiplexing (WDM) over the next few years. The use of white light lasers may increase the bandwidth still further in the long term.

The main advantages of point-to-point fibre (relative to GPON) are as follows:

- Point-to-point fibre potentially allows virtually infinite bandwidth, while GPON offers currently up to 100 Mbit/s per customer and perhaps 2000 Mbit/s in the future with WDM technologies.
- A break in the fibre affects service to one end-user rather than to 32 or 64 end-users.
- Point-to-point fibre allows fibre unbundling in a similar manner to copper unbundling. This gives more incentives for technology innovation in the fibre access network.
- With GPON it is simplest to upgrade the technology used to light the fibre for all 32 or 64 end users simultaneously. Upgrading individual users is possible but not straightforward. With point to point fibre there are no such difficulties in upgrading the technology used by individual end users.

The main advantage of GPON is that it is cheaper to deploy, especially in brown field sites where ducts are close to capacity. In many cases, point-to-point fibres would require the use of new ducts, which are expensive to build.[111] GPON is also cheaper in terms of the number of optical line terminators required at the network end of the fibre. There are many fewer fibres to terminate when using GPON. There is disagreement between various suppliers and operators as to what this price difference is. Some claim it is a very small. Others suggest a difference of up to 30%.

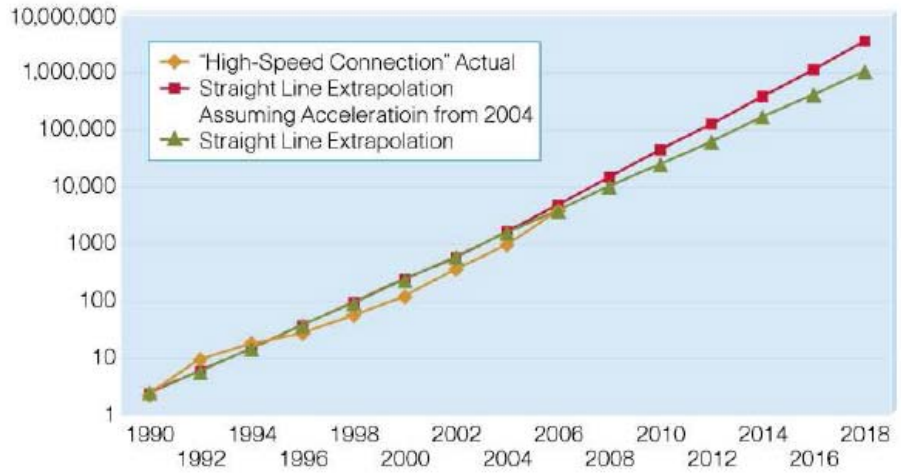
As a rule of thumb, the analysis above suggests that point-to-point fibre may be the best technological option in many greenfield situations, but GPON may be best for most brown field roll-out. However, a fixed incumbent might wish to use GPON for both brown field and greenfield rollouts so as to maximise its economies of scope.

[110] Initially developed by Cablelabs in the US, but since standardised in ITU-T J.112 and J.222

[111] A significant proportion of end-user premises are served by ducted cabling. Others are served by ducts from the cabinet to the pole and then by overhead or buried cable. Building new ducts, because of limited capacity in these existing ducts, adds very substantially to the cost of FTTH rollout.

H2O networks[112] have announced plans to roll out FTTH services using existing waste water conduits.

In summary, cable and fibre technologies face few technical bottlenecks in providing downstream data rates of over 100 Mbit/s. The major uncertainties relate to the economics of the roll-out of such networks beyond their current reach. xDSL techniques will always be disadvantaged by the variation of data rate that can be offered at different distances from the exchange, whether these are the 1-8 Mbit/s second currently typical, or the 20-250 Mbit/s that may be available using VDSL2. xDSL is also disadvantaged with regard to upstream data rates as it is generally limited to 0.5 Mbit/s or lower whereas fibre allows for symmetric bandwidth e.g. 20 or 50 Mbit/s upstream. This upstream distinction between the two technologies could be of importance if user generated content (which requires to be uploaded) becomes a significant element of entertainment traffic in the future.



Source: *FTTH Worldwide Market & Technology Forecast, 2006–2011*; Heavy Reading Report, June 2006

Nielsen's law of internet bandwidth states a high end user's connection speed grows by 50% per year. This law is based on data from 1983 to 2008 and has been confirmed and extrapolated by others (see graph above where the y-axis is kbps). If we take 10 Mbps as a reference point today the law suggests that over 33 Gbps would be available to individuals in 2028, implicitly confirming that the business case for fibre is there.

Core transmission networks

The previous section discussed the access network mainly because this is where current bottlenecks apply. The core transmission networks also need to be considered. Gilder's law is based on the observation around the year 2000 that network bandwidth tripled every 9 – 12 months. He then predicted that this would continue for at least 25 years. This implies that even if there is over capacity at any one time (e.g. dark fibre) the corresponding growth in traffic will catch up and the business conditions driving the further supply of capacity will prevail.

[112] http://www.h2o-networks.uk.net/

Satellite

The use of satellite for delivery of television services direct to the home came relatively late in the UK, largely owing to the very comprehensive coverage available from terrestrial networks (unlike, e.g., the USA or India). Since the launch of Sky television (later BSkyB, following the merger with the failed BSB operation) in 1989, penetration has increased steadily, with a current subscriber base of some 8.1 million. The original BSkyB digital transmissions made use of the DVB-S standard, which used fairly simple modulation and coding schemes.

BSkyB transmits services using the Astra 2 satellites at a position of 28.2° East in the geostationary orbit. These satellites use the Ku-band (12 GHz), and improvements in the noise performance of transistors at this frequency have allowed dish sizes to shrink to the point where they are (in Southern England) determined by the need to reject interference from other orbital positions rather than by sensitivity.

In principle, there should be little frequency congestion of satellite services, owing to the wide bandwidth available at 12 GHz, the use of polarisation discrimination, and the frequency reuse possible between orbital locations. In practice, the enormous installed base of domestic dishes aligned at the specific orbital position of 28.2°East places a significant premium on satellite capacity at this location.

This has led to the adoption of the DVB-S2 standard, which allows for higher order modulation and uses Low-Density Parity Check (LDPC) codes, allowing the performance in a Gaussian channel to approach within ~0.5dB of the Shannon limits (compared with ~2.5 dB for DVB-S). The use of this standard, together with MPEG-4 coding enabled the launch of the Sky-HD services in 2006.

A technology that was much-discussed two decades ago, but which has not proved significant to date, was that of the flat-plate satellite receive antenna. The original BSB service made much marketing play of the iconic ‘squarial’, which was used a phased array to synthesise an appropriate antenna response. In the event, though the device was relatively unobtrusive, it did not offer any significant technical advantage, and manufacturing problems delayed the launch.

A few years previously, the BBC had invested significant resources in research work on *steerable* flat plate antennas. At the time, significant problems were associated with affordable manufacturing methods and with the reduction of spurious sidelobes. If, however, a low-cost steerable antenna of this type could be developed, it might open the way to a much more efficient use of orbital resources, without the cumbersome and expensive solution of motorised dishes.

While satellite is a very attractive delivery medium for broadcast services, it rapidly becomes uneconomic for delivery of interactive or truly on-demand content. The lack of a return path is also a problem for many applications. As a consequence, BSkyB require that their set top box is connected to a BT socket, either to provide the full ‘Sky Broadband’ package over ADSL, or, as a minimum, to allow the subscriber management system to operate.

Satellite capacity for broadcast TV is limited not so much by the spectrum available and the corresponding in-orbit transponder capacity but by the installed base of user receive antennas pointing at a single orbital slot. This limits the channels to the number that can be supported by the spectrum available at that slot (currently over 550 free and subscription channels, including 12 high definition channels). This barrier has long been recognised in the US where various techniques have been used to allow a user antenna to obtain signals from more than one satellite located in different orbital slots. It is notable that Astra are now promoting a user antenna with a “duo-LNB” which allows

reception of their satellites in the two orbital locations at 23.5° and 19.2°. It can be expected that a similar arrangement could be made with respect to the main orbital slot used by UK consumers at 28.2° should the need arise for additional capacity. This method enables the doubling of capacity available and can probably be applied in further increments thereby securing sufficient capacity for the timescale of this study.

Terrestrial broadcast

UK analogue television services, which started in 1936, will have completed their pattern of regional closure by 2013, while digital terrestrial TV (DTT) transmissions (using the DVB-T standard) have been broadcast since 1998. This transition of 14 years is comparable to that from the start of UHF colour services in 1967 to the closure of the monochrome VHF network in 1984.

The use of the DVB-T transmission standard, coupled with MPEG-2 video compression, allowed a dramatic increase in spectral efficiency as some 4-5 programmes could now be radiated in the 8 MHz of spectrum previously occupied by a single channel; furthermore, the reduced protection ratios required by DVB-T allow a greater density of frequency re-use.

Capacity in the DTT network is constrained, during switchover, by the need to maintain a parallel analogue network, and to avoid mutual interference. However, even when these constraints are removed, the capacity provided by the DVB-T/ MPEG-2 combination would be insufficient to support more than a single HDTV programme per UHF channel.

To improve the capacity of DTT networks, a new standard, DVB-T2, has recently been finalised. This incorporates more efficient coding methods, and a more flexible selection of modulation options, to improve spectral efficiency by some 30%. Coupled with the use of MPEG-4 video coding, this should allow 3-4 HDTV programmes to be accommodated in a single RF channel. A significant problem for broadcasters and regulators, however, is that such new services will be denied to the large population of those with existing DVB-T / MPEG-2 receivers (i.e. existing set top boxes and those televisions with built in digital receivers currently being sold), the majority of which will have a significant lifetime. The consequent requirement for simulcasting will, for many years, offset the efficiency gains of the new techniques.

Similar considerations apply to the use of another new transmission technology. ‘Multiple Input, Multiple Output’, or MIMO techniques make use of the fact that signals from, or arriving at, physically separated antennas will be, to a greater or lesser extent, uncorrelated. The availability of cheap and powerful processing power in receivers offers the possibility of separating multiple data streams transmitted between such groups of antennas over the same spectrum. The technology is already quite widely used for wireless computer networking, and is staring to be applied to mobile networks. A variant has been proposed [4] for fixed broadcast transmission which makes use of polarisation diversity which would offer a near doubling in spectrum capacity. As the use of the method would, however, require the re-engineering of all 1,100 DTT transmitters, and (probably) the replacement of all domestic receive antennas the technique is not likely to be applied for broadcast use in the near future.

The current six DTT multiplexes are capable of supporting 8 standard definition TV channels each using current MPEG-2 technology. If the move to MPEG-4 were to be achieved successfully then there would be the potential to support 4 high definition TV channels per multiplex or up to 20 standard definition TV channels in the longer term.

At switchover, if the broadcasters do not secure any further spectrum, national terrestrial broadcasting capability will only ever achieve 24 high definition channels based on MPEG-4 unless significant advances in compression technology are achieved.

Much attention has been focussed, in recent years, on technologies enabling the delivery of broadcast television services to mobile devices, especially to mobile phones. The main competitors in this are:

- DVB-H, a new standard from the DVB organisation which is an evolution of DVB-T offering lower power consumption due to time-slicing;
- DMB, which is based on the physical layer of DAB (Eureka 147)
- MediaFlo, a proprietary system from Qualcomm

All of these technologies employ COFDM, and, although initially targeted at different parts of the spectrum, could work in a number of frequency bands. Operational networks or trials of all three systems, and others, are currently on-air but results, both in terms of commercial success and the quality of service delivered are, at best, mixed. Although exhaustively debated, there is little to choose between the systems from a technical point of view.

The fundamental problem with these services, regardless of the technology, is that to deliver the QoS expected by consumers, very dense networks of transmitters are required, demanding significant investment for a commercially-unproven proposition. One approach which has been adopted in Korea, and is proposed elsewhere, is to make use of a mixed satellite-terrestrial infrastructure, with the former providing blanket coverage of a large area to terminals used outdoors in rural or suburban areas and with dense terrestrial networks in urban areas providing indoor coverage.

An intermediate approach has been adopted in some areas (e.g. The Netherlands and some German Länder) in which the DVB-T services that have replaced analogue television have been targeted at mobile and portable users, employing vertical polarisation, low-order modulation and medium-density transmitter networks. This approach has generally been adopted in regions where the domestic use of terrestrial television is low due to the widespread adoption of satellite or cable services. The initial assumption was that main users of these services would be campers and caravanners, those with receivers fixed in (the back seats of) cars and secondary sets in, for example, children's bedrooms. Some mobile phones are now being produced, however, with integrated DVB-T receivers (despite the relatively poor battery life compared with bespoke mobile TV technologies).

Cellular and wireless LAN networks

The majority of cellular phone use is still via GSM networks, but take-up of 3G services is accelerating. Of particular interest is the rise in popularity of 'broadband wireless dongles' used to provide internet connectivity to laptops and typically connected over a flat rate tariff.

Despite the initial promotion of 3G as offering data rates of 2 Mbit/s, actual rates are generally less than 384 kbit/s. Since the autumn of 2006, UK networks have been upgrading 3G networks to offer maximum download rates of between 1.6 and 3.6 Mbit/s.

A great deal of effort is currently being invested in the definition of the next generation of cellular standards, dubbed 'Long Term Evolution' or LTE. As the name suggests, thinking within the industry has tended to move away from the concept of a jump in technology to a '4G' system, to a more flexible and gradual adoption of new technologies.

Some of the highlights of LTE are the use of MIMO techniques (see above) and the more flexible use of available spectrum resources, freeing operators from the need to identify spectrum in integer multiples of 5 MHz, with appropriately-spaced duplex bands. LTE will also support a single frequency network 'multicast' mode, offering another technology candidate for the delivery of mobile television. An aim of the project is to support peak downlink data rates of 100 Mbit/s in 20 MHz of spectrum. By 2028 it is likely we will have moved or evolved into the generation after LTE usually designated as 5G. It can be expected that peak download data rates will have been improved further to some hundreds Mbit/s (Edholm's law predicts over 100 Mbit/s for mobile devices in 2028) through wider bandwidths, channel bonding or improved modulation likely allied to smaller cell sizes. Furthermore, it is likely that if user generated content has taken off, more attention will have been paid to the uplink data rates which are usually the poor relation of the downlink mainly because of lack of demand but also because of power implications for the portable device.

An apparent competitor for the growing mobile data market is the growing availability of WiFi hotspots, using 802.11 technologies in (predominantly) the 2.4 GHz band. Such services are widely used in public buildings and spaces, and increasingly on public transport (the London-Brighton train service used track-train links at 5 GHz to support 2.4 GHz connectivity within the carriages). Although there are now over 11,000 such public 'hotspots' in the UK[113], significant limitations attach to such 802.11 networks, particularly regarding range and mobility.

WiFi is increasingly regarded as a complement to, rather than a competitor for, cellular. WiFi capability is increasingly being included in cellular devices, for example O2 has done a commercial deal with BT and the Cloud already which allows O2 users to access WiFi rather than cellular networks when they are in range. At the same time it also notable that some cellular operators have blocked the ability to use Skype over WiFi, when provided, due to potential loss of revenue.

WiMAX (IEEE 802.16) networks offer improved range and flexibility for fixed and nomadic data users, and the 802.16e standard adds mobility; as WiMAX offers both TDD and FDD options, and is based on OFDM technology, it is clear that convergence in techniques, if not in name, is gathering speed in the mobile world.

In-home distribution

As a wider range of entertainment, media and gaming devices are found within the home, so there is potentially a greater need for means of distributing content easily between devices.

In particular, if a home is connected to a high-bandwidth 'pipe' (xDSL, fibre, satellite) it is likely that access to the connection will be required by many devices (PC, televisions, radio, portable and mobile devices). Currently, such connectivity is most commonly achieved through the use of 2.4 GHz wireless LANs, using 802.11 standards. Such systems have a footprint that will cover smaller houses quite adequately, and provide data rates of up to 54 Mbit/s.

Congestion is growing, however, and though the 802.11 standards work robustly in the presence of interference, the reduction in available capacity, coupled with the growing bit-rate demands of applications such as HDTV suggest that other methods of in-home distribution may need to be found. It is notable that BT's broadband package, that includes the provision of video on demand over the internet, uses devices that support networking over mains supply wiring rather than a wireless link to

[113] Source: Ofcom

the wireless router that is also provided as part of the package. This indicates that the current state of Wi-Fi systems is not adequate for the streaming of video.

Some newly built houses include Ethernet cabling, but such homes will always represent a small fraction of the housing stock. Furthermore, users are increasing expecting wireless access, at least for smaller devices.

A considerable degree of hype marked the standardisation and regulatory processes associated with Ultra Wideband (UWB) systems a few years ago, but penetration into the consumer domain has, to date, been minimal. While UWB will offer very high bit rate connectivity over short ranges, it is unlikely to provide an appropriate solution to allow devices to roam throughout a household. While UWB might offer a means of connecting, say, a Blu-ray player to a large flat screen display mounted on a nearby wall, as the two devices will still require relatively bulky power cables a further data connection may not be a great constraint.

Proposals have been made that some of the spectrum capacity freed up by digital switchover (the 'digital dividend' spectrum) might be reserved for in home distribution. This UHF spectrum might initially seem attractive, as floor and wall penetration losses are lower than at higher unlicensed frequencies; unfortunately, the same low losses apply to interference between houses, and the amount of spectrum available is rather limited in the context of future entertainment-related bit-rates.

The (draft) 802.11n standard, which employs MIMO techniques (see above) can offer data rates of over 200 Mbit/s potentially over hundreds of metres in the open air and about 70 metres indoors on average. The final version of this standard is expected in 2009.

Edholm's law suggests that data rates for fixed (wired), nomadic and mobile communications increase on similar exponential curves with the slower rates trailing the faster ones by a predictable time lag. Continuing current trends would see nomadic rates of 10 Gbit/s by 2028.

Clearly the 2.4 GHz band would be unable to support this using current technology and channel bonding which would provide 600 Mbps and there will therefore come a time (partly already anticipated) when the already available 5 GHz band will be used. There is far more spectrum available here, and therefore increased opportunities for channel bonding if required, but propagation conditions are not as benign so ranges will not be as great (although MIMO will assist). The use of much higher frequencies is also possible but this would likely have to rely on an associated wired network throughout the house.

Overall, it is highly likely that a mix of one or more of the following technologies will exist within the home by 2028; wired, short range very high data rate wireless at 1000Mbps+ and longer range several hundred Mbps wireless.

Internet

The technologies described above relate to the 'Physical Layer' of a network, while 'the Internet', or elements thereof can be carried on a wide range of digital bearers.

Of particular relevance for the current project is to estimate the rate of roll-out and adoption of IP v.6. This revision of the current standard allows a very dramatic expansion in the number of unique

addresses available (by more than seven orders of magnitude). Apart from securing future growth in connectivity[114], this vast address space will allow more efficient network hierarchies to be employed.

The use of IP v.6 was mandated in the USA for all Federal agency backbone connections, while China has a five year plan for v.6 adoption. It might be expected that more widespread adoption will follow, and certainly within the relatively near future, as it is expected that addresses under IP v.4 will run out in a matter of years.

While addressing space should therefore not be seen as a constraint in the future it is perhaps worth noting the other possible constraints on keeping pace with 50%+ annual growth in Internet traffic predicted by Cisco. They are:

- The processing power of routers. This is not a problem while Moore's law holds (see earlier) and in any event development is already underway to undertake switching using meta-materials which avoids a lot of the signal translation activities that currently go on.
- Transmission in the core network. As noted earlier Gilder's law implies transmission is not a constraint.

C5 Power supplies

Batteries or, strictly, cells, fall into the two broad categories of 'primary' disposable cells and 'secondary' rechargeable units.

Primary cells can be categorised by the materials used for the anode and cathode, with the cheapest examples using zinc-carbon (anode and cathode respectively) construction. The use of different electrolytes gives different electrical properties, with ammonium chloride in basic cells, zinc chloride in 'high power' units, and potassium hydroxide in 'alkaline' cells. All these cells have a terminal voltage of 1.5, and a current capacity largely determined by the physical dimensions of the electrodes. Lithium cells use this material as the cathode, giving a higher terminal voltage, with reduced weight, higher energy density and longer shelf-life. Typical lithium cell applications are as computer memory back-up batteries.

In the context of the entertainment industry, rechargeable batteries are probably more significant. The first secondary cell was the lead acid battery (lead electrodes and sulphuric acid electrolyte). Although having a very low energy to weight ratio, these are still universally used as car batteries and for standby lighting circuits, application in which their ability to supply large surge currents are valuable.

More useful for small devices are Nickel-cadmium (Nicad or Ni-Cd) and Nickel-Metal Hydride (Ni-MH) cells, both of which have a terminal voltage of 1.2. Nicads have a relatively low energy density, and have been losing market position to Ni-MH cells (A Nicad C-size cell has a capacity of some 2.0 Ah compared to ~3.5Ah for the NiMH equivalent)

While Nicad and NiMH cells are popular for small devices with user-replaced batteries, for applications where size and weight are particularly important, Lithium-Ion (Li-ion)cells have come to dominate the market. These have a carbon anode, a metal oxide cathode and use lithium salt as the electrolyte, giving terminal voltages around 3.3 – 3.6. Energy density is high, and improvements are currently being made to the performance of Li-ion cells through nanotechnology.

[114] Some estimates suggest that the existing address space will be exhausted by 2011.

Despite this, it appears that no dramatic increase in the energy density of rechargeable cells is foreseen. The capacity of Li-Ion cells only doubled[115] in the ten years from 1995, while processor power increased by two orders of magnitude.

As an alternative to increasing capacity, manufacturers such as Toshiba are working on reducing the charge time of batteries. Toshiba's 'Super Charge ion Battery' (SCib) was launched, for industrial applications in 2007. These devices can recharge to over 90% capacity in five minutes, and have a useful life of some 6000 cycles. Currently, however, the power density of these devices is less than half that of the Lithium-Ion batteries typically used in laptops and mobile devices.

Fuel cells, which are a promising alternative to conventional batteries, have been researched for many years and yet have never made the breakthrough to consumer electronics. It is likely that the direct-methanol fuel cell (DMFC) will be the first to be introduced to the consumer market on a widespread basis and this is potentially imminent[116]. Toshiba's investment plan states that it will be making such cells for mobiles and laptops within a year and Sharp has developed techniques to fabricate fuel cells that are the same size and have the same electrical capability as lithium-ion batteries currently used in mobile devices.

Although methanol might be regarded as unsafe (i.e. inflammable and / or explosive) it is notable that US authorities are planning a rule change for aircraft to come into effect from 1st October 2008 that would allow passengers and crew to bring fuel-cell-powered electronic devices and one or two fuel cartridges on board in their carry-on luggage.

Note however that others are not as optimistic about fuel cells. The CEO of a Taiwan-based fuel cell manufacturer when asked "Will it *[fuel cells]* ever be a viable consumer product?" responded "I don't know. Technically it's possible, but batteries are very good."[117]

Overall, there is some uncertainty regarding the viability of fuel cells, although some of the signs indicated above are good. If successful they will open up the capability of portable devices significantly not only because of the improved energy density in the longer term but also because the convenience of recharging as this is achieved by a simple refill of methanol – this can be done anywhere and does not rely on being near an electrical source.

In the event that fuel cells fail to materialise as a power source for consumer items it is anticipated that the rate of improvement in power to portable devices could be a significant constraint. It is noted that the introduction of new technologies often coincides with consumers justifiably complaining about short battery life but the problem is usually subsequently resolved through better device integration and improved internal power management. However when it comes to portable devices transmitting significant amounts of data wirelessly the energy per bit requirement could become a significant demand on the power source unless the requirement is ameliorated by reducing the range of transmission (e.g. smaller receive cell sizes).

C6 Search, recommendation & metadata

In parallel to the manipulation of raw broadcast content, the generation, processing and transmission of 'metadata' is of increasing importance.

[115] http://www.nxtbook.com/nxtbooks/cea/5techstowatch/index.php?startid=20

[116] Consumer fuel cells – In search of forever. The Economist 12th June 2008.

[117] Fuel cells still years away for mobile devices. SearchMobileComputing.com - 30th April 2008.

Such metadata may be as simple as the 'service information' (SI) transmitted with a programme stream, or an electronic programme guide (EPG), but is increasingly likely to involve information mapping complex relationships between a wide range of multimedia objects, and to include elements related to search, archiving and recommendation, and to digital rights management (DRM). Service information, EPG and interactivity

One of the major benefits of digital television (and, indeed, radio) is that service-related data can be tightly integrated with programme material, aiding navigation, recording and interactivity.

The DVB standards define the format of Service Information (DVB-SI), which not only allows the receiver to address the required programme data from within a transport stream, but also provide the

User interaction with digital TV equipment and services requires mediation through software providing graphical interfaces and other tools. Even within the world of European terrestrial broadcast TV there are at least two platforms, both of which are used by DTT receivers in different markets.

In the UK, the MHEG-5 platform was adopted for DTT, largely because it was available at the relatively early launch of the original ON Digital platform. An enhanced version is also used for the Freesat service. A separate platform, developed directly by the DVB project, the Java-based Multimedia Home Platform (MHP) is increasingly used elsewhere, and offers greater functionality. Other platforms use other technologies – the proprietary 'OpenTV' platform is used for the BSkyB digital satellite service.

While such software allows user interaction with broadcast content, true interactivity is often assumed to involve the use of a return channel from the viewer or listener. While clearly straightforward in the case of cable systems, or broadcasting delivered to mobile phones, such return channels for satellite or DTT generally require a wired return link, generally over the domestic phone line. Some proposals exist for return paths provided by low-powered UHF transmitters (DVB-RCT) or by VSAT uplinks.

Digital rights management (DRM)

The management of copyright and IPR is a key issue in understanding and predicting the future of entertainment services. It is also a fearsomely complex area, cutting as it does across commercial, legal, engineering and consumer-behavioural fields.

One of the earliest cases to bring issues around DRM into the public forum was that of the file-sharing application, Napster, This application allowed users to share mp3 music files, bypassing the usual sales network and leading to claims of copyright infringement, upheld in court.

Currently, the most popular legitimate source of music (and other) download is the Apple 'iTunes' service, the content of which is rigorously protected by a proprietary DRM system, 'fairplay', which prevents users from playing downloaded files on unauthorised devices.

Broadcast systems have significant issues with DRM; at one level, organisations will have acquired the broadcast rights to a film or sports event pertaining only to specified territories. Particularly in the case of satellite services, they may be obliged either to limit the footprint of the satellite beam, or to restrict viewing, by way of encryption, to a closed user group (e.g. BSkyB, Freesat). It seems that some of the current operators offering Mobile TV services have had difficulty enforcing such limited access, and have had to restrict their offering of some sports coverage as a result..

A related issue is that broadcasters may wish, or be required, to limit the ability of viewers to record material; In the era of analogue video recorders, the ability of an individual to make multiple VHS

copies of broadcast material was of little commercial significance. With digital video recorders is it straightforward to make lossless copies of the broadcast material which may then be disseminated, either as DVD copies or, more likely, via file-sharing websites.

In the US, a system was mandated by the FCC in which HDTV content that was required to be protected would be identified by a signal (the 'Digital Broadcast Television Redistribution Control', often referred to as the 'Broadcast Flag') that would inhibit digital copying. In 2005, however, the FCC rule was overturned by a US appeals court.

Within the DVB project, somewhat similar functionality is made available through DVB-CPCM, ('Content Protection and Copy Management' system) which responds to signals contained within an updated version of the DVB-SI.

Search and recommendation

The growth of linear, broadcast TV channels alone, particularly on satellite or cable platforms, poses problems for viewers seeking to make an optimum choice of viewing. In the case of those browsing the internet for video content, or wanting to browse downloadable mp3 files, the choice is overwhelming.

This situation will get worse in the future, and will have an impact on a wide number of players; the BBC has ambitious plans to make much of its archive directly available on the internet, and intelligent search applications will probably be central to such offerings.

The MPEG-7 standard allows for the searching and querying of audiovisual content while MPEG-21 seeks to link multimedia resources that may be associated with different media, networks and devices. Rights management is an important element of the latter standard.

C7 Conclusions on technology developments

Perhaps the single most significant change in the past decade has been the availability of significant processing power at low cost, which has allowed the efficient compression of source material. While there appears to be no dramatic change in the algorithmic approach to compression in the offing, Moore's law will allow coding to become more efficient as greater areas of the picture can be coded simultaneously, and interpolation can be made over a greater number of frames. A year on year improvement in coding efficiency of around 5-7% has been suggested in [1].

A more recent, but potentially equally significant trend, has been the availability, and eager adoption, of much larger TV screens. Currently it seems that the public may not be very distracted by quality, as there seems to be a surprising tolerance for the coding artefacts revealed, particularly on standard definition material by these large displays.

This may not persist, particularly if broadcast content is increasing judged against content from Blu-Ray discs and other high quality sources. If viewers become more discriminating, this may offset the gains in coding efficiency discussed above.

It appears that broadcast delivery, on a global basis, is perhaps moving to a less standardised world; for example radio services may be delivered by DAB, DAB+, DRM, DMB or DVB-H in addition to FM and even AM transmissions. For mobile TV there is completion between MediaFLO, DVB-H, T-DMB and S-DMB, as well as 3G cellular technology. This fragmentation of the market may result in

extensive simulcasting to small audiences, and to technical inefficiencies due to the use of multiple technologies in the same or adjacent spectrum.

Memory capacities and prices continue to fall, with individual NAND Flash chips available with 128 GB capacity. Hard drives, however, continue to offer a significantly better price/capacity ratio.

In a 20 year timeframe, the most significant technological uncertainties are whether 'Moore's Law' will continue to apply as current techniques become limited by quantum effects, and what impact the increasing application of nanotechnology will have in areas as diverse as memory fabrication, display devices and battery manufacture.

C8 The capability of handheld devices in 2028

It is the author's view that the pattern of entertainment consumption is unlikely to be constrained by technology, but rather by consumer demands and by sector funding models.

Many areas of technology development have followed exponential capability trends (e.g. Moore's law). It is, however, increasingly foreseen that quantum effects will limit the packing density (and hence the economy) of semiconductor chips in two or three product generations.

For example, if the current rate of growth is maintained to 2028, individual NAND Flash memory chips will have a capacity greater than 100 Petabytes (100,000,000 GB). On the other hand, if the quantum fabrication limit is reached by 2012, the capacity would be 'only' 2 TB. The latter figure is adequate for the storage of some 400 standard definition movies at current compression rates – noting that significant improvements in compression rates (e.g. order of magnitude reduction) are not expected in the future. If HD and / or 3D were to be used on mobile devices this capacity constrained storage would be adequate for 100 – 300 movies.

The device will have a potential downlink data rate of over 100 Mbit/s, though this will be very dependent on available networks. Connectivity to a range of network types will be possible, with the majority (or all?) of the transceiver functionality implemented in software. The 3G LTE and WiMAX technologies that are currently under standardisation will be reaching the end of their life, perhaps having been superseded by ubiquitous pico cells and/or femto cells fed from the greatly expanded fibre network.

Display sizes, and hence resolution and bit-rate, will continue to be limited by device form factor though OLED technology is likely to reduce the power burden associated with large, bright displays. Projection techniques may be used, but the likely power demands, coupled with the need to identify appropriate surfaces seem likely to limit the adoption of such techniques. Wearable displays (glasses or contact lenses) may be an alternative route to higher resolution, but with obvious safety concerns.

The main area in which technology may continue to be a limiting factor is likely to be battery life. However there is a reasonable chance that the introduction of fuel cells will remove this limiting factor.

The functionality of the hand held device will undoubtedly be many and varied. However it will not be so radically different from some of the more sophisticated devices currently available. Firstly in terms of size, there seems little point in having devices much smaller than they are today unless we move away entirely from some of the user interfaces currently used. From the vision point of view there is an argument for having a larger size for a better screen although this is likely to be accommodated by some implementation of flexible screens.

Manufacturers and network operators claim that there will be huge differences but closer examination shows that many of these differences are just more of the same based on more storage and greater processing power. The main differences, supported by this greater storage and processing power, are likely to be:

- Multiple options for display which could include larger (flexible screens), eyewear and projectors
- Alternative user interfaces e.g. voice control and recognition
- The ability to interoperate with a wide range of other devices eg medical devices used for monitoring – in effect a personal gateway.

C9 The capability of home networks in 2028

The most reliable form of home networking would in theory be supported by Ethernet or fibre optic cable. Realistically this will only happen in new build houses and consequently will never be a widespread solution. Transmission over mains wiring offers a useful alternative but, like wireless is prone, to noise / interference. In any event, consumers have greater expectation of untethered connections offered by wireless.

Although current short range wireless connections in the home are adequate for video streaming in terms of data rates supported, the quality of service on the link in terms of delay and jitter (delay variation) is not adequate. Developments in WiFi standards (802.11n and beyond) aim to improve the quality of service on wireless links in the home and at the same time improve the data rates supported over longer distances with shorter distances potentially being supported by UltraWideBand devices and potentially systems operating at much higher frequencies. In addition efforts are currently being made to eliminate the black-art aspect of networking in the home environment by concentrating on more automated interoperability and network set-up as promoted by the Digital Living Network Alliance.

Assuming that the quality of service issues associated with wireless connections are resolved by work that is currently going on, it is expected that within the longer term timescale being considered by this study there will be no technology and / or capacity constraints preventing the distribution of high definition / 3D video material around the home.

C10 The capability of platforms in 2028

There are four main platforms to consider:

- The terrestrial broadcast network – there is a significant legacy investment in this means of providing broadcast material. In terms of additional capacity were it to be required, there are no constraints (at least in the near term future[118]) in terms of spectrum apart from whether the business case could justify it. From a technology point of view satellite distribution (see below) is more efficient. Opinion is divided as to whether the terrestrial broadcast network will be switched off in favour of a more efficient platform for the delivery of HD channels or because viewing habits move away from linear programming towards material on demand.

[118] If DTT gets no UHF spectrum in auctions in 2009 and demand for HD is strong the broadcasters will have to go to the market and obtain spectrum there.

- Satellite broadcasting – this has been established very successfully within the UK since 1990, not least as the result of significant investment. Satellite broadcasting is undoubtedly a very efficient way of delivering broadcast material over wide areas but not as good for the distribution of on demand programming to individuals. In terms of additional capacity the main constraints are that the capacity exists at a single orbital slot[119] and, once again, whether the business case can justify the need for extra capacity.
- The wireless network – this is considered to include all networks available to the general public including current and future technologies such as GSM, 3G, WiFi, WiMAX, DVB-H, LTE etc. Headline data rates attached to future developments in these networks are high and run to 100 Mbps. However, it must be noted that these are peak rates relating to a user close to a base station. The reality is that the average capacity of a cell is much lower and there will be multiple users. Providing user devices continue to be relatively undemanding as a result of a small screen, size network capacity will not be a serious issue. However, if screen size increases and resolution gets better demands on the wireless network will be great. It can however be expected that the generation beyond LTE will increase the peak data rate to several hundred Mbps as suggested by Edholm's law. Also, depending on how viewing habits change the balance between on demand and linear programming will determine the degree to which mobile broadcast TV is successful in relation to the other networks. Finally, if user generated content becomes a big generator of uplink traffic and given possible power constraints associated with portable user devices, it may be necessary to adjust architectures to accommodate shorter uplink ranges..
- The wired network consists of the access network and the core network. The access network is considered to include technologies supported by copper (e.g. DSL variants and cable standards) and fibre. There are clear limits to the capabilities of the DSL family and the provision of higher speeds is far from uniform because of the distance constraint. Implementation of fibre in one architecture or another would improve the situation in terms of higher speeds and uniformity of availability depending on the architecture. There are no technology constraints pertaining to the implementation of fibre across the UK. The constraint relates solely to the business case when impacted by the regulatory situation. While the current position makes it look as if fibre might never happen it is generally considered that it will be relatively ubiquitous by the end of the timescale being considered by this study if not sooner. Insofar as the core network is concerned traffic is growing at 50 to 60% per annum. Gilder's law accommodates this growth rate comfortably and currently Moore's law and traffic growth are in step. A breakdown in Moore's law could limit the capacity of the Internet but moves are already afoot to undertake switching without using conventional processors.

C11 Summary

By way of summarising the technology situation relative to the timescale being considered by this study, the table below outlines what can be expected in terms of future capability and what constraints might exist.

[119] Capacity is readily available at other orbital slots but this would require consumers to have multiple, motorised or multi-feed dishes.

C12 References

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Technology	Technology position	Constraints
Devices	Processing power, storage and display will pose no constraints unless quantum effects prove insurmountable and alternative approaches do not substitute with continuing improvements. Wireless downlink capability not constrained by device, more by network capacity. Wireless uplink capability possibly constrained by power requirements (see opposite).	Possible constraint from battery power unless fuel cells become widespread in consumer devices.
Home networking	Wired limited to new build. Transmission over the mains able to provide significant and useful capacity in some but not all cases. Wireless not sufficiently capable for video at present. Higher throughput and quality of service sufficient for HD streams expected over the next 5 years.	Capability constrained in the near term both in terms of capacity, reliability and usability. Longer term these will be overcome but there will always remain some performance deficit compared to a wired connection.
Platforms	Terrestrial broadcast – legacy system. Not constrained by technology except insofar as the installed user base prevents anything but slow change.	Constrained by the business case and installed user base (see opposite).
	Satellite broadcast – Has demonstrated the efficiency of this method of broadcast delivery. No technology constraint going forward.	Constrained by the business case and the current single slot situation.
	The wireless network – Many different types of network but principally either broadcast or two-way. User behaviour will determine which one predominates. Unlikely to be a spectrum issue for the broadcast type but could be for the two-way networks depending on what the user wants to do. Not so much a technology issue as bitrates etc are expected to improve significantly, but capacity provisioning could be difficult particularly on the uplink if this is required in quantity.	Constrained by the business case and in particular how to provide the necessary network capacity within a given amount of spectrum
	The wired network – capability of copper limited. Implementation of fibre in whatever architecture not constrained by technology. Fibre expected to be relatively ubiquitous by the end of the timescale being considered by the study – but note comment opposite.	Constrained by the business case in relation to regulatory issues.

C13 Glossary

ADSL Asymmetric Digital Subscriber Line. One of a number of technologies that use existing 'local end' analogue telephone connections to provide digital services (in this case with a higher speed to the customer than from the customer, hence asymmetric). Also ADSL2.

COFDM Coded Orthogonal Frequency Division Multiplexing. A modulation technique that spreads the transmitted data over a wide bandwidth, using a large number of subcarriers each modulated at a relatively low data rate. The technique can be very resistant to multipath interference.

CRT Cathode Ray Tube

DAB Digital Audio Broadcasting. A standard, also known as Eureka-147, for broadcasting, using COFDM and MPEG coding (q.v.), The standard allows for transmissions at frequencies of ~200 MHz and ~1.5 GHz.

DCT Discrete Cosine Transform. A mathematical technique for coding (spatial) frequency information, e.g. in a television picture

DIRAC A BBC open-source picture coding algorithm. Not an acronym, but named for the British theoretical physicist.

DMB Digital Multimedia Broadcasting. A Korean standard that built on the radio frequency modulation and coding system of DAB, but uses MPEG-4 video and audio coding to allow both radio and TV broadcasting to portable devices. Both terrestrial (T-DMB) and satellite (S-DMB) variants have been developed.

DOCSIS Data Over Cable Service Interface Specification. The standard used to provide broadband connectivity over 'Cable TV' connections.

DRM (1) Digital Rights Management (2) Digital Radio Mondiale, a standard for digital radio broadcasting at frequencies below 30 MHz (since extended to 120 MHz0

DVB The Digital Video Broadcasting Project is an industrial consortium, founded in Europe, that has been responsible for a wide range of inter-related broadcast standards, such as DVB-T for terrestrial television and DVB-S for satellite services.

DVD Digital Versatile Disc (originally Digital Video Disc).

FCC Federal Communications Commission (US)

FED Field Emission Display

FTTH Fibre To The Home. A direct optical fibre connection to individual households.

FTTC Fibre to the Cabinet (or 'Curb' in US English). A shared optical fibre connection from a hub to a point near to a number of homes. The final few metres of the connection to individual premises is by means of copper cable.

GPON Gigabit Passive Optical Network. A point-to-multipoint optical fibre network, using passive splitters, conforming to ITU-T Recommendation G.984.

HDTV High Definition Television

IEEE Institute of Electrical and Electronics Engineers (US)

IP Internet Protocol. A standard for the transmission of data in the form of addressed packets.

IPR Intellectual Property Rights

ITRS International Technology Roadmap for Semiconductors. A collaborative effort by the semiconductor industry

ITU International Telecommunications Union, a Specialised Agency of the UN, which includes the 'Telecommunication' (ITU-T and ITU-R) sectors.

Laws The following are, clearly, not 'laws' in the scientific sense, but assertions based on observation of historical trends. In the case, at least, of Moore's Law the revised assertion, made in 1975 has proved remarkably accurate.

Moore's law a doubling of optimum density of components per integrated circuit every year (later revised to two years, and often taken to predict a doubling in *performance* every 18 months)

Nielsen's law 50% increase in (high-end) internet connection speed each year

Gilder's Law 'Network bandwidth' grows 3x faster than computing power

Edholm's Law The data rates available via wireless, nomadic and wireline technologies increase according to similar exponential curves, offset in time.

Rudd's Law the number of 'laws' invoking exponential growth will tend to increase exponentially with time.

LCD Liquid Crystal Display

LNB Low Noise Block. The part of a satellite TV receiver mounted at the focus of the dish. This will generally comprise a low-noise amplifier and a frequency converter to shift the signal to a frequency of around 1 GHz for transmission via cable to the remainder of the receiver unit.

LTE Long Term Evolution. The next-generation standard for mobile communications from the 'Third Generation Partnership Project (3GPP), the developers of the UMTS standard.

MHEG-5 A software platform standardised by the Multimedia/Hypermedia Experts Group of the International Standards Organisation (ISO) enabling the carriage of interactive content on digital television.

MHP Multimedia Home Platform. A software platform standardised by the DVB (q.v.) enabling the carriage of interactive content on digital television.

MIMO Multiple Input Multiple Output. A radio transmission technology in which the limited orthogonality between a number of physical transmission paths is exploited by coding at the transmitter and sophisticated signal processing at the receiver.

MLC Multi-level cell. A technique in semiconductor memory in which an elemental cell can store multiple bits by using more than a single threshold voltage.

MPEG Motion Picture Experts Group. A standards-setting body working in the field of video coding and associated metadata.

NAND An architecture for semiconductor memory, in which elemental cells are connected in a way analogous to a NAND (not-and) logic gate

OLED Organic Light Emitting Diode (display technology)

PAL Phase Alternation (Line) An analogue coding method by which colour information may be added tom a monochrome signal in a way that was compatible with existing monochrome receivers. The phase alternation technique avoided the errors in Hue associated with the earlier NTSC (waggishly dubbed '*Never Twice the Same Colour*') system.

QAM Quadrature Amplitude Modulation. One method of imposing digital data on a 'carrier' signal.

QoS Quality of Service.

UHF Ultra High Frequencies. Frequencies between 300 MHz and 3000 MHz, but often used to indicate the spectrum currently allocated to broadcasting at 470 MHz – 862 MHz

UWB Ultra Wide band. Generally used to refer to wireless technologies allowing very high data rate connections over short (~10m) distances)

VDSL Very High Speed Digital Subscriber Line (see ADSL)

VHS Video Home System. The dominant system for domestic analogue video recording, developed by JVC in the 1970s.

VRML Virtual Reality Modelling Language

WDM Wavelength Division Multiplexing. Systems in which light of different wavelengths is used to carry multiple sets of data on the same optical fibre.

WiFi The trade name for the family of technologies standardised under the IEEE 802.11 standards, and generally used for the nomadic wireless networking of laptop computers and similar devices.

WiMAX The trade name for the family of technologies standardised under the IEEE 802.16 standards. A wide range of point-point, point-multipoint, nomadic and mobile networks can be supported.

Annex D A comparative tabular specification of the three scenarios for 2028

Figure D1: Economic situation and government initiatives

Scenario	Broadcast Plus	Infinite Choice	Anywhere Now
GDP (versus 2008)	+15%	+40%	+40%
Government intervention	No	Yes – to fund last 20% of NGA	Yes – to fund last 20% of NGA

Figure D2: Devices - capability and role

Scenario	Broadcast Plus	Infinite Choice	Anywhere Now
Functionality of personal device	Designed to allow people to organise their lives through a single device Can store 28,000 hours of CIF video or 1400 hours of HD video[120] Speech recognition, mobile TV reception Battery life problem is no longer a major constraint		
Role of personal device in entertainment	Limited mainly to pre-stored music and video Access to news via Internet and mobile TV network	Limited mainly to pre-stored music and video Access to news via Internet and mobile TV network	Control of entertainment devices in the home e.g. big screen HD viewing Substantial use of video streaming on the move. But still limited by price premium
Home server functionality	Can store 28,000 hours of HD video Can wirelessly and automatically connect to a wide range of in-house devices Connected to Internet via next-generation broadband for search and download when at home and remote access when away from home Hub for home automation PVR functionality Near ubiquitous by 2028		
Role of home server in entertainment	Archive for valued content Time shifted viewing Records 8 days of all broadcasts by 200 channels Provides information on consumption habits to enable service providers to supply targeted advertising Provide personal schedules assembled from broadcast content stored on a server	Archive for valued content Gateway from home devices to access services and search content on the Internet Local cache for entertainment content	Archive for valued content in Internet Other functions handled by personal device

[120] Assumptions: 0.7 GB per hour for SD video by 2028; 200 GBytes for a home server now and 10 GBytes for a personal device now; 500x increase in storage/$ in next 20 years; 20 hrs of CIF, 5 hours of SD or 1 hour of HD require the same storage

Figure D3: Networks – capacity and demand

Scenario	Broadcast Plus	Infinite Choice	Anywhere Now
Home networking capability	Wireless network with capacity to carry entertainment content around the home and handle three or four streams of HD/3-D content		
Fixed broadband	Universal provision at first generation broadband speeds Patchy provision of second generation broadband outside urban areas because of prolonged recession and inappropriate regulation on terms of access	Near universal provision of second generation broadband speeds to households (>50 Mbit/s down and >10 Mbit/s up)	
Cellular mobile network capacity	Sufficient for non-video mobile broadband applications only		Sufficient to meet a significant proportion of demand for video entertainment applications when on the move
Terrestrial broadcast network capacity	Sufficient for 24 HD/3-D channels only		Terrestrial broadcast switch off before 2028
Terrestrial broadcast network demand	Strong	In decline	Not available
Satellite network capacity	Sufficient for 500+ HD/3-D channels with N-slot dishes		
Satellite network demand	Strong	In decline	In decline

Figure D4: End user behaviour and preferences

Scenario	Broadcast Plus	Infinite Choice	Anywhere Now
Move to on demand for video entertainment	Most users want broadcast-based video given - sofa cinema experience - appointment to view - personal schedules	Most users want Internet-based entertainment given - near infinite choice - participation - UGC - innovative multi media services	
Demand for on the move entertainment	Personal device used to view pre- stored video, mobile TV, and streamed video when in WiFi hotspots For untethered mobile broadband: - Most use for non entertainment applications[121] - Entertainment demands limited to music and news - High price premium heavily constrains use		Demand for video streaming on the move plus video games High-density cellular networks makes this possible but demand is still rationed by a price premium

[121] Eg emails, web browsing for information

Figure D5: Characteristics of entertainment services on offer

Scenario	Broadcast Plus	Infinite Choice	Anywhere Now
Video formats	Move to HD and 3D for most video content		
Non-linear viewing	Time shifting Personalised channels assembled from broadcast content Limited requirement for on demand services	Substantial use of on-demand streaming and download services on tethered basis	
User generated content	Small proportion of total and aimed at youth audience	30% of entertainment is UGC which is popular across the whole population	
Globalisation of content	Limited	Significant	
Live events	Central to attractiveness of broadcast services	A handful of broadcast channels remained specially for live events (where demands on the Internet might lead it to collapse)	

Figure D6: Business models

Scenario	Broadcast Plus	Infinite Choice	Anywhere Now
Role of fixed and mobile network operators	Generate revenues to justify investments by selling access retail to end users and wholesale to service providers (eg premium quality of service, traffic monitoring, caching)		
Role of broadcast aggregators	Content commissioning and production Broadcast platform operators Some offer personalised schedules	Only a few survive by offering live video events. Small "multi-channel" broadcasters disappear to be replaced by Internet-based entertainment services	
Role of global service providers	Limited by continuing success of enhanced broadcast models	Global search engines offer free content with targeted advertising Global web stores offer easy to buy advert free content on pay per use basis	
Role of content owners	Continue to sell via broadcast aggregators	Sell their content via Web stores and direct to end users in wide range of bundles at different prices to extract maximum willingness to pay	
Transaction-based revenues	Not significant	Commissions to global service providers for click through to purchase goods and services promoted by IBE	
Promotion/discovery of content	Trailers in schedules Viewers stay watching following must see programmes Subscriptions to personal channels	Recommendations from personal and social networking friends Video search of the Internet Subscription to personal channels Viral marketing	
Targeted advertising	Restricted to those broadcasters who expanded into the personal schedules market	Major source of revenue to global service providers who are in best position to collect required information on consumption patterns and tastes	

Figure D7: Regulation

Scenario	Broadcast Plus	Infinite Choice	Anywhere Now
Funding of public service content	Significant funding of video and audio content continues for a combination of industrial policy and social cohesion reasons		
NGA fixed regulation	Legacy regulation of access terms limits investment	Freedom to price discriminate enables market players to invest in NGA rollout to 80% of population with remaining 20% funded by Government	
Net neutrality rules	Not required given non-discriminatory access requirements on providers of NGA networks		
Privacy regulation on consumption patterns	Strong resistance to use of such data leads to regulation which limits targeted advertising	Public accepted use of such data in return for better (and free) services	
Regulation of Internet content	Government move to "level up" content regulation for TV and Internet This restricts growth of Internet-based entertainment	Government promotes end user awareness and market supplies software to enable parents to protect children from harmful Internet content	

Annex E The use of wireless in content production

E1 Introduction

Many forms of entertainment material can be, and are, produced without the use of wireless. The production of newspapers, books, games and CDs has no need for wireless, and plays, films and many TV programmes can be made without its use. Conversely, some productions are not possible without its use. Many outside broadcasting events, such as golf tournaments, can only be linked back to the broadcast studio by means of wireless and modern musicals would be impractical if all the actors had to trail a lead to their microphone instead of using radio microphones. Where wireless is not essential it can often add value to the entertainment by enabling new views, such as the view from the cockpit of racing cars in action, or allowing a news reporter to present from closer to the scene of interest.

This Annex introduces the use of wireless as currently used in the production of entertainment. In considering the current professional use of wireless and how it may develop in the future it is convenient to categorise usage into 4 groups recognising that the boundaries between them are inevitably blurred.

- News gathering;
- Outside broadcasts;
- Local entertainment;
- Studio based production.

Amateur productions are considered briefly at the end of this section.

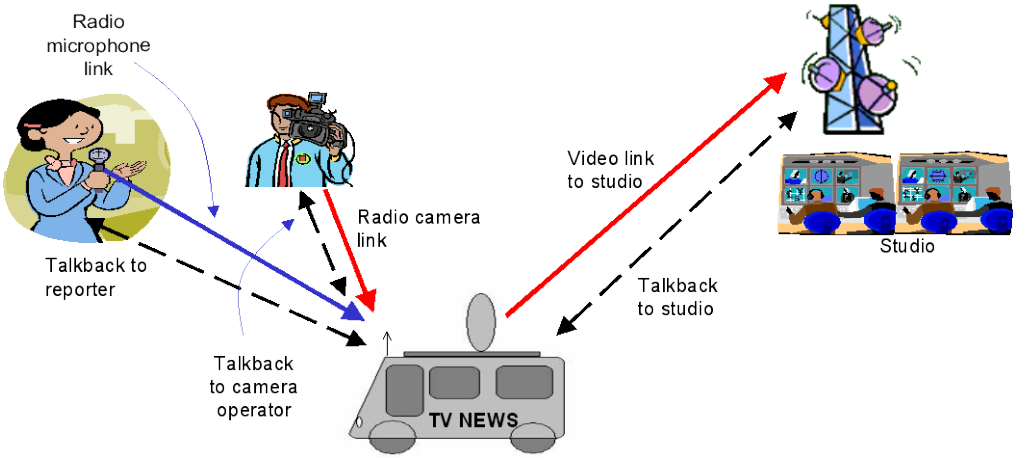
News gathering

Radio and TV reporters need to be able to report the news from wherever it happens, often at short notice. Wireless gives them the ability to provide live reports directly from the scene of interest.

Figure E1 illustrates how wireless is used in the production of a news item. The reporter's microphone and the camera man's camera are both wirelessly linked back to a control vehicle. A separate radio link (referred to as talkback) enables the producer in the control vehicle to talk to the reporter and camera man so that he can cue and coordinate their actions. The distance between a reporting team and its control vehicle is short, typically less than 100m.

News reports may be transmitted live back to the studio via a longer distance video link (typically several kilometres), or recorded and edited prior to transmission back to the studio. There will also be a talkback link between the studio and the control vehicle to enable coordination between the two.

Figure E1: An example of the use of wireless in the production of a TV news report.



With the advent of portable digital wireless cameras, operation has become significantly simpler and more reliable (and the equipment smaller and less expensive). As a consequence two person motorcycle based TV news teams (consisting of a reporter and camera man) are now possible. The set up is similar to that in **Figure E1** with the motorcycle replacing the control vehicle and relaying the wireless camera and radio microphone, and the local talkback link, back to the studio. Modern equipment also allows the reporter to edit their material in the field before sending it back to the studio.

Radio reporters use a similar set up with microphone and talkback wireless links back to a vehicle which relays signals to and from the studio. Cars are often used, equipped with a pump up mast which enables longer distance audio and talkback links to the radio studio to be used.

Drivers for the use of wireless

Although cabled microphones and cameras are often preferred for their extra quality and reliability, radio microphones, wireless cameras and local talkback provide a number of advantages. The most attractive is the ability it gives to the reporter to get close to the action and to obtain reports and views from places which would otherwise be impossible (such as the tops of buildings). The use of wireless also enables faster set up, and avoids the health and safety hazards that the use of cables in public places can cause.

News events can happen anywhere and wireless links can often be the only way of getting the report back to the studio, especially where live reporting is needed. Both terrestrial links (as described above) and satellite links are commonly used, with increasing use being made of satellite as equipment becomes smaller and the service less costly. Nevertheless, there are alternatives. Some regularly used locations have pre-wired points of connection and news material is also uploaded (in non-real time) to the studio over ADSL and from Wi-Fi hot spots as well as over 3G mobile phones. Radio reporters also link back to their studios using mobile phones, broadband connections and the plain old telephone. TV reporters will often be equipped with video enabled mobile phones but would only use them if no other means were available.

The users

The major users are, naturally enough, national and regional broadcasters including the BBC, ITV News, BSkyB and Anglia Television. The BBC is by far the largest user. However, the broadcasters are increasingly subcontracting the provision of communications to specialist providers. For example,

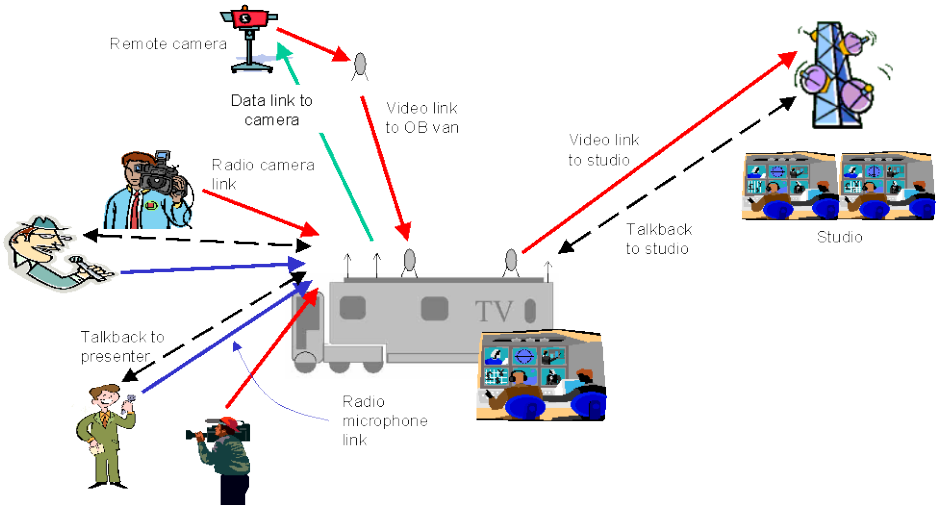
in 2007 Sky News and Channel 5 entered into a five year contract with SISLink for the provision of satellite services and uplink vehicles.

Outside broadcasts

Outside broadcasts (OB) can be defined as the temporary establishment of radio or TV programme making facilities outside of a studio to cover any event other than a news event. A large proportion of outside broadcasts are of sports events but indoor and outdoor concerts, pageants such as the Trooping the Colour, and exhibitions are also broadcast and the majority of such broadcasts are transmitted live.

The use of wireless in the production of small outside broadcasts is similar to that of news gathering using radio microphones, wireless cameras and talkback in much the same way. Larger events will of course use more frequencies to support the larger number of wireless cameras, presenters and production staff. And, where an event takes place over a wide area, additional video and audio links may be used to connect more distant wireless cameras and radio microphones back to the OB vehicle as illustrated in **Figure E2**. Air to ground radio is also used at some events to link airborne cameras back to the OB vehicle.

Figure E2: An illustration of the use of wireless in the production of an outside broadcast.



Also shown in this figure are data links which are used to control remote equipment and, increasingly, to feed back data from the event (such as game statistics) to the production team, presenters and audience. The OB vehicles often provide very sophisticated control and production facilities enabling the producer and his team to produce the complete broadcast on site.

It should be noted that the use of wireless at OB events is by no means universal. Many venues have pre-wired camera, microphone and presenter positions which will be connected to the OB vehicles by cable. In such cases the use of wireless equipment is confined to any roving cameras and presenters operating, for example, on the touch line.

Wireless links, either terrestrial or satellite, are commonly used to carry the broadcast material back to the studio and to provide the talkback communication links. However, major, regularly used venues are increasingly equipped with fibre or cable connectivity. Where this exists it will usually be used in

preference to wireless links. In some cases, satellite is used as a back up to fibre. Satellite links are also commonly used to transmit the broadcast material to overseas broadcasters.

Drivers for the use of wireless

The benefits of wireless vary with the type of OB event but it often significantly enhances the viewing (or listening experience) by enabling:

- Mobile camera views (for example tracking cyclists or giving the view from the racing driver's position);
- Roving presenters, following the players (in a golf tournament for example), on the scene interviews, and views from within the crowd;
- Camera views that would otherwise be impractical.

The users

The major users are independent production companies, which manage outside broadcasting events on behalf of broadcasters or the rights holders, and some broadcasters. The BBC used to be one of the largest users but BBC Outside Broadcasts[122] was acquired by SIS Outside Broadcasts Limited in 2008.

Local entertainment

This category covers theatres, concerts, touring shows, sports and other local events which provide entertainment. Musicals and rock concerts are particularly large users of radio microphones and also use talkback to provide communications for production and stage staff. Other events will typically use just a few (and very often just one) radio microphone[123].

Radio microphones are indispensible to the production of modern rock concerts and musicals. They have enabled new show formats by allowing the performers much greater freedom of movement and by enabling larger numbers of simultaneous performers, and have significantly improved the sound quality. For other shows and events, wireless brings the same benefits as identified earlier namely freedom of movement, reduced health and safety issues, and improved productivity. For many of the smaller events the prime advantage is simply convenience.

At larger events, particularly sports events and outdoor concerts, wireless may also be used for the control of scoreboards or for transmitting video to large screens to enable the crowd to view out of sight action. Racing cars and cyclists use wireless telemetry to transmit engine and other data back to their support teams.

In addition, there is a small but growing use of wireless to enhance the experience of the spectators at sports fixtures. These take the form of very local radio or TV broadcasts (essentially confined to the site of the event) which can be picked up by special receivers purchased or hired by members of the crowd. These are designed to enhance the spectator's enjoyment of the event by providing additional information and views, including replays, as well as guides to the venue.

The users

[122] BBC Outside Broadcasts was part of BBC Resources Limited which was already a separate company from the BBC.

[123] The one exception is Hospital radio which use wireless links to transmit programmes between hospital buildings. Note, Hospital radio does not broadcast over the airwaves but is distributed around hospital buildings by wire.

As identified above, the greatest use of wireless in this category occurs in theatres (for musicals) and rock concerts.

Studio based production

This category encompasses TV, video[124], film and radio studios although the largest use of wireless occurs in TV studios.

The key advantage that wireless brings to studio production is the increased freedom of movement it enables for presenters and actors. It can also improve productivity by, for example, reducing set up times between scenes and talkback provides an effective means of communication between the production team and the presenters, particularly in the case of live broadcasts. Thus radio microphones and talkback are extensively used in TV studios. Wired cameras are preferred to wireless as they are considered more reliable, give better quality images (wireless cameras use compression over the wireless link) and are less expensive. Wireless cameras are reserved for use where camera cables inhibit the required movement or position. Director's monitors, which display the view from the camera, are often used and these are increasingly wireless based to give the director greater freedom of movement.

Video and film studios make less use of wireless than TV studios preferring cabled microphones and cameras wherever possible for the additional quality and reliability. Radio studios, with very little need for freedom of movement, make minimal use of wireless.

The users

The major users are the TV broadcasters, the BBC and ITV, and independent studios such as Teddington Studios and Fountain Studios.

Amateur productions and user generated content

Amateur dramatic groups make some use of radio microphones and film / video clubs make limited use of wireless cameras in their productions. Such use is very largely confined to licence exempt equipment – a number of frequencies are available for licence exempt radio microphones in the UK and wireless video camcorders operate in the 2.4 GHz or 5 GHz licence exempt bands.

There is also an on-going rise in user generated content driven by the development of websites such as YouTube. Some of this material is generated using the video capabilities of mobile phones, and is passed to other people or equipment wirelessly. This is achieved either through transmission over the mobile network or, more commonly, via the licence exempt Wi-Fi or Bluetooth technologies.

E2 Some financial values

The cost of producing entertainment varies widely from a few thousand pounds to hundreds of millions of pounds. In this section we provide estimates of the production costs for two major UK outside

[124] A video studio captures and stores video material in electronic form and may produce material for a wide range of uses including TV broadcasting, public and private corporate communications, advertising and internet video streaming. A TV studio uses essentially the same techniques but is dedicated to TV programming and will produce both pre-recorded and live shows.

broadcasting events, the Formula One Grand Prix and premiership football[125]. These are compared with cost of film production.

Formula One Grand Prix

Formula One Grand Prix is the major motor racing event of the year, The UK race is currently held at Silverstone. Approximately 200 staff are required to set up and operate the outside broadcasting equipment which includes up to four OB trucks, two to four helicopters (for aerial views) and multiple cameras. The cost of producing the TV broadcasts for the complete series of 18 races has been estimated to be €50M or £2.2M per race.

The TV rights are believed to sell for around €500M for the series.

Premiership football

Live coverage of major matches typically uses 22 cameras (only a small number are wireless) and takes 6 video feeds back to the studio. The production costs per match are estimated to be around £30K.

The TV coverage rights are auctioned every three years and are understood to fetch £1B to £1.5B or up to £5M per live broadcast.

Film production costs

The costs of producing a film are usually considered in two parts; that required to complete the final film negative (the Negative costs) and that required for the publicising, duplication and distribution of the film (P&A costs). To give values roughly comparable with those for outside broadcasts we give values for the negative costs alone.

The average negative cost for films produced entirely within the European Union is about €4M[126] each. For comparison, the average negative cost for films produced by the major US studios is around €60M. The major US blockbuster films cost three to five times more than the US average, and the most expensive film to date, the Titanic, cost ten times as much.

E3 Expected and potential developments

In this section we summarise developments that may be expected in the production of entertainment and speculate on some of the more esoteric changes that could occur. Since our ultimate interest is in the impact on the use wireless, we consider these issues under the categories that were introduced in Section E1. The results here are based upon a series of interviews with industry players, literature searches, and some speculation.

The production of entertainment is a creative process and the industry is continually searching for new ways to make content more exciting and more alluring. New ideas can have a profound effect on production and its use of wireless, or no effect at all. The Reality TV genre required, and was only practical with, the extensive use of radio microphones. On the other hand programmes such as “Who

[125] These estimates were made during an earlier Ofcom study of PMSE carried out by Quotient Associates and Spectrum Strategy Consultants. See “Supply and demand for spectrum for Programme Making and Special Events in the UK”, report for Ofcom, July 2006.

[126] The film production costs given here are taken from the OECD report, “Remaking the movies: Digital content and the evolution of the film and video industries”, 2008.

wants to be a millionaire" can be produced with very few. Thus we have to recognise that unexpected and perhaps unpredictable developments have the potential to cause large changes.

The most significant change to the production of music, film and TV entertainment has been the digital capture, recording and processing of material. This has enabled much of the production process to be computerised with the result that:

- Reviewing, editing and processing is faster and more flexible;
- Special effects, animation and graphics can be more readily and inexpensively achieved;
- The duplication of material is faster, more reliable and less expensive;
- Material can be transposed from one medium to another quickly and inexpensively.

Today music, video and TV programmes are produced digitally. Films are still largely shot on film although animated films can be entirely computer generated. However, it is already common for films to be digitised for post production (editing, addition of special effects, etc.) and some films are now shot digitally. In parallel, digital cinema projectors have been developed and the British Film Council has a fund to bring digital projection to 240 screens in the UK[127].

Digital technology has also brought about the advent of high definition TV with Ultra high definition and 3D TV now being realised in research laboratories. Computer generated images (CGI), originally developed for computer games, are now approaching the quality and realism that could make them truly lifelike[128]. If this is achieved, CGI might replace actors, presenters or celebrities in some situations.

News gathering

Although news broadcasting is not generally a profit making activity for broadcasters it is considered to be an essential part of any major brand, and for some broadcasters it is part of their public service obligation. Integrity and topicality are, of course, key to a strong brand but broadcasters also compete on their ability to:

- Cover breaking news (preferably first) and the latest stories;
- Provide live coverage from the scene;
- Deliver high quality images and unique shots from the scene.

Thus there is continuing pressure for news teams to have the ability to get to the scene rapidly and quickly establish a link back to the studio, and to have as much flexibility as possible to move around and report from the scene of interest. News is also enhanced by the studio presenter, by background material and analysis, and by graphics and relevant inserts.

Developments over the next few years are therefore likely to include:

- Increased use of wireless cameras;

[127] "Celluloid tsar strives to bend it for Britain", Financial Times, 7 January 2007.

[128] "Lifelike animation heralds new era for computer games", Times Online, 18 August 2008.

- Increased deployment of cellular receive sites[129] allowing wireless cameras to link directly back to the studio or to be relayed through wireless equipment mounted in a car or, preferably, on a motorcycle;
- Increased deployment of modern, small satellite equipment which can be car mounted (as opposed to requiring an OB van);
- A move to the use of HD format wireless cameras[130].

In the somewhat longer term, 10+ years, it is conceivable that public communications networks could be used to provide news teams with live video links back to their studios[131]. This could be achieved with future mobile networks, which are expected to support bit rates of 100's of Mbit/s. Alternatively, if high capacity wireless broadband access points become common place within urban areas, news teams could link directly through them into the telecommunications infrastructure. It should be noted, however, that in both cases broadcasters would need to be convinced that such links would be able to support high quality video links in real time and would be available when needed.

Outside broadcasts

Outside broadcasting is dominated by sports and we therefore focus on developments in the broadcasting of such events. There are also developments in the production and presentation of these events to the crowds that attend, and these are considered in the section on local entertainment below.

As reported in the earlier working paper on markets and business models, major sporting events are becoming increasingly important as a way of attracting large audiences in a world where viewing is becoming increasingly fragmented, and this is reflected in the growing value of sports rights and sponsorship. As a result the production companies, which compete to undertake production on behalf of the broadcasters, are continually looking for ways to enhance the viewer's experience and to make new events accessible to the TV viewer.

Today's sports viewer has come to expect high quality pictures (HD), selectable camera views and enhanced graphics. An example of the latter is the replaying of an action with accurately superimposed graphics allowing the viewer to see precisely what happened (for example the flight of a tennis ball[132]). These graphics capabilities are being extended to provide the viewer with greater insight into the action. An example is the generation of accurate 3D models of events which take place over an area too large to be viewed at once so as to provide a real time picture of the whole event to the viewer[133]. Yacht and air races are potential applications. Unlike some of the other developments this has the potential to reduce the amount of spectrum used for an outside broadcast.

Developments foreseen within the next 5 to 10 years include:

- Greater use of wireless cameras with HD format becoming the norm;

[129] This is where one or more radio sites are established in a city such that news gathering teams can establish a wireless link back to the studio, ideally without regard to their location, and so provide live reports from wherever the news happens.

[130] It is already used for news in the USA

[131] Video material is today uploaded to studios in non-real time.

[132] Hawk-Eye is the well known example.

[133] See www.virtualspectator.com.

- Use of telemetry across a wider range of sports to track and/or monitor participants for the generation of statistics for the viewers and the provision of information to team managers;
- Further development of graphic capabilities to give the viewer greater insight into the action;
- Continuous 360 degree viewing which will allow the viewer to choose any (within reason) viewing position, and to zoom in and out at will. This is technically possible today and is becoming more practical and less expensive with time;
- 3D TV which will further enhance the realism of the viewing experience.
- Real time rendering of realistic computer generated images enabling the broadcasting of large scale or otherwise difficult to capture events;
- The fusion of games with sports broadcasting allowing, in the longer term, a viewer to become a virtual participant in an event, perhaps racing alongside a Formula One race as it happens.

Ultra HD which gives a 16x increase in resolution[134] is in the research laboratories today. In the longer term it could become the standard for TV programming. Somewhat more speculatively one can imagine virtual reality being used in the longer term to give the home viewer the experience of being in amongst the crowd.

Programme material is transmitted back to studios via terrestrial radio links (audio or video), satellite or fibre. Use of terrestrial links is largely confined to the BBC, other production companies generally rely on satellite or fibre. At present, fibre is cost effective at venues which are regularly used for outside broadcasting events, such as premier football clubs, particularly where multiple video feeds are required. For other events, satellite is normally more cost effective. This is changing in favour of fibre but only slowly. Thus we expect:

- Decreasing use of terrestrial links as equipment becomes obsolete or unreliable;
- A slow expansion in the use of fibre with satellite continuing to be used for many years particularly for less frequently used and more remote venues such as horse racetracks and golf courses.

However, an expansion of satellite capacity (primarily in K_a band) is planned over the next 3 to 5 years, largely to support broadcast TV and broadband services. The lower cost per bit that is expected could lead to a lowering of satellite charges, slowing or perhaps halting the move towards fibre. Either way, the developments in production identified above will lead to an increase in the volume of programme material sent back to studios.

Local entertainment

Theatres and concerts

The primary drivers of value in theatre and concert productions are the concept and the artists and, to a lesser extent, sets, costumes and special effects. However, the use of wireless microphones has enabled the development of new and more spectacular formats particularly for musicals and outdoor concerts. Indeed, musicals and outdoor concerts are the largest users of radio microphones with the biggest UK events utilising in excess of 100 at one time. What concepts and formats will prove to be

[134] And a corresponding increase in the required information rate.

successful in the future is impossible to say with any certainty. Instead, we consider what changes to current formats would affect their use of wireless.

In today's largest shows every performer is equipped with a radio microphone, and the stage may be filled to capacity suggesting that little further growth in the use of wireless is to be expected. However:

- Current productions make use of in-ear monitors[135] to provide feedback to performers and presenters. Future productions may make greater use of feedback to performers;
- New special effects could require wireless control;
- Future performances might make use of miniature wireless video cameras, perhaps secreted on a performer or a prop, to support special effects.

Sports events

Sports events will continue to evolve driven by the governing sports bodies (such as the introduction of Twenty20 cricket by the ECB), by the requirements of broadcasters and sponsors, and by the need to continue to attract spectators to the event itself.

One way of enhancing the spectator's experience is to replicate some of the features that enhance TV viewing of the same event as exemplified by Ref!Link and Kangaroo TV. Ref!Link allows spectators to hear the referees comments and other commentary on personal radio receivers. With Kangaroo TV receivers, spectators can see views from other parts of the venue and access action replays, check the scoreboard and other statistics, and view the concurrent TV broadcast. These are new developments whose future could evolve in various directions, and perhaps differently for different sports:

- They could prove popular and expand in both usage and functionality, and track developments in outside broadcasting (including 360° views for example);
- They could be replaced by mobile phones or mobile internet devices[136] (MIDs) offering similar facilities (conceivably including 3D[137]);
- Future stadium seating could provide similar wired-in facilities;
- They could prove to be of limited popularity.

Telemetry is already used for real time condition monitoring of racing cars, and this may extend to other sports and, in the longer term, to the monitoring of individual players. For example, a footballer might be monitored for tiredness and this information used to decide on substitutions. Some sports might allow wireless communication between players.

Video referees have already made an impact on the sports world and it is likely that electronic officiating assistants will become more widely used across a greater range of sports. As these develop

[135] In-ear monitors are essentially reverse radio microphones. They are used to feed a performer's voice or instrument back to the performer, or to enable a producer to communicate with presenters.

[136] By MIDs we are referring to portable devices which are always connected to the internet (via WLANs, WMANs or mobile networks). MIDs may evolve as separate devices or converge with mobile phones. See ABI Research press release, "Mobile Internet Devices will be targeted to a variety of consumer segments", 8 February 2008.

[137] Infosys was recently granted a patent which, it is claimed, would enable complex 3D holographic images to be sent to mobile phones, see "Holograms on handsets by 2010", www.silicom.com, 19 June 2008.

they may lead to the need for more precise tracking[138] and monitoring of participants and their equipment, and for associated telemetry links. The current voice link to referees could well be extended to provide additional text or even video information to the referee.

Studio production

The primary driver of value in TV, video or film studio productions are again the concept and the artists and directors and to a lesser extent, sets, costumes and special effects. Wireless can add value by allowing artists and presenters greater freedom of movement, particularly in the case of live programmes. Thus TV studios are major users of radio microphones and talkback but make limited use of wireless cameras.

As with theatre and concert productions, what future concepts and formats will evolve is impossible to say with any certainty. However, possible developments with an impact on the use of wireless in TV productions are very similar, namely:

- Greater use of in-ear monitors by performers and presenters;
- Wireless control of special effects;
- Use of miniature wireless video cameras.

In addition two other developments are possible. Firstly, where wireless cameras are used these will increasingly be HD. This could have implications for spectrum use since, where quality is at a premium, there are advantages in recording with little or no compression. This in turn means that HD wireless cameras for use in studios would require high bandwidths to accommodate their transmissions. Secondly, the use of wireless director's monitors may expand. However, the expectation is that cable (and fibre for HD cameras) will continue to be preferred over wireless.

In film and video studios there is a general preference for the use of cabled microphones and cameras and the additional quality and reliability that they can provide. We have identified no strong drivers for change in this regard. Indeed, should technology advance to the point where artists and presenters can be realistically substituted by computer generated images[139], the need for wireless cameras could be diminished. Furthermore, the high levels of resolution demanded with film production would result in particularly bandwidth hungry and expensive wireless cameras. We therefore expect that the use of wireless in film and video studios will lag behind but be similar to that in TV studios.

Low cost editorless production

The ease and low cost of distribution via the internet is generating new business models. One approach envisages similarly low cost production of sports events for 24/7 streaming over the internet[140]. In the case of a car rally, for example, video information from cameras fixed at key points

[138] Wireless tracking could have an advantage over video systems here as it would not suffer from the problem of one player being obscured by another. However, current real time tracking systems will need to become smaller and improve in accuracy before they could be deployed on individuals.

[139] Recent advances suggest that this is not an unreasonable assumption, see "Lifelike animation heralds new era for computer games", Times Online, 18 August 2008.

[140] The concept was described by Professor Andy Nix of Bristol University and is illustrated by the research project Visualise (see www.3cresearch.co.uk)

around the course and mounted within the cars would be fed to a central server along with car location and timing data. The server then automatically generates a number of video feeds, for example tracking the leader or specific drivers, and adds relevant statistics. Internet viewers select between the different feeds according to their interests.

To minimise costs, camera feeds could be fed back over any broadband connection including Wi-Fi or public mobile networks. The video output could also be distributed to spectators over a Wi-Fi network to mobile phones or PDAs to give a low cost version of Kangaroo TV (described above).

The expectation is that such autonomous systems will initially be targeted at niche sports and events, which are largely ignored by the main broadcasters, and to internet viewers for whom the lower video and production quality will be acceptable. However, the internet and wireless access networks[141] are expected to develop to accommodate more and more demanding video applications, perhaps driven in part by this application and user generated content (see Section E1). With the consequential improvements in production quality, autonomous systems could perhaps become a significant alternative to traditional outside broadcasting over linear TV networks.

Amateur and other productions

Amateur productions of plays and videos are not expected to drive developments in entertainment or its use of wireless but rather to adopt techniques and technologies developed for the professional market as they become affordable.

The future of user generated content (UGC) is more uncertain. Some expect continued rapid developments in this area while others see it as of little relevance to the world of entertainment. A study sponsored by Nokia suggests that within 5 years up to 25% of entertainment consumed will be created, edited and shared within social circles[142]. Of course not all of this will necessarily involve the use of wireless but the expectation that more and more in the way of communications, information and entertainment will be available on the move suggests that a significant proportion could be generated on and exchanged between mobile phones or mobile internet devices.

Given that developments in UGC will be driven by developments on the web and in the capabilities of mobile devices, it is likely that the related use of wireless will continue to be based around mobile networks and licence exempt technologies. Developments that may be expected as a result of growth in UGC and other web-based video applications include:

- On-going improvements in video coding techniques[143] (although the demand for higher quality may lead to an increase in the bit rate required);
- Wireless protocols optimised for the transmission of video over various wireless access networks[144].

[141] Wireless access networks include WLAN, WMAN and mobile networks, both public and licence exempt.

[142] The study, “A glimpse of the next episode” is reported at www.futureofmusic.com.

[143] See Section E1.

[144] See http://www.provision-comm.com/.

E4 Spectrum and technology issues

Much of the use of wireless in connection with content production is for short periods of time. Sports events, pageants, concerts and touring shows, and any associated outside broadcasting, usually last for a day or two and seldom longer than 2 weeks. And their use of wireless is very often highly localised since these events occur over small geographical areas. Use in theatres and studios is on a longer term basis but is again highly localised.

An important implication is that the spectrum required to support PMSE[145] activities is determined by size of the largest events rather than by the number of events. The largest demands come from events such as Formula One Grand Prix races and major golf championships. The largest outdoor concerts and the major TV studio complexes also make large demands on specific sections of the PMSE spectrum.

To accommodate this continually changing demand for spectrum, and to ensure equitable access for all users, JFMG Limited (working under contract to Ofcom) assigns frequencies to users as required on a temporary and localised basis.

JFMG Limited and Programme Making and Special Events

JFMG Limited is contracted by Ofcom to manage the assignment of frequencies for programme making and special events. Programme making and special events (PMSE) consist primarily of those activities which use wireless in support of programme making and broadcasting, including all those already described (in Section E1). Special events include a number of activities that fall outside our definition of entertainment. Thus JFMG also assigns frequencies for use in churches, educational establishments and conferences, for example. However, the great majority of assignments made by JFMG are related to the production of entertainment material.

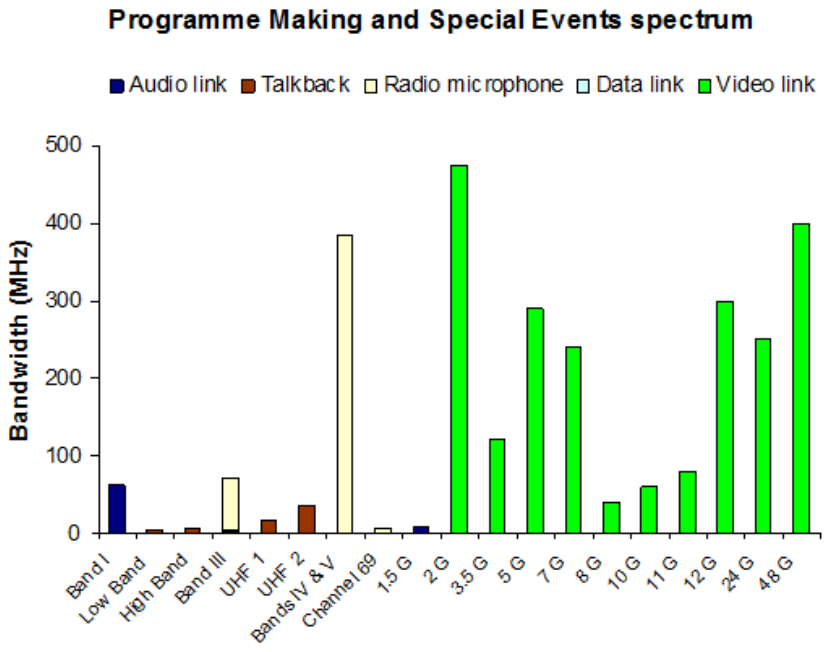
News gathering also uses wireless for short periods and on a localised basis at any one time. However, news teams need to be able to respond more quickly to events than the frequency assignment process can accommodate and, as a result, they are often assigned frequencies for a year at a time on a regional or national basis. Again, JFMG manages these assignments.

The PMSE spectrum

JFMG has a range of frequency bands, together referred to as the PMSE spectrum, from which assignments can be made and these are summarised in **Figure E**3. This figure also illustrates how the different types of wireless (radio microphones, talkback, video links, etc.) are generally distributed across the bands.

[145] Programme making and special events (PMSE) spectrum is used primarily in support of outside broadcasting and programme making of all sorts including TV, film, theatre, festivals and concerts. It is also used to support the production of "events" in churches, educational establishments and conferences but the major use is related to the production of programme material.

Figure E3: Spectrum available to JFMG for assignment to programme making and special event applications.[146]

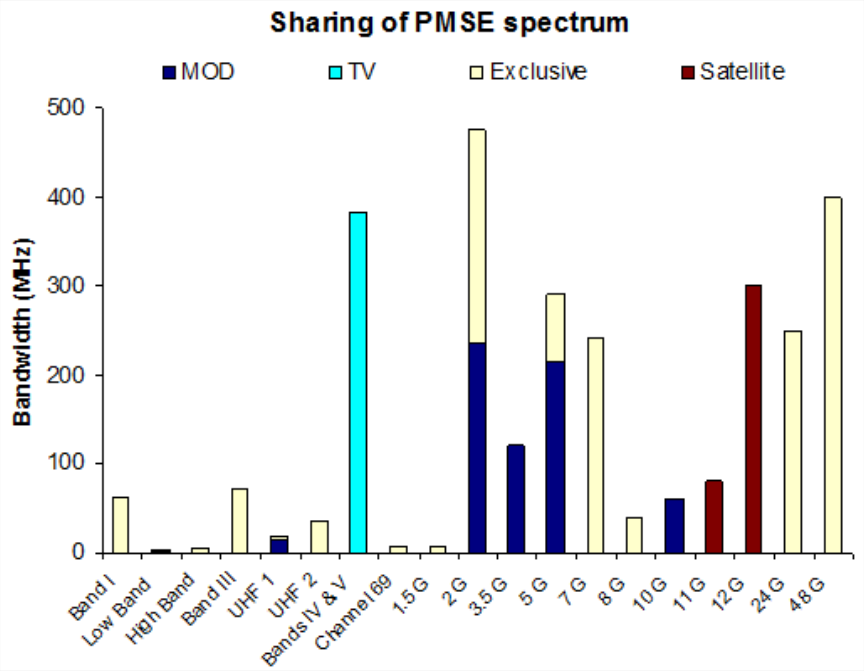


The short term and localised nature of many of these assignments makes them well suited to share spectrum with other users. As illustrated in **Figure E4**, a significant amount of the spectrum at and above 2 GHz is shared with the military (on a geographic basis). In addition, the great majority of radio microphone use shares the TV bands (Bands IV and V) with the TV broadcasters by using the so called interleaved spectrum[147].

[146] The colour coding shows the primary PMSE use to which the different bands are put. Note, that wireless cameras are included in the video link category. Note also that for clarity the bandwidth shown has been increased by a factor of 10 for the UHF 2 band and below.

[147] The very low transmitted power used by radio microphones combined with careful selection of the frequencies used at any given location permits radio microphones to be used without interference to domestic television reception. JFMG is responsible for assigning these frequencies which are collectively referred to as the interleaved spectrum.

Figure E4: The proportion of each PMSE band which is shared with other users is illustrated[148].



Other spectrum

Spectrum other than PMSE spectrum is used in the production of entertainment material. In particular, satellite links are commonly used to link outside broadcasters and news gathering teams back to their studios. Capacity is purchased from the satellite operators, usually in K_u or L bands, and can be for short or long term use. A small number of the larger outside broadcasting events, Formula One Grand Prix races and the Open Golf championships for example, require more spectrum than is available within the PMSE bands. On these occasions, JFMG's current practice is to temporarily borrow spectrum (through the offices of Ofcom). For example, fixed link spectrum is borrowed for pit to car telemetry in motor racing.

Licence exempt spectrum is also used in places, although the industry does not consider this to be a satisfactory solution in general since the quality and reliability of the link cannot be guaranteed. Licence exempt uses include:

- The use of DECT equipment to provide talkback facilities in theatres;
- The use of the 2.4 GHz (and potentially 5 GHz) licence exempt bands to operate wireless scoreboards, for radio microphones and for consumer wireless camcorders;
- The use of licence exempt microphones in (small) bands in both the VHF and UHF bands.

UWB radio microphones, which operate between 3 and 10 GHz, are available in the USA and could become available in Europe within the next few years.

[148] Bandwidths are multiplied by 10 in the UHF 2 band and below.

Recent and forthcoming changes to PMSE spectrum

The availability and amount of PMSE spectrum has recently changed and will continue to change over the next 10 years largely as a result of spectrum awards and the switchover to digital TV. These changes are summarised below.

- **Band I** – Ofcom has asked for expressions of interest in this band which could affect current PMSE use. However, little interest has been expressed to date and it is reasonable to assume that PMSE users will continue to have access to this spectrum.
- **Band III** – This band has recently been rearranged to accommodate the award of DAB multiplexes reducing the available spectrum by 0.5 MHz to 4.1 MHz.
- **UHF TV bands IV and V** – With the switchover to digital TV (due for completion in 2012) a significant proportion of the UHF TV spectrum will be released for other uses[149]. As a result the 46 TV channels which are currently available for interleaved use by PMSE users will be reduced to 32, and Ofcom plans to auction some of the interleaved spectrum within these 32 channels for local TV and mobile services[150]. The actual impact on PMSE users depends on the detailed digital TV plan and the specific location where PMSE use is required. Analysis carried out by Ofcom suggests that there may be only two locations where there will be a significant shortage of interleaved spectrum following switchover[151].
- **1.5 GHz band** – 3 MHz of the 11 MHz available in this band was auctioned to Qualcomm in June 2008. Their plans are unknown.
- **1.8 MHz band** – Although proposed as a harmonised European band for digital radio microphones the 15 MHz available in this band has remained unused. It has now been awarded for other uses in Northern Ireland (and the Republic of Ireland) and may be made available for other uses in the rest of the UK.
- **The 2 GHz band** – The spectrum available in this band is expected to be substantially reduced. The spectrum between 2500 and 2690 MHz will shortly become unavailable[152] for PMSE use in preparation for the forthcoming auction of this spectrum. In addition, the growing use of the band from 2400 to 2483 MHz by licence exempt equipment is further limiting the use that PMSE users can make of the band. The overall effect is expected to reduce the available spectrum from 475 MHz to 195 MHz. A further 10 MHz in the 2200 to 2290 MHz band may become unusable if the plans for a pan-European mobile satellite service come to fruition.
- **The 5 GHz band** – The licence exempt RLAN bands A and B, and the lightly licensed band C, overlap the spectrum currently available to JFMG. As new uses expand into these bands the bands are expected to become effectively unavailable for traditional PMSE video links. The effect will be to reduce the available spectrum from 291 MHz to 75 MHz.

[149] "Digital dividend review: 550-630 MHz and 790-854 MHz", Ofcom consultation, 6 June 2008, and "Digital dividend review: geographic interleaved awards 470-550 MHz and 630-790 MHz", Ofcom consultation, 12 June 2008.

[150] Although these are the uses to which this interleaved spectrum is expected to be put, the licences will not restrict the use to which the spectrum may be put.

[151] "Access to interleaved spectrum for programme making and special events after digital switchover", Ofcom Statement, 16 January 2008.

[152] Precise dates are unclear as the auction is currently delayed by legal action.

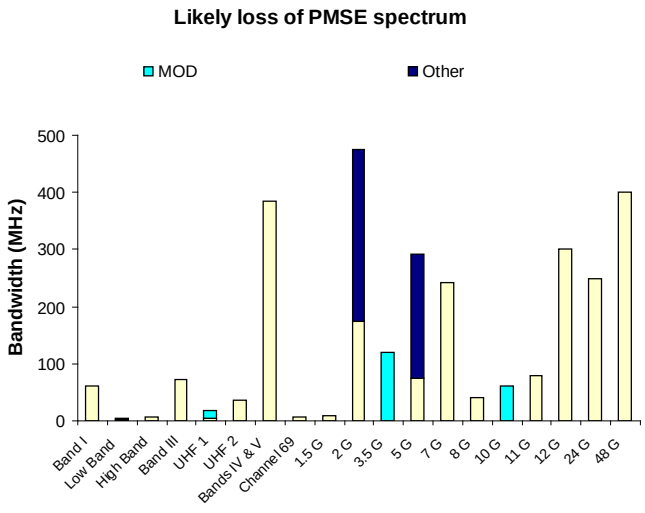
As illustrated in **Figure E4**, JFMG has shared access to a number of bands managed by the MoD. Following the review of public sector spectrum holdings the MoD is reviewing its use and management of spectrum[153,154]. The MoD has identified several bands which it expects to release (into the market or back to Ofcom) or share more extensively, including a number currently shared with PMSE users. The impact on existing sharing arrangements is not yet clear but the MoD has stated that it will take the longer term use of its holdings by PMSE into consideration. Nevertheless, we can expect the existing arrangements to become more commercial over time.

The bands, currently shared with PMSE users, that could be affected in this way are summarised below. (Note, bands whose availability is expected to change for other reasons as given above are not repeated here.)

- **Low Band** – Up to 150 kHz of the 375 kHz could be affected, but the MoD will not be auditing this band until after 2012.
- **UHF 1** – Up to 1.34 MHz of the 1.84 MHz in this band could be affected, but the MoD will not be auditing this band until after 2012.
- **3.5 GHz band** – This is identified as a band for early release or sharing, and all 120 MHz currently used for PMSE could be affected. Ofcom is currently assessing plans for this band with the MoD.
- **10 GHz band** – The whole of this band (60 MHz) could be affected with new arrangements potentially in place by March 2010.

The potential future reductions in PMSE spectrum identified above are illustrated in Figure E5.

Figure E5: Potential future reductions in PMSE spectrum[155]



[153] See www.spectrumaudit.org.uk.

[154] "UK Defence Spectrum Management", Ministry of Defence consultation, 30 May 2008.

[155] Illustrated by band. Light blue denotes spectrum likely to be released by the MoD, dark blue spectrum likely to be subject to other awards. Note, the bandwidth scale is the same as in the previous figures.

Implications

Two key implications arise from these forthcoming changes. Firstly, although the amount of interleaved spectrum available for radio microphone use after digital switchover is expected to be broadly adequate, future musicals and shows and some large OB events may require more spectrum than will be readily available. In this regards, we note that ETSI is currently examining the possibility of radio microphones sharing spectrum in the 1.5 GHz band.

Secondly, wireless camera usage is very largely confined to the bands between 2 and 7 GHz, with the best operation being achieved in the 2 and 3.5 GHz bands. Above 7 GHz operation is increasingly limited to line of sight situations[156]. As already noted, however, a substantial proportion of the most useful spectrum (approximately 45% in the worst case) is likely to become unavailable for PMSE use within a few years. Some new spectrum in this frequency range is likely to become available both from Ofcom and the MoD, as summarised in Figure E6.

Figure E6: Some of the spectrum below 10 GHz potentially being released onto the market by Ofcom or the MoD within the next few years[157]

Potential release by Ofcom	Potential release or sharing with MoD
2010-2025 MHz	4400 – 4500 MHz
2290-2302 MHz	4500 – 5000 MHz
2302-2310 MHz	7250 – 7300MHz
3600-4200 MHz	7900 – 8400 MHz

The total for release is around 1800 MHz, substantially in excess of the expected loss of 695 MHz. However, the PMSE community is not well positioned to purchase spectrum as it comes on to the market, and Ofcom has decided to appoint a band manager to act on behalf of the sector.[158]. The band manager could play a role in co-ordinating sector requirements for spectrum for wireless cameras.. The balance of spectrum demand and supply is considered in more detail in Sections E8 to E11.

Changes in the spectrum management regime

Currently JFMG manages spectrum for PMSE use on behalf of Ofcom, and PMSE users pay charges which largely reflect the cost of administration rather than the value of the spectrum. As part of its approach to managing the digital dividend Ofcom is planning[159] to award a block of interleaved spectrum, and much of the other Ofcom spectrum currently allocated to PMSE use, to a commercial band manager. This band manager will pay AIP for the spectrum and be able to recoup its costs from its customers. The band manager will be able to make the spectrum available for other uses but will be

[156] Since line of sight propagation between a wireless camera and its receiver cannot always be achieved, these higher frequencies are less useful.

[157] The band 2500 – 2690 MHz is not included here as it will clearly be out of reach to the PMSE community.

[158] Ofcom's digital dividend review recognises this and proposes that PMSE spectrum be awarded to a commercial band manager by means of a beauty contest, as discussed in the following section.

[159] "Digital dividend review: Band manager award", Ofcom consultation, 31 July 2008.

required to satisfy the reasonable demands of the PMSE community on fair, reasonable and non-discriminatory terms for a transition period lasting until 2018.

Current charges for PMSE spectrum relatively low. For example the cost of spectrum licences for radio microphones and wireless cameras at a premier league football match would contribute only £400 to £500 to the total production cost of around £30,000 (with the value of the broadcasting rights being around £5M). The annual spectrum costs to a theatre using 40 radio microphones[160] would be £560, a small percentage of their annual production costs. If the costs of spectrum access did rise in future this analysis would suggest that they could be absorbed by the industry and/or have little impact on final prices for the event. Indeed, one production company we spoke to stated that they would "simply pay any higher charges".

Technology developments

Radio microphones

Digital radio microphones have been available for a few years. However, the digital signal processing required introduces delay and leads to synchronisation problems. Furthermore, they offer no significant advantages over analogue radio microphones. As a result take up has been low and is likely to stay this way at least until the delay is substantially eliminated.

Radio microphones operating in the 2.4GHz band or using UWB technology are now becoming available, largely for non-professional uses. However, as the use of licence exempt devices becomes better understood, it is possible that their use may become more widely accepted especially in those situations where the user is able to control the use of other licence exempt equipment in the vicinity (as in case of theatres and studios).

Wireless cameras (and video links)

The coded orthogonal frequency division multiplexing used with digital wireless cameras provides a very reliable wireless link even in poor propagation conditions. They work well, and are widely used, in the 2 GHz and 3.5 GHz bands and are usable at frequencies up to 8 GHz. Above this frequency, propagation is increasingly limited to line of sight situations which limits the locations in which the cameras can be used.

Compression techniques are used to minimise the bandwidth required and HD signals can now be transmitted in channels as narrow as 10 MHz. However, this is at the expense of picture quality and larger bandwidths are also used.

Research on both modulation and compression techniques continues. The physical limitations of radio propagation above 8 GHz may limit the advances that can be made in this area[161]. Compression techniques, however, have shown steady progress over the years and further advances can be expected over the coming 10 to 20 years[162].

As with radio microphones, it is possible that there will be greater use of wireless cameras operating in licence exempt spectrum. Again this is most likely in those situations where the user is able to control

[160] Some productions, especially musicals, do use greater numbers but many use fewer.

[161] Doppler shift at these high frequencies is also a limitation for moving wireless cameras.

[162] The bit rate required for HDTV could be halved over the next 20 years, see the section on compression techniques later in this annex.

the use of other licence exempt equipment within the vicinity. The forthcoming 60 GHz licence exempt band may be particularly relevant here as it will have the bandwidth to support uncompressed HD transmissions as required in studio productions provided line of sight communication is possible.

Audio links

We are not aware of any developments in audio links for PMSE use. As with radio microphones, existing analogue equipment provides the necessary quality so there is little incentive to invest in new developments. In the longer term, however, DAB and/or DRM[163] components may fall sufficiently in price to make the use of these technologies commercially attractive.

Talkback

Much talkback equipment is based on conventional private mobile radio technology. As this moves to digital technologies[164] talkback equipment is likely to follow gaining from the increased functionality and greater capacity of the digital systems.

Talkback systems are also being offered in licence exempt bands and, as above, there may be increasing use of such equipment in future.

Cognitive radio

Cognitive radios incorporate intelligence which, in principle, enables the equipment to identify what frequencies are currently unused in the vicinity of the radio. Ofcom's current proposals for the use of the UHF TV bands following digital switchover would allow licence exempt cognitive radio devices to operate in the digital TV bands provided that they were shown not to cause interference to TV reception or to radio microphones operating in the interleaved spectrum.

Such equipment has recently been accepted by the FCC for use in interleaved spectrum in the USA, subject to meeting certain conditions, and cognitive radios suitable for operation within the UK TV spectrum may be seen within a few years. In the longer term, cognitive radio has the potential to allow automatic sharing of spectrum between a greater range of applications. The implications for PMSE users are:

- The range of other users with which PMSE users could share spectrum would be expanded. At the same time, it could also lead to greater competition for shared spectrum as it becomes practical for more applications to operate in a spectrum sharing mode. However, cognitive radios in principle share without creating interference to other users so it is unclear whether this will cause a problem.
- Cognitive radio could also enable PMSE equipment to self assign frequencies as needed at events overcoming the delays inherent in the current human operator based approach, and lead to a much more dynamic and potentially more efficient use of spectrum. Such a system would, of course, need to accommodate the real time nature of entertainment use. Conceivably this could be managed through the assignment of software priority tokens by the band manager.

Compression techniques

A recent Ofcom study[165] has examined likely future developments in video codecs and drawn three conclusions.

[163] Digital Radio Mondiale, a digital audio broadcasting technology designed to replace current AM broadcasting.

[164] ETSI is currently completing a digital mobile radio standard designed to replace conventional analogue equipment.

- The bit rate required to transmit SD and HD TV will improve over the next 20 years, reducing from 3 to 6 Mbit/s to 1.5 to 3 Mbit/s for SD TV, and from 20 to 25 Mbit/s to 7 to 10 Mbit/s in the case of HD TV.
- Driven by the pressure for improved quality, IPTV will utilise higher bit rates over a wider range, going from the 64 to 512 kbit/s of today to 0.5 to 1 Mbit/s.
- Mobile TV requirements will reduce from 256/512 kbit/s to 64 kbit/s.

E5 Drivers for change

In this section we bring together the drivers relevant to content production and its use of wireless, the changes expected, and the implications for the use of spectrum. These are detailed in Figure E7

As discussed in Section E4 the amount of PMSE spectrum required is largely driven by the demand at the largest events, rather than by the number of events. Figure E7 therefore focuses on potential changes to events rather than on changes in the frequency of events.

In developing alternative scenarios it is important to identify those drivers which can have a large effect but which are uncertain. The final development of the scenarios covers the whole of the entertainment sector, here identify the key drivers related to content production.

Enhancing the experience at sports events

Major sports events are often also very valuable business events and there are strong commercial pressures to find new ways to make the spectator's experience, both at the venue and on TV, more enticing and more valuable. Where this is achieved for the TV viewer through the use of techniques such as 360° views, 3D or ultra high definition formats there will be a potentially significant increase in the spectrum required both for on-site links and for the contribution links back to the studio. Where enhancement of the on-site spectator's experience is achieved by providing spectators with additional information or views to individual wireless devices, further spectrum will be required. And bringing new sports (yacht or air races for example) to broadcasting can also lead to additional spectrum requirements.

The uncertainty lies in identifying which new techniques, and what new sports, will prove to be attractive to viewers and spectators.

Development of a new genre of theatrical or TV shows

New genre or new formats could lead to significantly greater use of wireless, and particularly of wireless microphones. The uncertainty lies in the impossibility of identifying what may emerge and be successful.

[165] "Future performance of video codecs", Report for Ofcom, University of Essex, November 2006.

The arrival of ubiquitous broadband wireless connectivity

There is little doubt that broadband connectivity will expand both in bandwidth and in availability, and that wireless access will become commonplace. However, to be attractive to broadcasters and in particular to news teams, capacity has to be bookable at short notice and be suited to real time video transmission. It is not clear that broadband wireless access will develop in this way. Should it do so it could substantially reduce the use of satellite.

Alternatively, lower cost satellite capacity for outside broadcasting and news gathering could become available on the back of new broadband and DTH satellites, and lead to an expansion in the use of satellite connectivity.

A more commercial approach to spectrum management

The changes now beginning in the management of PMSE and MoD spectrum will introduce a more commercial approach to spectrum access, opening up additional spectrum and facilitating new uses and new users. Whether or not this will lead to strong competition and high prices is unclear as a more commercial approach to spectrum access could lead to an expansion in supply but parts of the industry are clearly concerned that it will do so. Should it do so, access to spectrum in places of high demand would be limited to the bigger PMSE users and there would be pressure to find alternatives to, and more efficient means of using, the spectrum.

Figure E7: Summary of drivers for change in the production of entertainment content, potential changes and their implications for spectrum and the PMSE community.

Drivers	*Changes*	*Implications*
Flexibility and speed of response to news events and falling cost of wireless cameras	Increased use of wireless cameras, greater use of "cellular receive" sites in cities, continued use of satellite elsewhere	Requires use of lower frequency video links.
More immersive viewing experience for OB viewers	Introduction of 360° views, 3D and longer term possibly Ultra HD. Greater use of electronic aids to referees / umpires, data collection & tracking of participants, communications between team members.	Greater capacity required for wireless cameras and contribution links. Requirement for telemetry, real time location systems, and communication & video links within an event.
New and more "remote" sporting events (e.g. yacht and air races)	Tracking of participants, greater use of onboard wireless cameras, operation over larger areas.	Greater use of telemetry, communications & video links over wider areas. Greater use of air to ground frequencies. Possibly mitigated by greater use of computer generated images.
Events become more international	Video feeds are required to more international destinations.	Increased use of satellite links.
Internet driven "outside broadcasting"	Very low cost production techniques are used to cover new events in new ways.	Use mix of public and licence exempt wireless access networks (where needed) to stream material back to an internet studio.
More spectacular shows and concerts	Increased numbers of wireless microphones / In ear microphones(IEMs), telemetry & video links for special effects.	The largest events may exceed the current capacity of interleaved spectrum.
Improved experience at sports events through duplication of TV features for on-site spectators (especially sports events)	Expanded availability of local audio and video broadcasting to spectators within an event.	Greater use of local audio and video broadcasting frequencies, or: Provision of same services over mobile phones, or: Provision of same services over local WLAN.
Production flexibility and new genre in studio productions	Increased use of wireless, particularly wireless cameras and director's monitors.	Cameras will be HD and minimal compression will be demanded to maintain quality resulting in high bandwidth requirements.

Drivers	Changes	Implications
Communications technology	Real time broadband wireless connectivity becomes ubiquitous in urban areas. High bandwidths become available in rural areas over mobile networks. Fibre connectivity becomes available at more and more venues.	News gathering and OB make less and less use of satellite which is required only for the very remote events.
	Satellite capacity expands and prices fall on the back of new broadband and DTH capacity in K_a band. Use of licence exempt wireless cameras becomes more acceptable in protected environments, and 60 GHz band enables low compression for HD.	News gathering and OB make greater use of satellite. Greater professional use of licence exempt wireless cameras in protected venues (studios, stadia).
	Cognitive radio enables more sharing of spectrum.	Results in more spectrum being suited to sharing but increases the number of users competing for it.
Competition for spectrum access	Increased demand from other applications and PMSE leads to a much more competitive spectrum access market.	Spectrum charges rise in areas of high demand.
	Changes to spectrum management lead to greater availability of spectrum (particularly on a shared basis from MoD). Few sharers other than PMSE emerge.	Spectrum charges remain affordable for the PMSE community.

E6 Developing scenarios for spectrum assessment

The analysis of content production identified two potential future developments for which the degree of uncertainty is high and there is the potential for a significant impact on the demand for spectrum. They are:

- Enhanced outside broadcasting events. The use of new technologies to enhance the viewing experience for outside broadcast events, particularly sports events, for both spectators and TV viewers. Examples include 360° views, 3D TV, and multiple on-site video streams to spectator carried viewing devices. The major impact would be on the spectrum requirements for wireless cameras and video links.
- New genre shows. New genre for concerts, theatre or TV shows requiring greater use of radio microphones or other wireless devices. The major impact would be on radio microphone (& IEM[166]) usage with rock concerts expected to be a key driver of spectrum demand.

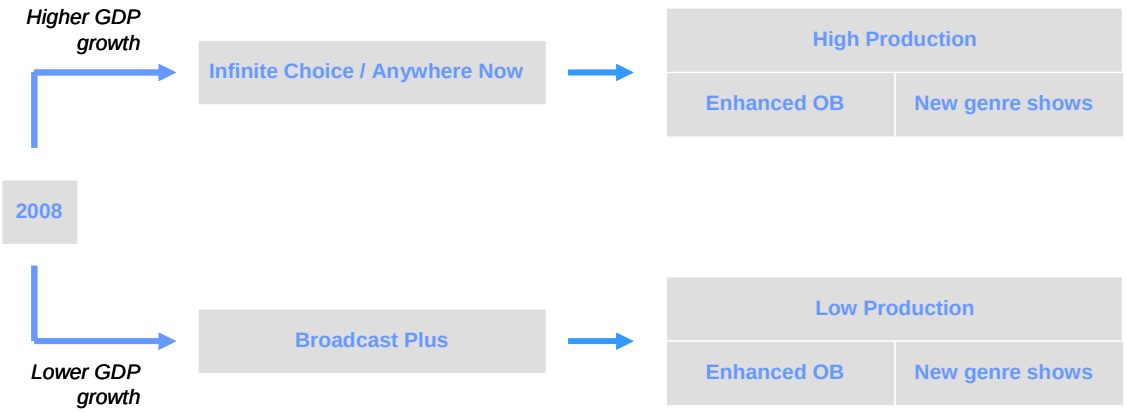
In addition there is some uncertainty as to the extent to which access to broadband wireless connectivity will become ubiquitous and attractive to PMSE users, and the extent to which satellite and/or fibre will satisfy the requirement for backhaul links.

We first develop scenarios based on these possibilities and estimate the resulting requirement for spectrum and then examine the implications for the content production industry.

[166] In-ear monitors.

Many of the potential changes identified in the scenarios for the distribution and consumption of entertainment have little or no effect on the production of content. For example, even though there is substantial consumption of content on the move in the *Anywhere Now* scenario and distribution is very largely via the internet, a significant amount of material will still be viewed on large screens in the home and elsewhere. As a result production quality will remain an important factor for attracting viewers and there will be a continuing drive for ways to enhance the viewing experience. The key factor in the consumption scenarios likely to affect production is the growth in GDP. This is 15% to 2028 in the *Broadcast Plus* scenario but 40% in the *Infinite Choice* and *Anywhere Now* scenarios. Lower GDP growth is likely to be reflected in lower levels of investment in new technology and new developments and we therefore see the main effect to be on the rate at which new developments are taken up[167]. This leads to two content production scenarios with two cases to be considered in each as illustrated in Figure E8.

Figure E8: The two content production scenarios



Enhanced outside broadcast events

Several developments may contribute to the enhancement of the viewing experience of outside broadcasting events. Figure E9 provides a summary and shows how they are associated with the High and Low Production scenarios. Points of note are:

- High definition TV is already well established as a production format. Although terrestrial TV will continue to be limited in its ability to broadcast HD programmes for the foreseeable future, many programmes are shot in HD format and we expect all production to use this format in the near future.
- 3D TV is currently a topic of research and development. However, with ITU study groups now developing standards and demonstration transmissions already taking place, this is a development that is likely to be widely adopted within the next 20 years even under the Low Production scenario.

[167] Of course a lower level of GDP growth does not necessarily reduce the likelihood of new genre but it would reduce the probability that they would be exploited if significant investment were required.

- 360 degree viewing is technically possible today but expensive to implement. We assume that even with slower GDP growth it will be implemented by 2028 (although it may still be limited in respect of the platforms over which it may be distributed).
- Ultra HD format TV is a research topic today. We judge that it is unlikely to be used in practice by 2028 under the Low growth scenario but could be used to some extent under the high growth case.

As illustrated in Figure E9 other viewing enhancement techniques are expected to have a limited impact on spectrum requirements. Enhancements aimed at on-site spectators, for example the localised broadcasting of action replays, are already in limited use and may well become widespread within the next 20 years. They can, however, make use of local TV channels, local Wi-Fi networks, mobile networks including mobile TV networks or the interleaved UHF TV spectrum. Given this range of options we conclude that the interleaved spectrum will only be used where there is local spare capacity and, as such, these systems will not contribute to the peak demand for PMSE spectrum.

There is already a trend towards greater use of satellite and fibre for backhauling content from outside broadcasting events. Under the low growth scenario we assume that this trend continues but that it increases noticeably in the high growth case augmented by the increasing proliferation of public wireless broadband access.

Note that although the discussion here focuses on outside broadcasting events several of the changes considered (for example, the take up of the HD format) will also affect other events such as news gathering. Where it does so, our analysis (described later) takes the effect into account.

New genre shows

Theatres, TV studios and rock concerts are major users of radio microphones and IEMs and generate the largest demands on the interleaved spectrum. In the largest events all performers can be equipped with radio microphones and a substantial proportion with IEMs, and up to 125 devices may be used at a single event. Since the number of performers cannot increase significantly, extending the use of IEMs to all performers will lead to only a limited growth in the demand for spectrum.

However, new genre shows have the potential to make significant new demands on spectrum. Although these cannot be predicted in any detail wireless controlled special effects, wireless video displays used as part of the performance, or special effects based on the use of wireless cameras can be envisaged and could lead to substantial additional spectrum requirements.

These potential developments and their allocation between the High and Low Production Scenarios are also summarised in Figure E9.

Figure E9: Summary of possible future developments and their incorporation into the two production scenarios.

Enhancement technique	Comment	Included in Low Production scenario	Included in High Production scenario
HD format	Expected to be ubiquitous within a few years.	✓	✓
3D TV	Expected to be widely adopted within 20 years and probably sooner.	✓	✓
360° viewing	Expected to be widely adopted within 20 years.	✓	✓
Localised on-site broadcasting	Assumed to use PMSE spectrum only where there is spare capacity.	×	×
Ultra HD format	Research and new standards required so unlikely under the Low Production scenario.	×	✓
Enhanced graphics & computer generated video images	Processing is carried out after content capture and will require little additional spectrum.	×	×
Fusion of games and real time events	Largely a question of processing after content capture with little additional spectrum required.	×	×
Greater deployment of in-ear microphones (IEMs)	The maximum demand will be when all performers are equipped both with radio microphones and IEMs.	✓	✓
New genre shows	Unpredictable but assumed to double the amount of spectrum required for a single show.	×	✓
Video backhaul replaced by satellite, fibre and/or wireless broadband	This trend is already underway	Trend continues	Satellite / fibre / wireless broadband become ubiquitous

E7 Technology developments assumed for spectrum assessment

The demand for spectrum will also be affected by developments in PMSE equipment that take place over the next 20 years. These include both expansion in bandwidth requirements resulting, for example, from 3D TV and reduced requirements resulting from improvements in coding and compression techniques. Our assumptions are summarised in Figure E10. Three key assumptions are discussed below.

- Today PMSE equipment is typically designed to operate within one of the 19 PMSE bands. Restrictions on equipment availability at a particular event can therefore constrain the optimal packing of bands and effectively reduce spectrum utilisation efficiency. Over the coming 20 years, as pressure to use the spectrum more efficiently grows, we expect equipment to become more

frequency agile enabling better packing of the bands. The grouping of bands[168] into blocks over which equipment can be considered inter-changeable by 2028 is given in Figure E11.

- Wireless cameras are today limited by technology and propagation characteristics to frequencies mainly at or below 7 GHz. However, developments including beam steering, on-frequency repeaters and new modulation schemes hold out the promise of making higher frequencies practical for this application. We have therefore assumed that wireless cameras will be usable up to 12 GHz[169] in many production situations by 2028.
- The number of radio microphones that can operate within a single 8 MHz TV channel is limited by both interference issues and the difficulty of coordinating multiple different users. As a result a packing density of around 4 to 5 per TV channel is typical today although higher densities can be achieved in some circumstances. Digital radio microphones, which are just entering commercial use, and improved frequency coordination are expected to raise this number substantially by 2028. We have also assumed that radio microphones for operation in the 1.8 GHz band will be widely available by this time and that improved frequency coordination will allow optimal use to be made of Band III, the 1.8 GHz band and the interleaved spectrum in combination.

[168] This grouping includes the interleaved spectrum within the UHF TV bands but we also consider the situation in which terrestrial TV is switched off leading to the loss of this spectrum (see later discussion comparing unmet demand with the potential supply of new spectrum).

[169] Wireless cameras operating in the expected 60 GHz licence exempt band are likely within the time scales considered here. However, the proliferation of other licence exempt devices is expected to limit their use for professional applications, see the discussion in section E10.

Figure E10 Summary of relevant technical developments accounted for in the analysis.

Technical development	Performance in 2028
Frequency agility	Equipment is expected to be significantly more frequency agile and frequency assignment more efficient with the result that equipment is inter-operable over multiple bands (as summarised in Figure E11).
Wireless camera frequency bands	Usable up to 12 GHz[170].
HD format wireless cameras & video links	Full quality requires channel bandwidths of 10 MHz.
3D wireless cameras & video links	Full quality requires channel bandwidths of 15 MHz.
Ultra HD wireless cameras and video links	Requires channel bandwidths of 80 MHz but deployment limited to ~25%.
Radio microphone frequency bands	Available in Band III, UHF TV & 1800 MHz bands.
Digital radio microphones	Ubiquitous with a packing density of 15 per TV channel [171].
Talkback and audio links	Channel bandwidths halved giving a net reduction in occupied spectrum of 25%.

E8 The available spectrum

Under Ofcom's current proposals management of the PMSE spectrum will move from an administrative model managed by JFMG Limited to commercial management by a new band manager with obligations to satisfy the reasonable demands of PMSE users on fair, reasonable and non-discriminatory terms until 2018. The band manager will pay AIP on its spectrum and be able to recoup its costs from its customers. By 2028 we can therefore expect the PMSE community to be competing with others for access to spectrum and paying commercial rates.

For the purposes of this analysis we have assumed that the spectrum that will be transferred to the new band manager is as currently proposed by Ofcom[172]. The bands are listed in Figure E11. These include bands at 2.4 and 5 GHz which overlap with the licence exempt bands at these frequencies. As the volume of licence exempt use increases it is likely that this spectrum will become less usable for professional productions[173] and we have therefore ignored the licence exempt parts of these bands.

The spectrum expected to be transferred to the new band manager also includes most of the interleaved spectrum within the spectrum that will be used for digital terrestrial TV broadcasting. Under the consumption scenario, *Anywhere Now*, the terrestrial networks are assumed to close down potentially making the interleaved spectrum unavailable though this depends on how the spectrum is refarmed. For example we note that the lower frequencies may not be suitable for mobile services

[170] Wireless cameras operating in the expected 60 GHz licence exempt band are likely within the time scales considered here. However, the proliferation of other licence exempt devices is expected to limit their use in professional applications, see section E10.

[171] Higher packing densities are likely to be achievable in particular well controlled environments. The figure given here is considered appropriate for situations (out door rock concerts) modelled here, see section E9.

[172] Details may be found in "Digital dividend review: Band manager award", Ofcom consultation, July 2008. Allocations that are identified as uncertain were assumed to be made to the band manager. The recently proposed changes to the UHF TV bands are not expected to change the net amount of interleaved spectrum available to the band manager, see "Digital Dividend: Clearing the 800 MHz band", Ofcom consultation, 2 February 2009.

[173] Professional users often require certainty that capacity will be available at very specific times and be interference free, and this is hard to guarantee in licence exempt spectrum.

because of the need for large antennas and so some spectrum may be available for use by other services such as PMSE. The implications of this are considered later in our comparison of unmet demand and the potential supply of new spectrum. For now we treat the interleaved spectrum as available to the band manager.

E9 Estimation of spectrum requirements

Approach

The highly localised and often temporary nature of PMSE events means that the spectrum required to support content production is largely determined by the bigger events and our analysis therefore focuses on these. Some events, such as the Olympic/Paralympic and Commonwealth Games occur infrequently but make very substantial calls on spectrum. In these cases special measures are taken to make the necessary spectrum available and it would exaggerate the apparent spectrum requirement to include such events in the analysis. Our analysis therefore considers only those events which occur at least once a year. Thus the Live8 concert which took place in 2005 would be excluded from this analysis.

The estimation of spectrum requirements has been carried out in two parts. The first considers the impact of enhanced outside broadcast events on the demand for all bands other than those used for radio microphones. The second considers the impact of new genre shows on the radio microphone bands.

The first analysis was derived from earlier work by Quotient[174] which modelled PMSE wireless usage across the whole of the UK. Starting from the actual assignments made in 2004/05 at over 3000 individual locations this study modelled the impact of increased usage taking into account the coverage required and the need to avoid co-channel, adjacent channel and inter-modulation interference. The results of this modelling were scaled to the growth expected in the two scenarios considered here to determine the peak demand for each spectrum block. The resulting shortfall (or surplus) in spectrum relative to the spectrum that the future band manager is expected to have was then computed. In doing so account was taken of the ability of JFMG to "borrow" spectrum for individual events on the assumption that the same amount of spectrum could be borrowed in 2028 as was borrowed during 2004/05.

The second analysis considered just the radio microphone bands. Of these, the interleaved spectrum within the UHF TV bands provides the greatest capacity. However, the number of interleaved TV channels available varies widely with location depending upon the local area frequency plan with the result that the capacity available for production events varies in the same way. Rock concerts, theatre shows and TV studios are all major users of radio microphones. Theatres and studios are generally well shielded, and can be shielded further if necessary, with the result that they normally have access to a large number of interleaved TV channels. Therefore, to derive a reasonably representative estimate of the match between spectrum demand and supply, this analysis evaluated a large rock concert (based on the Party in the Park concert) at seven show venues across the UK. The availability of interleaved spectrum at each venue was based on the expected availability following digital

[174] "Supply and demand of spectrum for Programme Making and Special Events in the UK", Report to Ofcom, Quotient Associates Limited, December 2006.

switchover as given on the JFMG website[175]. The most spectrally demanding case was taken into the analysis. Demand in Band III and in Channel 69 was estimated by scaling the earlier Quotient analysis and then combined with the interleaved results to determine the total demand for radio microphone spectrum under the two scenarios.

Results

Figure E11 shows the estimated shortfall or surplus of PMSE spectrum in 2028 for the High and Low Production scenarios. Figure E12 then presents the findings in graphical form[176].

Low Production scenario

Under the Low Production scenario there is adequate spectrum supply in all parts of the spectrum other than in Block 5. This consists of the PMSE bands between 2 and 12 GHz which are used for wireless cameras and video links. The shortfall comes about through the deployment of 3D wireless cameras and the additional wireless cameras required to support 360º viewing combined with the reduction in spectrum that is expected to be available to the new band manager. The shortfall amounts to approximately 200 MHz or 25% more than the band manager's assumed supply. Block 6 (the 24 and 48 GHz bands) shows a surplus of a similar size. However, the development of wireless cameras at these frequencies appears unlikely and it would be imprudent to assume that this surplus could be used to offset the deficit in Block 5.

High Production scenario

Under the High Production scenario there is greater use of wireless cameras (and associated talkback and data links) and new genre shows are assumed to use double the amount of spectrum in use today. In this case, there is a small shortfall in spectrum at the lower frequencies, a larger shortfall for radio microphone frequencies and a significantly larger shortfall for Block 5 - far greater than the surplus in Block 6.

Although relatively small in absolute terms, the shortfall in Blocks 1 and 2 amounts to a significant proportion of the total supply available to the band manager at these frequencies. However, their primary use is for wide area talkback and audio links, and Block 4 (the 1.5 GHz band), which is currently also used for audio links, shows a surplus of 4 MHz. Some equipment development and rearrangement of the 1.5 GHz band of Block 4 would be necessary to accommodate the shortfall from Blocks 1 and 2 but it is reasonable to assume that this would come about if a shortage developed at the lower frequencies. In addition some MoD spectrum in the VHF and UHF bands may become available in the coming years.

[175] We note that availability may change as the DTV plans are progressed and that these early estimates may under-estimate the available spectrum.

[176] Note that the results for Blocks 1 to 4 have been multiplied x10 to aid clarity. Thus, in Block 3, the surplus of 390 MHz shown corresponds to an actual surplus of 39 MHz.

A larger shortfall, amounting to 2 to 3 TV channels, is apparent in the radio microphone spectrum (Block 3), and an even greater shortfall, some 1800 MHz, is apparent in Block 5. As discussed above it is unlikely that the surplus in Block 6 could be used to offset the shortfall in Block 5. Even if it could the Block 6 surplus is insufficient. The shortfall in radio microphone spectrum is likely to have the largest effect on rock concerts and similar shows but it could also affect other uses, such as in theatres or TV studios, in particular situations.

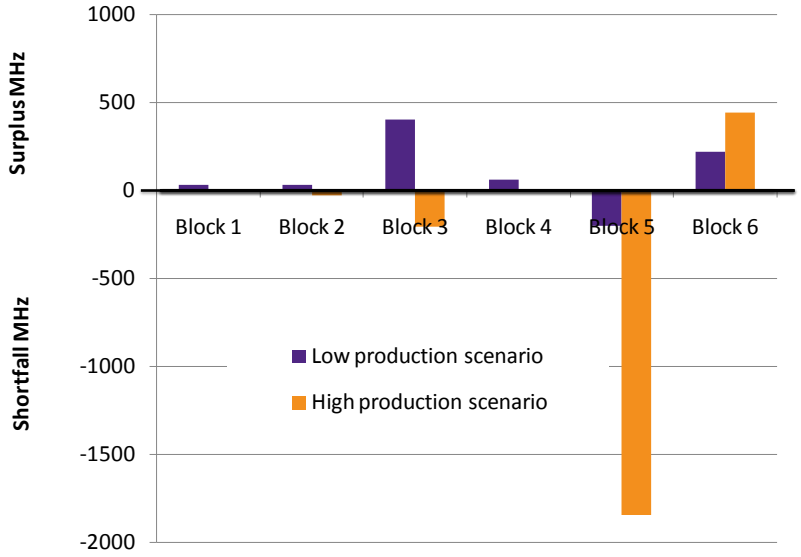
Figure E11: Quantitative results for the two production scenarios (MHz)[177].

	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Bands	Note 1	Note 2	Note 3	1.5 GHz	2, 3.5, 5, 7, 8, 10 & 12 GHz	24 & 48 GHz
Expected band manager allocation	6.6	6.3	254.6	8.0	1055	650
"Borrowed" spectrum available to the band manager	0.0	3.2	0.0	0.0	536	0
Expected demand under Low Production scenario	3.4	6.3	52.6	2.0	1794	431
Surplus under Low Production scenario	3.2	3.1	39.6	6.0	-203	219
Expected demand under High Production scenario	6.9	12.7	161.1	4.0	3437	209
Surplus under High Production scenario	-0.3	-3.2	-21.0	4.0	-1846	441

Note 1 = Band 1 (47 to 62 MHz) and Low Band (67 to 86 MHz)
Note 2 = High Band (139 – 148 MHz), Band III (181 – 200 MHz), UHF 1 (420 – 450 MHz) and UHF 2 (450 – 470 MHz)
Note 3 = Band III (173 – 210 MHz), UHF TV (470 – 862 MHz) and 1.8 GHz

[177] All results are given in MHz with negative values representing a shortfall relative to the assumed band manager allocation. Note that the shortfall in spectrum can be less than the difference between the expected band manager allocation and expected demand due to the ability of the band manager to "borrow" spectrum. Note also that the allocation given for Block 3 gives the total from within which the interleaved spectrum is derived and includes Channel 69 and the radio microphone frequencies in Band III. The surplus in Block 6 is larger in the High Production scenario due to the greater take up of satellite and fibre backhaul in this case.

Figure E12: Spectrum surplus or shortfall for each spectrum block for the High and Low Production scenarios.



We are conclude that, under the Low Production scenario, the future band manager is likely to suffer a shortfall in spectrum in Block 5 (the 2 to 12 GHz bands used for wireless cameras and video links) of some 200 MHz. Under the High Production scenario this shortfall rises to 1800 MHz and there is also a shortfall equivalent to 2 to 3 TV channels in the spectrum available for radio microphone use. It is important note that in both cases the demands are rather speculative as they assume the advent of super HD TV and the loss of all radio microphone allocations at UHF.

E10 Possible sources of supply to make up the shortfalls

By 2028 we assume the content production community will compete with other users for access. Spectrum is expected to be available through the proposed band manager and may be available from other band managers such as Arqiva and any new managers established in the meantime. Ofcom will have released further spectrum on to the market, and the MoD may well be offering access to some of its spectrum on a shared basis. Figure E13 lists spectrum between 1.4 and 13 GHz that the current plans of Ofcom and the MoD suggest could become available within the next several years[178].

[178] See www.ofcom.org.uk/radiocomms/spectrumawards/timetable/ for the Ofcom spectrum awards programme and "UK Defence Spectrum Management", Ministry of Defence Statement, 5 December 2008 and "Defense demand for spectrum: 2008 – 2027", PA Consulting Group, 24 November 2008 for potential MoD releases.

Figure E13: Summary of spectrum that could become available over the coming years[179].

Band (MHz)	Estimate of spectrum potentially available (MHz)	Band currently managed by
1427 – 1452 MHz	25	MoD
2310 – 2450 MHz	60	MoD
3100 – 3400 MHz	240	MoD
3400 – 3600 MHz	40	MoD / Ofcom
3600 – 4200 MHz	200	Ofcom
4400 – 4500 MHz	100	MoD
4500 – 5000 MHz	325	MoD
5300 – 5850 MHz	170	MoD / Ofcom
8400 – 8500 MHz	40	Ofcom
8500 – 9000 MHz	400	MoD
9500 – 10125 MHz	50	MoD / Ofcom
10225 – 10500 MHz	130	MoD / Ofcom
Total	1780	

Licence exempt spectrum can also be used for wireless cameras and radio microphones. However the lack of guaranteed capacity and interference free operation limits the situations in which it is considered acceptable by professional users. The 60 GHz band, which is expected to be made licence exempt within a year or two, has the potential to provide very high capacity. As noted before, the lack of guaranteed link quality combined with the limited range at this frequency and the increasing use of the band by other licence exempt applications might restrict its usefulness for professional uses. Whilst licence exempt spectrum will undoubtedly be used in some situations its contribution towards overcoming the shortfall in capacity is therefore expected to be small.

E11 A comparison of unmet demand and the potential supply of new spectrum

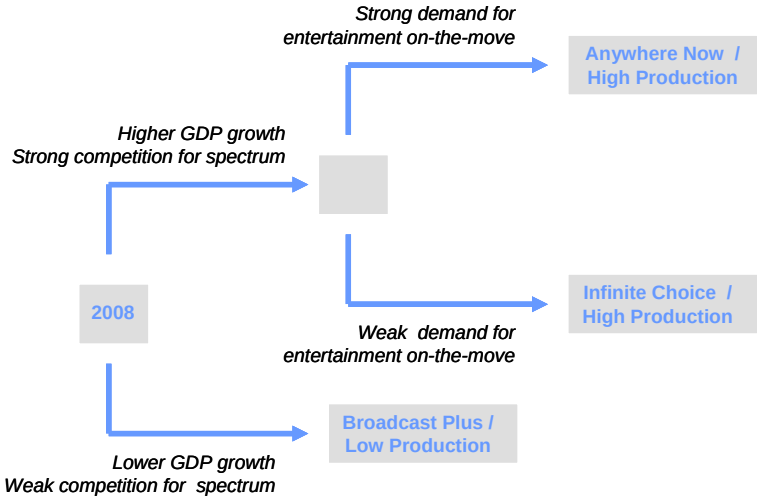
To provide an indication as to how the spectrum shortfalls identified above might be satisfied we consider the three situations illustrated in Figure E14.

- Case 1: There is a low level of demand from other sectors for access to PMSE band manager spectrum and to the spectrum opened up by the MoD for civilian access. This most closely corresponds with the *Broadcast Plus* / Low Production scenario.
- Case 2: There is a high demand for access to band manager spectrum and to the spectrum opened up by the MoD for civilian access. This corresponds to the *Infinite Choice* / High Production scenario.

[179] The two major forthcoming awards, the cleared spectrum within the UHF TV bands and the 2.5 to 2.69 GHz band, have not been included here as both are expected to be attractive to major wireless network operators and to be beyond the current financial reach of the content production sector.

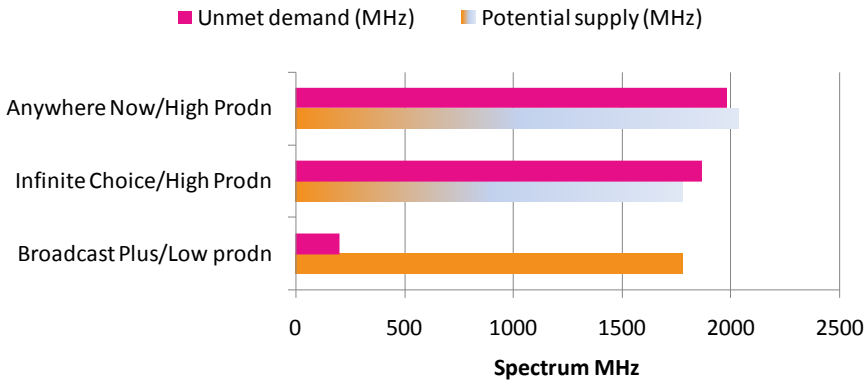
- Case 3: As for Case 2 but with the terrestrial TV service switched off to release the UHF TV spectrum for other uses. This corresponds to the *Anywhere Now* scenario, in conjunction with the High Production scenario.

Figure E14: The three situations considered and the corresponding consumption and production scenarios.



There is no technical reason why radio microphones (and the other equipment currently operated in interleaved spectrum) could not be redesigned to use the higher frequency bands although this would lead to additional costs to the industry if equipment had to be developed specifically for the UK market. So, in comparing the unmet demand for spectrum with the potential supply of alternative spectrum, we consider the combined amount required for radio microphones, wireless cameras and video links[180]. The comparison is shown in Figure E15.

Figure E15: Total unmet demand for PMSE spectrum vs the potential supply of new spectrum[181]



[180] It is also possible that some or all of the demand for radio microphones would be met by MoD spectrum in the VHF and UHF bands that may become available in the coming years.

[181] Note that the graduated colouring of the spectrum supply here indicates that strong competition for the spectrum is assumed to limit the amount that the production sector will be able to access.

In ***Case 1*** the unmet demand of 203 MHz is to be compared with the 1780 MHz of potential new spectrum. With a low level of competition from other quarters there is a high probability that the full requirements of the production sector would be met in full at prices well within the sector's willingness to pay.

In ***Case 2*** the unmet demand of 1865 MHz exceeds the potential new supply of 1780 MHz. At the same time there is strong demand from other users for access both to the band manager's spectrum and to the new spectrum. Prices could therefore rise. The larger and more popular production events generate very strong revenue streams and the production sector would be expected to be in a position to compete with the other users in these cases. The production sector might also benefit from the fact that some of the spectrum will be available on a shared basis and their requirements are likely to be more compatible with shared operation than will be the case for the competition.

In ***Case 3*** the assumed closure of the terrestrial broadcasting network might remove the major current source of radio microphone spectrum in the UK though this depends on how the spectrum is refarmed and of course other frequencies might become available for radio microphones.[182] However, we assume that the spectrum released in this way would likely be auctioned by Ofcom so as to increase the potential supply of new spectrum. The overall unmet demand[183] would rise to 1980 MHz and the potential new supply would rise by a somewhat greater amount[184] to 2035 MHz. Although this almost equalises the unmet demand and potential supply, there will also be strong demand from other users. Thus the overall situation would be similar to the second case above.

E12 Conclusions

Our analysis has considered two production scenarios both of which result in a shortfall of spectrum for content production purposes relative to the amount of spectrum that is expected to be available to the future band manager with PMSE obligations. The Low Production scenario results in a relatively small shortfall of 203 MHz in the spectrum required for wireless cameras and video links. The High Production scenario leads to a significantly greater shortfall of some 1850 MHz of wireless camera and video link spectrum, and a further possible unmet demand equivalent to 3 TV channels for radio microphones though this depends on how the UHF spectrum is refarmed. However, these shortfalls have to be compared with the likely availability of suitable alternative spectrum.

Within the next several years blocks of spectrum between 1.4 and 13 GHz, largely similar to those already used for wireless cameras and video links, can be expected to become available both from Ofcom and from the MoD. It amounts to some 1780 MHz.

The Low Production scenario is associated with the *Broadcast Plus* consumption scenario in which overall GDP growth is assumed to be low. In this situation the level of competition from other users for access to the new supply of spectrum is likely to be weak. In this situation, with the unmet demand amounting to little more than 10% of the potential supply, the production sector's requirements would likely be met..

[182] If the UK has switched off terrestrial TV so will other countries in Europe and elsewhere that have less dependence on terrestrial broadcasting (e.g. the US) in which case other bands for radio microphones may be opened up.

[183] This is of necessity a very rough estimate as a geospatial analysis of the demand for wireless microphones across the UK would be required to establish a firmer value.

[184] Since the amount of TV spectrum is greater than the amount of interleaved spectrum available within it.

The High Production scenario can be associated with both the *Infinite Choice* and *Anywhere Now* consumption scenarios. In the case of the *Infinite Choice* scenario combined with the High Production scenario the total unmet demand (for wireless cameras, video links and radio microphones) of 1865 MHz is to be compared with the same supply as above, namely 1780 MHz. In this case, however, economic growth is assumed to be significantly stronger and to result in more competition from other users for access to the alternative supply of spectrum. While there will be demand for this spectrum from other users the strong revenue streams associated with the larger and more popular production events would be expected to make them competitive with these demands on the spectrum. It also needs to be borne in mind that such large requirements will only be required if Super HD production occurs and this is likely to be targeted on the main events.

In the case of the *Anywhere Now* scenario the terrestrial TV network is assumed to close down and the UHF spectrum is refarmed. Depending on refarming decisions and demand from other services this could remove the major source of spectrum for radio microphones, although we note that the lower UHF frequencies are less likely to be attractive for cellular mobile services because of the requirement for larger antennas.

While there could be additional costs to radio microphone users if equipment had to be re-banded it seems likely the frequencies would also be used to other European countries where shutdown can also be expected to occur - particularly those less dependent on terrestrial broadcast services than the UK.

Annex F Spectrum need for the distribution of entertainment

F1 Demand for the main platforms used for distributing entertainment

In all scenarios we expect that the core fixed network will have sufficient capacity to meet the demands caused by the additional video traffic generated under the *Anywhere Now* or *Infinite Choice* scenarios. See Annex G for detailed calculations.

The assumed capacity of the access network under the three scenarios is as follows

- *Broadcast Plus*: Universal provision at first generation broadband speeds and patchy provision of second generation broadband outside urban areas because of prolonged recession and inappropriate regulation on terms of access
- *Infinite Choice* or *Anywhere Now*: Near universal provision of second generation broadband speeds to households (>50 Mbit/s down and >10 Mbit/s up)

Under the *Broadcast Plus* scenario, the fixed network delivers limited video entertainment and the bandwidth available from fixed broadband access is unlikely to be a significant constraint.

Under the *Infinite Choice or Anywhere Now* scenarios households might require three or four simultaneous streaming videos in high definition and/or 3-D formats. This is a reasonable limit on requirements given the caching offered by local storage in the home network server (*Infinite Choice* scenario) or personal device (*Anywhere Now* scenario). We assume super HD formats (e.g. Ultra-High Definition using 7680 x 4320 pixels) may start to be used for production in the Anywhere Now scenario, but assume this format is not required to be transmitted by 2028 in any of the scenarios.

An HD/3D video stream will require 9 Mbit/s by 2028. The *Infinite Choice* and *Anywhere Now* scenarios both assume NGA offers 50 Mbit/s downstream on a universal basis. So the average household would have the bandwidth required for four simultaneous HD video streams plus a number of other, lower bandwidth, applications.

Public WiFi hotspots might generate significantly greater demand for bandwidth than the average household. But such bandwidth could be provided using multiple FTTN connections or a single FTTH connection.

Figure F1 lists the main wireless platforms we expect to be used to distribute entertainment content and services. The figure summarises, in qualitative terms, the requirements placed on each platform now and in 2028 under the three scenarios. We consider the implications of these requirements on spectrum demand in Sections 3 to 7.

Figure F1: Demand for distribution of entertainment by wireless platform

Platform\Scenario	Baseline – 2008	Broadcast Plus	Infinite Choice	Anywhere Now
	Current use of platforms	Broadcast oriented entertainment	Tethered Internet based entertainment	Untethered Internet based entertainment
Home entertainment network and server	Limited	Near ubiquitous	Near ubiquitous	Home network but no central home server
Terrestrial broadcast	500 channels of SD	Capacity for HD limited	Capacity for HD limited	Terrestrial switch off
Satellite broadcast	Sky + Freesat	Major platform – 500 HD channels?	Big on HD but in decline	Big on HD but in decline
Wide area wireless access eg WiFi hotspots	Widespread but limited bandwidth	Limited demand for entertainment	Substantial demand for entertainment	Substantial demand for entertainment
Cellular network access	Very limited for entertainment	Limited importance	Limited importance	Major demands

F2 Home networking

This part of the overall architecture is essentially the interface between other delivery platforms and user devices in the home whether they are fixed units such as televisions or personal mobile devices. The home network will therefore consist of one or more of the following:

- A gateway to other networks
- A server[185] with intelligence and storage
- A communications network (wired and/or wireless).

The form that each of these elements is likely to take is discussed below with respect to the current situation (designated Baseline) and the three scenarios (identified as *Broadcast Plus*, *Infinite Choice* and *Anywhere Now*).

Baseline

Cable and ADSL routers are relatively common with an interface to outside networks running at up to 8 Mbps with a few up to 24 Mbps but it is notable that lesser speeds are often provided because of shortcomings due to the existing copper infrastructure.

Dedicated home servers (as opposed to more general purpose PCs) are available but these are not widely used at present. More rudimentary devices, which can be described as advanced STBs / PVRs, and which interface both to broadcast platforms and the internet (for on demand content) are becoming more common but market penetration is low.

Many routers also contain a wireless access point and it is therefore possible to establish a domestic wireless network. However, current wireless networks are relatively difficult to establish because set

[185] It is not necessarily the case that a home server is a single machine. It is sensible that a single controller be involved but multiple machines on the home network could exist and serve material.

up is complicated and there are reliability / coverage issues. Because of this it is difficult to maintain even a single video stream consistently. In this regard it is notable that even though routers provided by BT as part of their broadband package contain a wireless access point, BT has elected to provide users with powerline adapters (which provide an Ethernet connection over mains wiring) as these are more reliable than a wireless connection in most cases. It can be seen that although the elements of a fully fledged home network already exist, integration difficulties and current shortcomings mean that further developments are required before more general public acceptance leads to more widespread deployment. One near term development is the growth in the capacity of in-home wireless networks.

Wireless capacity in the near term

If one takes 802.11b (running at up to 11 Mbps) as somewhat historical, standard channels for 802.11g (2.4 GHz) and 802.11a (5 GHz) run at up to 54 Mbps with some propriety extensions (e.g. channel bonding) enabling 108 Mbps. These data rates are over the air and the payload capability, or usable throughput, is approximately half these figures.

The recent commercial launch of 802.11n devices, based on a draft form of the standard, introduce new technologies to devices operating in both the 2.4 GHz and 5 GHz bands. In terms of throughput the use of MIMO and channels of twice the bandwidth (i.e. 40 MHz rather than 20/22 MHz) suggest that over the air or raw data rates approaching 300 Mbps might be achieved, remembering that the payload rate is likely to be half this unless protocol overheads are improved. Furthermore, these data rates are the maximum that are likely to be achieved and are generally associated with relatively short distances. Having said this, it is reasonable to suppose that one might achieve a payload data rate of 50 Mbps in most parts of an average house.

The other important aspect relating to 802.11n is that certified devices will also be required to pass the Wi-Fi WMM (Wi-Fi MultiMedia) Quality of Service certification which brings prioritisation to latency sensitive data streams such as voice and video.

The amount of spectrum that is currently available in the 2.4 GHz and 5 GHz bands is enough to support 3 non-overlapping channels in the 2.4 GHz band[186] and 19 non-overlapping channels in the 5 GHz band[187]. The channel bandwidths are effectively the same in both bands at 20 MHz although historically the 2.4 GHz channels are referred to as having a 22 MHz bandwidth.

In the event that wireless is not able to overcome all its limitations, particularly in challenging environments, it might be necessary to consider the inconvenience and expense of wiring or a hybrid of wired and wireless where the wireless link is relatively short range and therefore not prone to as much degradation. In this case (where the wireless link is in the same room) higher frequencies can be considered (e.g. 60 / 70 GHz) as can UWB which thus far has not had a rapid rate of introduction to the market place in spite of its earlier promotion.

As well as considering the use of higher frequency bands there is also the possibility of considering frequencies lower than the existing licence-exempt RLAN bands. TV digital switchover will be releasing significant amounts of UHF spectrum for licensed services and at the same time may also

[186] There are 13 overlapping 22 MHz channels (5 MHz channels spacing) that have been defined for use in Europe. 11 have been defined for use in the US. It is common to use 3 non-overlapping channels (Channel N^{os} 1,6 and 11) but this is largely driven by US spectrum availability. In Europe it is possible to use 4 near non-overlapping channels (Channels N^{os} 1,5,9 and 13) with little or no adverse effects.

[187] There are currently some constraints on this while the Dynamic Frequency Selection (DFS) mechanism is revised to take better account of weather and other recently identified radars that are operating in the same band.

provide the opportunity to access the interleaved spectrum that will continue to be used for TV broadcasts. Use of this spectrum could be on a licence-exempt basis and will crucially depend on no interference being caused to the primary users (i.e. the broadcasters). This will require the use of smart (cognitive) radio and/or geo-location techniques. Proposals have already been made to use this so called "white space" spectrum for residential internet / multimedia applications both on a wide area basis (i.e. fixed wireless access) and for home networking within a residential unit. In terms of capability it can be noted that the bandwidth available will be less significant than that already available (at 5 GHz for example) but on the other hand the propagation characteristics at UHF could provide the benefit of a more consistent coverage throughout a building than is currently achieved.

Broadcast Plus

In this scenario scheduled programming delivered over broadcast platforms dominates. This programming is either watched in real-time or recorded for time shifted viewing and / or the construction of personalised schedules. The recording of scheduled programmes will use tuners associated with a home server. The real-time watching of programmes could either be based on streaming the content directly from a tuner in the home server or by using individual tuners in the various devices around the home. From a cost and ease of use point of view it is thought that the real-time watching of scheduled programmes will continue to be based on tuners embedded in each device.

The implication for the communications network in this scenario is that there will be a large amount of material stored on the home server for later distribution either to fixed clients (e.g. televisions) or personal devices. Note that the majority of the material is for consumption (rather than being generated by individuals) so the communications requirement is primarily down linking.

The amount of spectrum required to support the distribution of recorded programmes is driven by the number of household members who are simultaneously engaging in this activity. It can be assumed that they will be accessing different programmes but it can also be noted that some members of the household will be accessing scheduled programming in real-time using tuners in their local device and thereby not requiring any home network capacity.

There is a limited requirement for access to on-demand services in this scenario so this will have a minimal impact on the amount of spectrum required *vis a vis* other content consumption. There will be a slight uplift in spectrum requirement if on-demand consumption displaces real-time access to scheduled programming as the former will use spectrum for streaming whereas the latter uses embedded tuners. Such displacement is not regarded as being significant.

There will however be a requirement for side loading content from the home server to personal devices and this could have a more demanding requirement with regard to spectrum than video streaming. Earlier it has been assumed that the storage capacity of personal devices will increase one thousand fold over the timescale being considered from a current average of 10 GBytes.

Spectrum requirement

Assuming that improvements can be made to wireless networking such that high definition streams can be supported without degradation, the amount of spectrum required in an individual residence is determined by the number of household members simultaneously accessing stored material to consume in real time, noting that some members of the household are likely to be watching broadcast material in real-time. In addition there is the requirement to side load personal devices with content.

If four members of a household are streaming HD content at 7 Mbps per channel then even taking account of anticipated (near term) payload data rates of 50 Mbps in most parts of a house this should be enough to accommodate the aggregate stream rate of 28 Mbps on a single 40 MHz RLAN channel. If the streamed content is 3-D based then the required throughput is expected to be approximately 30% higher at 36 Mbps in aggregate (i.e. 9 Mbps per HD/3-D stream). This is still within the foreseen near term capability of a single 40 MHz RLAN channel but that channel will be operating at a point where the protocols are likely to work less efficiently and degradation might be expected. In the longer term it is expected that RLAN channel throughput will be extended, along with quality of service protocols, such that sufficient throughput headroom is provided to support four or more HD/3-D streams on a single channel.

In addition to the streaming of channels there will also be a need for members of a household to side load their personal devices with content for use later. For convenience this has to be done at a data rate considerably higher than the rate associated with real-time watching. In order to put such side loading in context, Figure F2 shows the amount of time it would take to refresh a current device and a future device under different circumstances (complete or partial refresh, different transfer rates).

It can be seen that while current / near term side loading activities are manageable, it is likely that future requirements will not be so easily accommodated by wireless connections when these are more than short range. In particular the side loading of the whole capacity on a personal device is likely to be inconveniently long and the current approach using a wired connection may well continue to prevail.[188]

If these two activities (i.e. streaming of content for watching and side loading of devices for later use) are undertaken simultaneously it is clear that at least two high capacity RLAN channels will be required per household[189]. Given that these high capacity channels will be 40 MHz or more (rather than the 20/22 MHz channels currently used) it is possible that congestion will arise in some circumstances as the number of channels available will be limited (fewer than the 19 in the 5 GHz band as the channel bandwidths will at least double). In well spaced residential districts there should not be an issue of interference with the amount of spectrum currently available. In the case of high density flats though there is always the potential for interference as RLANs are generally uncoordinated. However, some of the techniques used in enterprise access points, such as intelligent channel and power selection can improve the situation significantly and future standards usefully address a more cooperative approach to frequency planning.

If this solution is not feasible then there could be a requirement for significant additional spectrum to provide sufficient isolation between individual homes in the three dimensional space that is a block of flats. While current RLAN protocols are very efficient at sharing out channel capacity when there is mutual interference on a channel (which is particularly relevant to uncoordinated usage), further knowledge of the impact on the user experience is required before an estimate of the additional spectrum can be made.

[188] Use of mesh networks or high frequencies for sideloading will be mainly limited to downloads in the same room as the home server, because walls will block radio paths.

[189] If more than one member of a household wants to side load their personal device at the same time then the time to complete the operation shown in the table will increase in proportion to the number of people side loading simultaneously, assuming they are using the same RLAN channel.

While the industry supporting 802.11 protocols has been very successful at implementing systems that make best use of the spectrum through various sharing mechanisms, it is notable that other types of licence-exempt system are also allowed to access the same spectrum space. Sharing between 802.11 based systems and other types of system is less successful and consideration could be given to mandating the use particular protocols in order to make best use of the spectrum. However, this might be seen as a move away from the more general aim of technology-neutrality and in any event would not be immediately effective because of the multitude of existing non-conformant devices in the field.

Figure F2: Time required for side loading at different data rates

Maximum transfer rate	10 GB capacity (now)	5,000 GB capacity (future)	Degree of refresh
25 Mbps	53.3 minutes	Superseded	Complete
150 Mbps	8.9 minutes	3.1 days	
500 Mbps	Not available	22.2 hours	
25 Mbps	5.3 minutes	Superseded	10% (equivalent to loading approximately 100 hours of HD/3D)
150 Mbps	53.3 seconds	7.4 hours	
500 Mbps	Not available	2.2 hours	

Infinite Choice

In this scenario scheduled programming is a residual affair (the opposite of the Broadcast Plus scenario above) with most users accessing on-demand material over the internet either when they need it or later on having downloaded the material in advance.

Since wideband access to the internet is only assumed to be available at fixed locations, this scenario also relies on significant storage being available particularly for personal devices. The knock on implication for the home network is that personal devices will be side loaded at home so there will also be a requirement for significant storage on the home network and a sufficiently capable broadband connection for downloading material. It has been assumed that these storage and gateway connectivity requirements do not give rise to any bottlenecks.

In the worst case, noting that there is little if any consumption of broadcast material, the amount of spectrum required in this scenario is potentially greater than the Broadcast Plus scenario because all members of a household will potentially be consuming streamed content simultaneously and also, to some extent[190], downloading content for later use. The requirement for side loading personal devices, as in the Broadcast Plus scenario, also exists in this scenario. Furthermore, there is a significant presence of user generated content (UGC) which implies greater uplink requirements in the home network.

[190] This recognises that not everyone will always be efficient enough to schedule such downloading overnight.

Spectrum requirement

The same considerations as the Broadcast Plus scenario also apply here, especially since we have already considered the possibility of all members of a household watching streamed content simultaneously. The same conclusion can be reached that at least two high capacity RLAN channels will potentially be required per household and that there is the potential for congestion in blocks of flats unless more intelligent and/or cooperative frequency management is implemented. However, in this scenario there is also the requirement for UGC uplinking and the question then arises as to whether this happens simultaneously with the whole household watching streamed content and some degree of side loading taking place. It is considered that the amount of UGC being uploaded is orders of magnitude less than the content being side loaded as the need for choice does not enter the equation. It is therefore considered that the impact of UGC on the spectrum required is minimal in the context of the other spectrum based activities going on.

Anywhere Now

In this scenario the reception of unicast material and the ability to upload UGC will be available to people on the move without constraint. Because of this there is less emphasis on local storage[191] as material will be available as required from a source on the internet wherever the user is located.

In the home environment this means that content will largely be streamed on demand and there will be less of a requirement for wireless links to support the downloading of material to personal devices for later consumption. There will be a requirement to support UGC uplinking as in the case of the Infinite Choice scenario.

Spectrum requirement

On the basis of the Broadcast Plus assessment it is considered that two high capacity RLAN channels (at most rather than at least) will be required per household. One channel will be required for the watching of streamed on demand material as before and the other channel will be required for other activities such as the uploading of UGC and side loading, again as before. Due to the reduced requirement for side loading (because of the wider availability of wireless unicast) this second channel is described as “at most” rather than “at least”.

F3 Terrestrial broadcast – fixed and mobile

Terrestrial broadcasting is considered to include the transmission of scheduled programming (both TV and sound) over the airwaves from ground based transmitters. This includes both the wide area coverage to fixed receivers provided by the traditional high power transmitter network and the coverage provided for mobile receivers by a denser network of lower power transmitters, the latter often referred to as Mobile TV.

The form that each of these methods of delivery might take is discussed below with respect to the current situation and the three scenarios.

The implications of the delivery of the same or similar scheduled programming over cable networks and the internet is considered elsewhere where it is assumed that the former method (i.e. cable) will die out as the internet based on NGA takes over.

[191] This is not to say that there won’t be any local storage on home servers or personal devices, it is simply that there will be less of a need for as much local storage as the Broadcast Plus and Infinite Choice scenarios. It can be envisaged that many might not have a home server per se and simply connect wirelessly to a router at the internet gateway.

Baseline

TV analogue to digital switchover is scheduled to be complete by 2012. The current six multiplexes are based on the DVB-T / MPEG-2 standard and each one carries a number (4 to 8) of standard definition channels along with lower capacity radio and other channels. There is a plan to make one of the six multiplexes available for (3, 4 or, perhaps ultimately, 5) high definition channels based on the DVB-T2 / MPEG-4 standard by squeezing more standard definition channels on the remaining five digital multiplexes.

Mobile TV trials have been undertaken in the UK with limited success so far. One commercial service has been launched and failed and spectrum at L band that could possibly be used for mobile TV has been sold at auction though it is unclear at present whether it will be used to deliver a mobile TV service. There are indications from implementations elsewhere in the world that certain business models can be successful though this too is uncertain.

Radio broadcasting is supported by a mixture of analogue and digital (DAB) transmission. It currently appears that the future of digital radio is far from certain although the possibility analogue switch-off has been mooted.

Broadcast Plus

In the long run it can be seen that there is likely to be a migration to high definition TV channels. However, from a terrestrial broadcast point of view the amount of spectrum available for this is severely limited even if broadcasters were to purchase digital dividend spectrum. Assuming that all UHF channels (N^{os} 21 – 68) were available to broadcasters (i.e. including the released spectrum), it would be possible to provide 8 multiplexes nationwide, which might support[192] between 24 and 32 HDTV channels depending on the degree of compression applied.

This situation is even more limiting than first appears as the terrestrial broadcasters would need additional spectrum for simulcasting while the transition takes place.

There will also be a tension here because the additional spectrum that the DVB-T(2) broadcasters might require is likely the same spectrum as that required for Mobile TV (DVB-H).

It can be seen therefore that there is a severe and largely irreducible constraint on making hundreds of HD channels available using terrestrial broadcast means. In some ways this is acknowledged by the BBC / ITV through their involvement with Freesat. This confirms that any requirement to broadcast a significant number of HD channels is best done using a satellite platform.

Spectrum requirement

There is insufficient UHF spectrum to satisfy future requirements for HDTV broadcasting by terrestrial means and it is unlikely bordering on impossible that sufficient spectrum could be provided for hundreds of channels. Terrestrially broadcast TV will remain constrained to post-DSO UHF spectrum with a possibility that some of the released UHF spectrum is acquired by the broadcasters for additional channels.

The spectrum requirement for mobile TV is likely to be modest, supporting real-time channels such as news & sport. Based on a single frequency network up to two (8 MHz) channels would be required to support a pair of multiplexes, which is the likely requirement to provide a cost effective service. It is possible that some of the released UHF spectrum will be acquired (in competition with DVB-T broadcasters).

[192] Assuming the use of DVB-T2 and MPEG-4

Infinite Choice

Because on-demand material rather than scheduled programming is the dominant means of consumption, terrestrial TV broadcasting is likely to decline.

The situation for mobile TV is slightly different. This scenario is based on the user obtaining material either at home or at fixed locations (e.g. Wi-Fi hotspots) when out of the house. This means that there will be a role for mobile TV to play with regard to users accessing real-time programmes (e.g. news / sport) while on the move.

Spectrum requirement

As terrestrial broadcasting is seen to decline in this scenario ultimately there is less of a requirement for spectrum than in the Broadcast Plus scenario above. However, between now and then a similar consideration applies - terrestrially broadcast TV will remain constrained to post-DSO UHF spectrum with a possibility that some of the released UHF spectrum is acquired by the broadcasters for additional channels.

As in the Broadcast Plus case, the spectrum requirement for mobile TV is likely to be modest, supporting real-time channels such as news and sport. Based on a single frequency network only two (8 MHz) channels would be required to support a pair of multiplexes, which is the likely requirement to provide a cost effective service. It is possible that some of the released UHF spectrum will be acquired (in competition with DVB-T broadcasters).

Anywhere Now

In this scenario the dominance of other platforms means that there has been a terrestrial TV transmission switch-off and mobile TV as a broadcast medium has been supplanted by cellular delivery which is expected to be able to support the relatively limited real-time programming (e.g. news / sport) needs.

In this situation it is worth noting that this means the demand for UHF spectrum has to a very large extent vanished. Furthermore, the value of this spectrum to other users is limited because in this scenario the main wide area radio platform is likely to be a development of the cellular system but mainly using very small cells in order to support high uplink data rates. UHF spectrum is not good for obtaining a high density of frequency reuse and such cellular systems are more likely to be migrating towards higher frequencies.

Spectrum requirement

None, as content carriage (including mobile TV) has migrated elsewhere.

F4 Satellite broadcast

The move from analogue to digital to HD television has been much quicker on the satellite platform. A significant amount of Ku-band spectrum (in the range 10 to 15 GHz) is available to satellite services and consequently there is a much larger capacity for TV channels when compared to the terrestrial broadcast platform. Some 600 SD, 30 HD and 200 radio channels are currently available from the 28.2°E/28.5°E orbital slot(s) at which the overwhelming majority of UK dishes are pointed.

Radio listening at home via fixed satellite receivers has become increasingly significant in recent years, but these services cannot be received directly by portable or car receivers. The Worldspace system, operating at 1.4 GHz which does allow portable reception, has achieved a very small take-up

for its pan-European services. In the US, the direct broadcast radio services provided by XM and Sirius have been much more successful, driven by a lack of contiguous radio coverage beyond cities, and by commercial links between car manufacturers and the broadcasters. There has also been talk of a similar satellite based system in Europe but there is little evidence of it emerging and it is hard to see how it might be justified commercially.

The way in which the TV platform might develop is discussed below with respect to the current situation and the three scenarios.

Baseline

While there are several satellites broadcasting TV services across Europe, in the UK the main TV services originate from a single orbital slot. This is largely driven by the constraint imposed by the fixed pointing of users' satellite dishes. The capacity for TV services is therefore constrained by the spectrum available at that slot which although large is finite. With the increasing demand for bandwidth resulting from HD programming it is clear that the capacity in the favoured slot is or will shortly reach saturation[193]. There is recognition in the industry that the reliance on single slots has to be broken and it is notable that Astra is promoting satellite dishes that are able to receive from two slots simultaneously[194].

Although the provision of satellite based broadcasting in the UK is currently dominated by Sky, it is notable, as mentioned earlier, that the BBC and ITV are both becoming more directly involved in satellite broadcasting through their interest in Freesat which launched recently.

Broadcast Plus

This scenario suggests that there could be several hundred broadcast high definition channels. However, as noted earlier the ability to do this using conventional terrestrial broadcasting is severely limited. The main and proven alternative platform to do this is satellite broadcasting. This scenario therefore plays to satellite strengths namely capacity and wide area broadcasting.

Although there is an artificial satellite broadcasting capacity bottleneck, in principle there is no real capacity limitation if the inconvenience of using multiple orbital slots can be overcome – technically this not an issue.

Spectrum requirement

There is no additional spectrum required to support the many hundreds of TV channels foreseen. The satellite downlink allocations at Ku-band are extensive (10.7 – 12.75 GHz, although some parts are constrained by various orbital plans) and adequate for future needs considering that existing technical obstacles can be overcome.

[193] There is also currently a limitation on the number of channels that the satellite Electronic Programme Guide (EPG) can accommodate. This is mainly due to memory limitations in older receivers. While this is an inconvenience in terms of usability, in principle it should not constrain the number of channels that can be received.

[194] http://www.ses-astra.com/resources/pdf/en-shared/technical_support/DUO_LNB_II_3_1_2.pdf

Infinite Choice

In this scenario there is less emphasis on the broadcasting of scheduled programmes with more emphasis placed on individual programming (based on non-broadcast material) and on-demand services. While satellites can support such services from a technical point of view they cannot generally be justified due to cost particularly when an extensive terrestrial communications infrastructure is available.

This scenario would therefore see satellite broadcasting in decline.

Spectrum requirement

As satellite broadcasting is seen to decline in this scenario the requirement for spectrum is ultimately[195] less than the Broadcast Plus scenario which in itself has no additional demand for satellite spectrum (see above).

Anywhere Now

As far as satellite broadcasting is concerned this scenario looks very similar to the Infinite Choice scenario in that there is less emphasis on the broadcasting of scheduled programmes and more emphasis placed on individual programming and on demand services.

This scenario would therefore also see satellite broadcasting in decline.

Spectrum requirement

As for the Infinite Choice scenario, satellite broadcasting is seen to decline. The requirement for spectrum is again ultimately less than the Broadcast Plus scenario which in itself has no additional demand for satellite spectrum (see above).

F5 Cellular network access

Baseline cellular technology

Current cellular technology in the UK is based on the 3GPP family of standards with the 2G networks based on GSM and the 3G networks based on UMTS. Enhancements to the standards have been made to incorporate high speed data access using GPRS and EDGE on 2G networks and High Speed Packet Access (HSPA) on 3G. HSPA is able to provide up to 14.4 Mbit/s download speeds in an uncontended environment and up to 5.7 Mbit/s upload speed. The speed that is achievable is highly dependent upon the location of the user. Users at the edge of cells experience poorer performance.

Future development of cellular networks is centred around two network standards.

- Long Term Evolution (LTE) is an enhancement of the 3GPP family of standard that will be capable of providing up to 100 Mbit/s peak data rate in the downlink and 50 Mbit/s peak data rate in the uplink when using a 2 x 20 MHz channel. Practical throughputs are lower due to contention and variation in transmission distances. Likely mean throughputs are expected to be around 20 Mbit/s in the downlink and 10 Mbit/s in the uplink. Initial systems are planned for deployment in the 2.6 GHz band paired spectrum, but since the standard may be applied in a variety of channel

[195] Even if between now and then the demand is at some point the similar to the Broadcast Plus scenario.

bandwidths from 1.25 to 20 MHz it may be implemented in any of the 2G and 3G bands in the future.

- WiMAX is a new technology that is starting to be implemented in the mobile environment. The version of the standard supporting mobility IEEE 802.16 (2005) – often referred to as 802.16e – has been launched by Sprint in the US and is planned for other advanced markets. It has a capability of delivering around 20 Mbit/s in a 10 MHz channel. Again practical throughputs are likely to be lower but it represents a significant advance on current 3G capability.

Both LTE and WiMAX are based on OFDM which offers higher efficiency than current cellular technologies. Both will benefit from more advanced antenna technology and increased complementary use of public wireless hotspots in the future, which will offset the amount of additional spectrum required.

Cellular capacity will be increased by the introduction of WiMAX networks and it is debatable whether these networks should be considered part of the cellular network access infrastructure or wireless hot-spots in the future. If they are unable to command dedicated subscriptions with end-users or coverage is provided on an ad hoc basis with little formal planning, then they may provide a hot-spot coverage service for the cellular operators.

Spectrum supply

We can consider spectrum for cellular use in categories according to the degree of harmonisation that is likely with other countries. Existing spectrum and the bands to be awarded imminently have good harmonisation prospects with other European countries. The remaining WAPECS band at 3.4 to 3.8 GHz may be harmonised across some countries. Additional spectrum may be released for mobile communications from MOD bands, however they are not likely to be harmonised for some time. With strong demand, moves to harmonise additional spectrum would be likely to occur. The bands are summarised in Figure F3.

Model of spectrum demand

We cannot model demand for spectrum which will be used for entertainment applications in isolation from other mobile broadband applications. Figure F4 lists the main assumptions we make in order to project future demand for cellular mobile traffic while Figure F5 shows our projections to 2028 under the *Anywhere Now* scenario. We note that:

- The demand which entertainment places on cellular networks under the *Broadcast Plus* and *Infinite Choice* scenarios is modest and total demand can be represented by the IP data traffic projections alone under these scenarios
- We have modelled demand in the 218 km² of central London, where the population density is highest in the UK during the working day[196].

[196] The population density in central London during the working day reaches over 12000 people per sq km compared with an average for the UK of 245 per sq km.

Figure F3: Spectrum supply for public mobile communications

Category	Band	Frequency range	Total spectrum	Availability
Existing	GSM 900	880 to 915 MHz 925 to 960 MHz	2 x 35 MHz	Assigned for mobile use
	GSM 1800	1710 to 1785 MHz 1805 to 1880 MHz	2 x 75 MHz	Assigned for mobile use
	UMTS	2000 to 2020 MHz 2020 to 2080 MHz 2100 to 2160 MHz	1 x 20 MHz 2 x 60 MHz	Assigned for mobile use
Imminent	2010 MHz	2010 to 2025	15 MHz	2009
	2.6 GHz	2500 to 2690 MHz	190 MHz (note 1)	2009
	800 MHz	790 to 862 MHz	72 MHz (note 2)	2013
Partially harmonized	3.4 – 3.6 GHz	3.4 to 3.6 GHz	2 x 40 MHz (note 3)	Assigned for mobile use
	3.6 – 3.8 GHz	3.6 to 3.8 GHz	2 x 84 MHz (note 4)	Not liberalised for mobile use
Non-harmonised	MOD release[197]	406.1 to 430 MHz 3400 to 3600 MHz 4400 to 4500 MHz 4500 to 5000 MHz 5300 to 5850 MHz	Depends upon extent of current MOD use	From 2009 for 406.1 to 430 MHz band. Others depend on development of Recognised Spectrum Access (RSA) rights
	600 MHz	550 to 606 MHz	56 MHz	2013

Note 1: The 2.6 GHz band is due to be assigned by auction in 2009. Up to 140 MHz may comprise paired spectrum

Note 2: This part of the digital dividend cleared spectrum appears favoured by mobile operators

Note 3: Spectrum currently assigned to UK Broadband

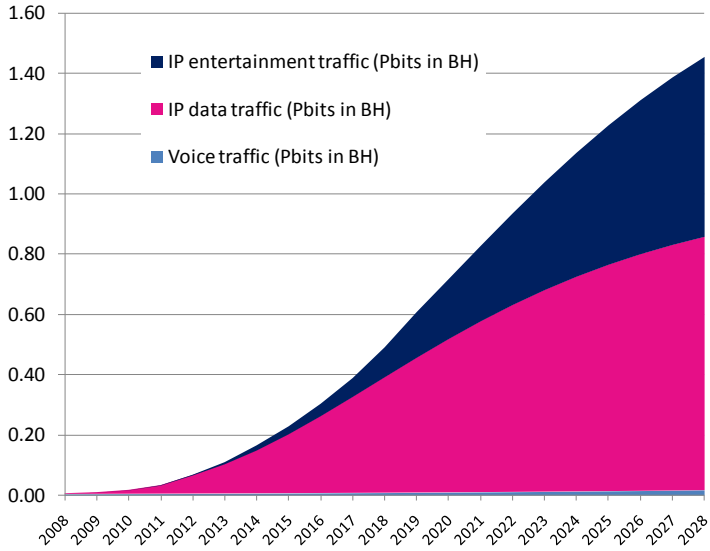
Note 4: Spectrum currently assigned to Freedom4

[197] See "Spectrum management. A statement on: An implementation plan for reform", Ministry of Defence, 5th December 2008. http://www.mod.uk/NR/rdonlyres/40622FC9-DC7B-40FC-B48A-90408F6F7676/0/spectrumstatement_051208.pdf

Figure F4: Assumptions used to model future demand for cellular services

Parameter	2008 value	2028 value	Source
Penetration of cellular services	122.8%	150%	2008 value from Ofcom market data. 2028 value is Plum estimate[198].
Voice traffic per user	16mErlangs	51mErlangs	2008 value from Ofcom market data. 2028 value extrapolated from recent historical growth of 6% p.a.
IP data traffic in UK (PBytes per month)	2.5	916	Cisco projections[199] extrapolated using a Gompertz curve
% IP data traffic from mobile devices	0.6%	17.7%	Cisco projections extrapolated using a Gompertz curve and with ceiling of 20%
Ceiling on IP entertainment traffic	19.2 Pbits[200] in the busy hour	19.2 Pbits in the busy hour	Assume a ceiling of 10 minutes per day of entertainment video per subscriber at 2 Mbit/s for 80 million subscribers with 20% of traffic in the busy hour.
Growth in IP entertainment traffic	0% of ceiling	68% of ceiling	Assume that the growth curve towards the ceiling has the same shape as the IP data mobility growth curve but lagged by five years.
% of traffic from mobile devices using public wireless hotspots	20%	74%	Plum assumption. See text
% population in Central London	4.6%	4.6%	Population statistics

Figure F5: Projections of cellular mobile traffic for central London – *Anywhere Now* scenario



Source: Plum projections

[198] Note that some markets are already approaching this. e.g. Hong Kong has a penetration rates of 142%.

[199] *Approaching the Zettabyte era*, Cisco June, 2008

[200] 1 Pbit = 1 Petabit = 10^{15} bits

We note that our assumption about the proportion of traffic generated by mobile devices which is routed via public wireless hotspots is no more than a credible guesstimate. We made it following discussions with stakeholders and taking account of the fact that over 70% of calls from mobile devices are currently made when the user is at home, at work or in a public place with WiFi coverage. We also note the trend for mobile operators such as 3 and O_2 to bundle public WiFi services with their mobile offerings.

Cellular network capacity in central London

To estimate the capacity of cellular networks in central London in 2008 we use the assumptions of Figure F6.

Figure F6: Key assumptions for cellular network capacity in London in 2008

Driver	Value in 2008	Source/rationale
Proportion of traffic on microcell layer	50%	This is the proportion of traffic handled by microcells in areas where microcells are implemented.
Macro site spacing	1 km	Spacing is limited by site availability with sufficient positional accuracy
Micro site density	33/km^2	2008 value based on current site density in 5 km^2 of Central London. 2028 value as demanded by traffic levels.
Spectrum efficiency (voice)	0.03 Mbit/s / MHz / cell	Average uplink and downlink, based on homogenous network deployment 2008 voice spectrum efficiency based on GSM 2008 data spectrum efficiency based on HSPA 2028 spectrum efficiency based on LTE with an assumed doubling of spectrum efficiency
Spectrum efficiency (data)	0.15 Mbit/s / MHz / cell	
Spectrum deployment factor	70%	Allows for variations in topography and traffic density

We estimate that current demand can be met using 275 MHz of the 360 MHz which is currently available. We then use the following simple model to estimate how capacity (C) in an area might change over the next 20 years:

$$C = \alpha SNe \quad \textbf{\textit{Equation F1}}$$

where:

α is a constant
S is the total spectrum available for use by mobile networks
e is the level of spectrum efficiency and
N is the number of cells per operator in the area[201]

To assess the likely increase in capacity we note that:

[201] Note that capacity is a function of the number of cells per operator rather than the total number of cells for a given assignment of spectrum for cellular mobile use. This reflects the fact that, if the number of operators increases while the number of cells per operator is held constant, then the total number of cells increases but the spectrum per operator declines and with it the capacity per cell.

- There are substantial problems, both in reducing macro cell spacing from (the current assumed) 1000 metres to less than 600 metres, and in increasing microcell density, in the 5 square km in which they are deployed, by more than a factor of three. This leads us to assume a three fold increase in cell density
- We also expect significant increases in throughput per cell. We assume a five fold increase following the deployment of OFDM technologies like LTE.

In combination these changes give us a 15 fold (5 x 3) increase in network capacity.

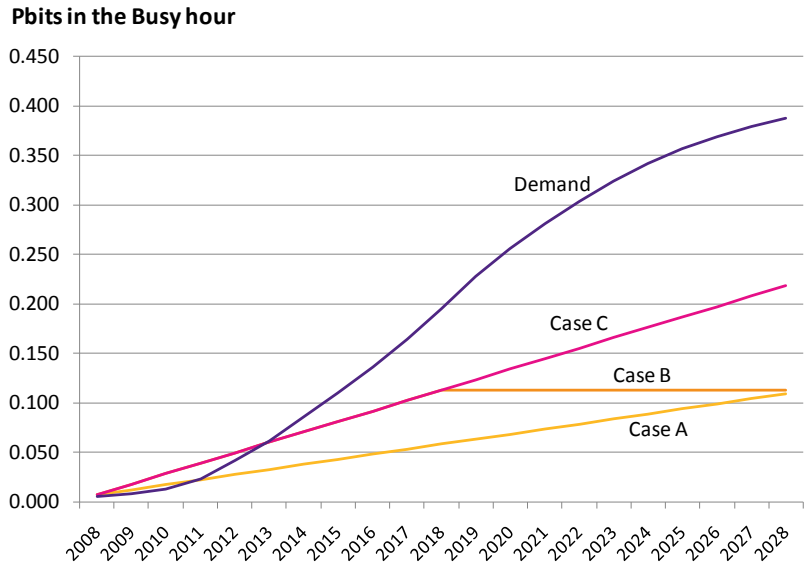
Demand versus capacity

Figure F7 plots demand under the *Anywhere Now* scenario against capacity in central London for the next 20 years assuming no additional spectrum is made available. We consider three cases:

- ***Case A***: Capacity increases linearly by 15 fold between 2008 and 2028
- ***Case B***: Capacity increases linearly by 15 fold between 2008 and 2018 and there are then no further increases in network capacity
- ***Case C***: Capacity increases linearly by 30 fold between 2008 and 2028. Here we assume that capacity gains continue at the same rate between 2018 and 2028 as in the previous 10 years. At the moment we do not know where such improvements in network performance will come from. But it seems reasonable to assume some continuing increases in cellular network capacity[202].

We consider that an outcome somewhere between Case B and Case C is the most likely.

Figure F7: Cellular demand vs capacity in central London – *Anywhere Now* scenario



Source: Plum projections

[202] Cooper's and Edholm's "laws", as set out in Figure 4.1, state that we can expect a 250 fold increase in the capacity of the cellular network over the next 20 years if the historic trends of the last 20 years continue

Additional spectrum required

Given the plots of Figure F7, how much additional spectrum is required so that capacity just meets demand? Figure F8 and F9 show our estimates for the *Anywhere Now* and *Infinite Choice/Broadcast Plus* scenarios respectively. We use Equation F1 to calculate the additional spectrum required to close the gap between the capacity curves of Figure F7, which assume no additional spectrum is provided, and the appropriate demand curve. For the *Anywhere Now* scenario of Figure F8 we use the total demand curve of Figure F7; and for the *Infinite Choice* and *Broadcast Plus* scenarios we use the demand curve represented by IP data traffic plus voice traffic of Figure F5.

Our estimates show the minimum spectrum which is required. Supply of more spectrum than is shown in Figures F8 or F9 would lead to lower capital expenditure, since fewer base stations would then be required.

The two figures show demand for spectrum declining slightly from 2021 on. This decline reflects the fact that from 2021 capacity grows more quickly than demand. In practice it is unlikely that mobile operators would hand back the surplus spectrum created by this decline. It is more likely that they would use it to reduce their capital expenditure on base stations. In any case it is quite likely that new, and as yet as unforeseen, applications would emerge to use this surplus spectrum.

Figure F8: Additional spectrum required in MHz – *Anywhere Now* scenario

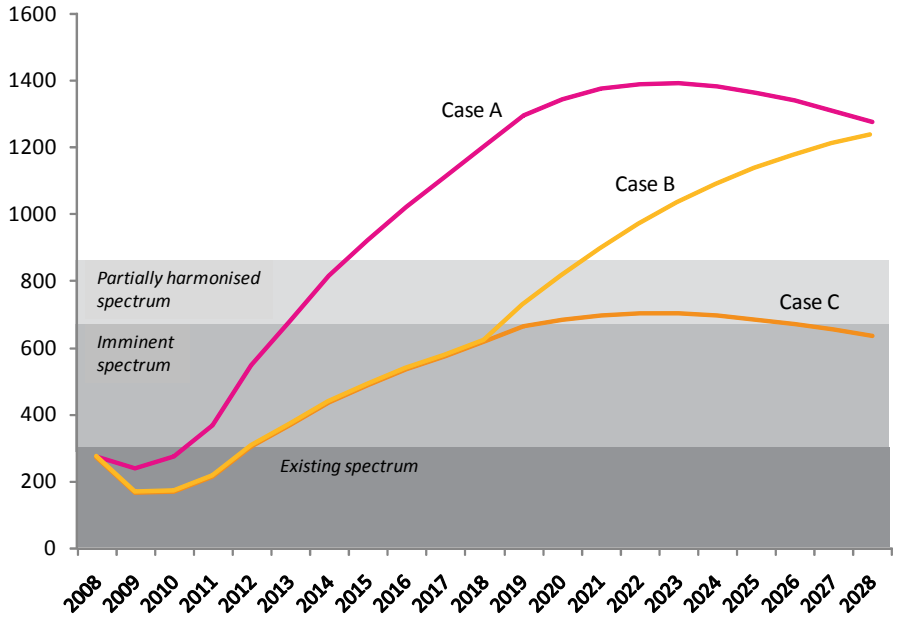
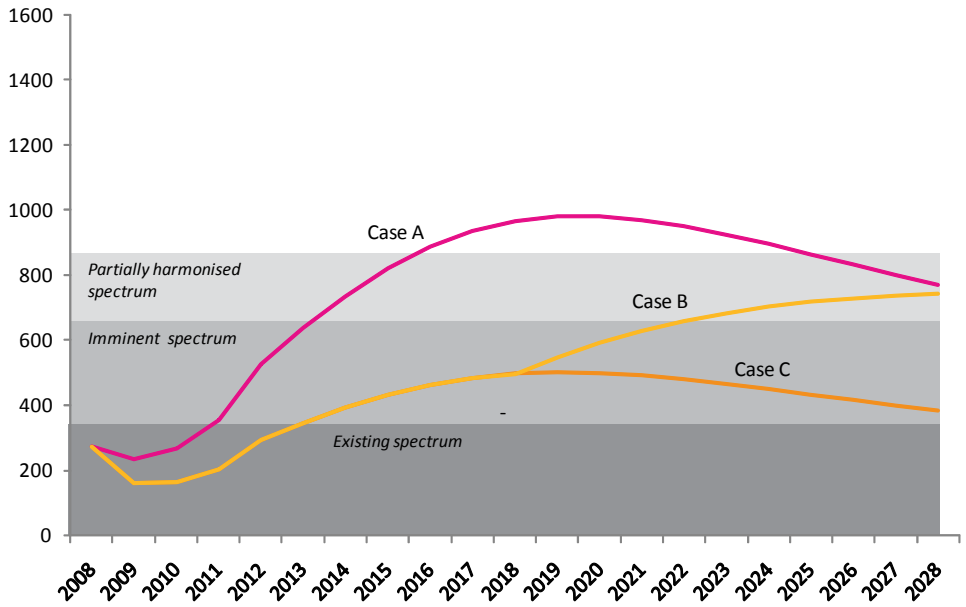


Figure F9: Additional spectrum required in MHz – *Infinite Choice* or *Broadcast Plus* scenario



Figures F8 and F9 show that:

- In Case C there are no significant shortages of spectrum under any of the three scenarios
- In Case B there is adequate spectrum at least until 2018 under the *Anywhere Now* scenario, and until 2023 under the *Infinite Choice* or *Broadcast Plus* scenarios
- Only in Case A is there an imminent shortage of spectrum. Here demand for spectrum exceeds the Imminent supply level by 2013 or 2014 under any of the scenarios.

Our estimates are very sensitive to the assumptions we make about demand projections. These are uncertain and need monitoring to see whether the problem situations identified above will be realised.

The impact of User Generated Content (UGC) in the wide area

User generated content imposes two demands on network capacity associated with its production and consumption respectively. We have assumed that consumption of UGC is part of the overall time spent viewing video entertainment and that as UGC becomes more popular it will displace other content. The production of UGC will require additional resources but we have assumed that these requirements are modest (at around 1% of total viewing time per user). This reflects an expectation that only a few users will generate UGC and this will form only a portion of their total time spent consuming entertainment services. Therefore the overall amount of spectrum required is similar to the case without UGC in the wide area.

The major impact of UGC is in the nature of the network that the operator needs to deploy. Outside of the most congested areas operators would need to deploy additional microcells specifically to cater for the uplink requirements of UGC, since the power available for transmission from a personal device is limited by both battery life and radiation power limits and for health reasons. In rural areas it may be completely impractical to cater for UGC except for low resolution screen formats.

Operators are currently interested in UHF spectrum for cellular network deployment because it has better propagation characteristics offering lower cost deployment in rural areas and deeper in-building penetration in urban areas. If network operators were able to justify extensive deployment of microcells to support UGC in urban areas then this would also provide enhanced in-building penetration. The benefits of UHF spectrum would be reduced in the longer term.

The need to deploy additional microcells to support UGC should not increase the demand for higher frequency spectrum. The total demand for spectrum is dictated by the areas of highest congestion where extensive use of micro cells is highly probable. Provided that these cells are able to support UGC uplink data rates then additional microcells should not be required beyond those required to support total data throughput.

F6 Public wireless hotspots

Definition

For the purposes of this assessment, wireless hotspots are defined as base stations providing coverage, where:

- The objective of the coverage is outside the home environment or private premises
- Each site incorporates a low power transmitter and has small coverage area (within buildings or an open concourse)
- Sites tend to be located with an objective for contiguous coverage
- Equipment uses non-proprietary access technology commonly available in end-user devices
- Subscription may be direct to the public wireless hotspot operator or commonly bundled with cellular mobile subscriptions

Although public wireless hotspots are traditionally associated with WiFi (based on the IEEE 802.11 standard), new technologies may emerge to utilise additional frequency bands or ad-hoc coverage may be provided using cellular technology. Similarly they have used licence exempt spectrum at 2.4 GHz. This need not necessarily be the case in the future, however widespread availability of end-user devices and chipsets is more achievable with licence exempt spectrum.

Our definition of public wireless hotspots is independent of the technology used and method of licensing. For example, hotspots may use WiMAX or LTE (as micro or pico cell implementations) and they may be provided by cellular operators, third party operators or independent property owners on an ad hoc basis.

Public wireless hotspot technology

Currently, public wireless hotspots use WiFi technology based on the IEEE 802.11 standard. These are generally used by laptop users for internet and email access. However, we can expect increasing complementary use of public wireless hotspots by mobile phone users. For example, iPhone 3G users with O_2 are already able to access BT Openzone and The Cloud WiFi hotspots.

The provision of capacity is usually on a best effort service provision. Capacity is provided by the owner and all users in the vicinity share the same access bandwidth. Performance over the link is variable depending upon the number of users. Whilst this suits general web-browsing activity, it is less appropriate for real-time or entertainment users. In the absence of formal service control, sufficient capacity is required to ensure an adequate grade of service for entertainment services.

The range of a hotspot is 10s of metres and they are typically located in airport lounges, cafes and public places. Access speeds are limited by the fixed network connection and the number of users concurrently using the hotspot (a typical hotspot currently provides shared access for its users to a 2 Mbit/s ADSL link).

We can expect the capability of hotspots to increase in the future in a number of ways:

- Access speeds to the internet will increase in line with residential access to include ADSL2, ADSL2+ and fibre access
- Increasing numbers of hotspots for more ubiquitous coverage in urban areas
- Technology migration to IEEE 802.11n for faster access speeds and other subsequent standards in the longer term
- Hotspots will incorporate 5 GHz spectrum as this becomes more popular in user terminals
- Use of new technologies such as WiMAX for hotspots. These have potential to provide high access speeds over a wider area
- Potential use of other licence exempt bands

Although the 802.11 standard was ratified in 1997, it was the 802.11a and 802.11b standards in 1999 that opened the door to mass market deployment. The 802.11a standard was aimed at the 5 GHz band and the 802.11b standard was aimed at the 2.4 GHz band. The 2.4 GHz band has proven to be most popular and its use is widespread in the home, offices and public wireless hotspots. Since then the standard has been enhanced with the introduction of the 802.11g standard in 2003. This expanded the air interface data rate to 54 Mbit/s. The next stage of development is the IEEE 802.11n standard which is scheduled for ratification in 2009 and will be able to be deployed in either the 2.4 GHz or 5 GHz bands.

To achieve the higher speeds of 802.11n requires investment by equipment manufacturers, and this is likely to be forthcoming as access speed expectations increase and more devices use the 2.4 GHz band. We are already seeing wireless routers appear based on the draft 802.11n standard at similar prices to 802.11g. As equipment will be backwards compatible, we see few barriers to the implementation of the more advanced technology following ratification.

Equipment manufacturers have the options of implementing the advanced standard or expanding capacity using the 5 GHz band. Continued use of the 2.4 GHz band using the advanced standard is more likely since propagation conditions are better at the lower frequency and dual band devices will be more expensive initially. However, the 2.4 GHz band is also used by other devices such as microwave ovens, cordless phones, Bluetooth products and baby monitors. As the options to increase throughput at 2.4 GHz are exhausted we are likely to see increased use of the 5 GHz band and dual frequency devices.

Spectrum supply

The 2.4 GHz and 5 GHz bands are already allocated for licence exempt use. Ofcom believes that spectrum use should be licence-exempt if the value that is expected to be derived from the spectrum under such an approach is predicted to be greater than if spectrum use were licensed. It is considering the licence exemption in other bands as summarised in Figure F10.

Figure F10: Future release of licence exempt bands

Band	Sub-band	Status
40-105 GHz	59-64 GHz	Jointly managed by MOD and Ofcom. Already available for licence-exempt use in the US and Japan, and is currently being studied by CEPT for Multiple Gigabit wireless systems and intelligent transport systems.
	102-105 GHz	Currently unused
105 – 275 GHz	Various	94 GHz within this range has been identified by Ofcom for potential licence exempt use.

Of the bands in Figure F10 the 59 to 64 GHz band has the best prospects for harmonisation. However, the high frequency results in poorer propagation performance. This short range means that they are not a direct substitute for the 2.4 and 5 GHz bands but may have a role in the longer term if there is widespread take up of devices incorporating the technology.

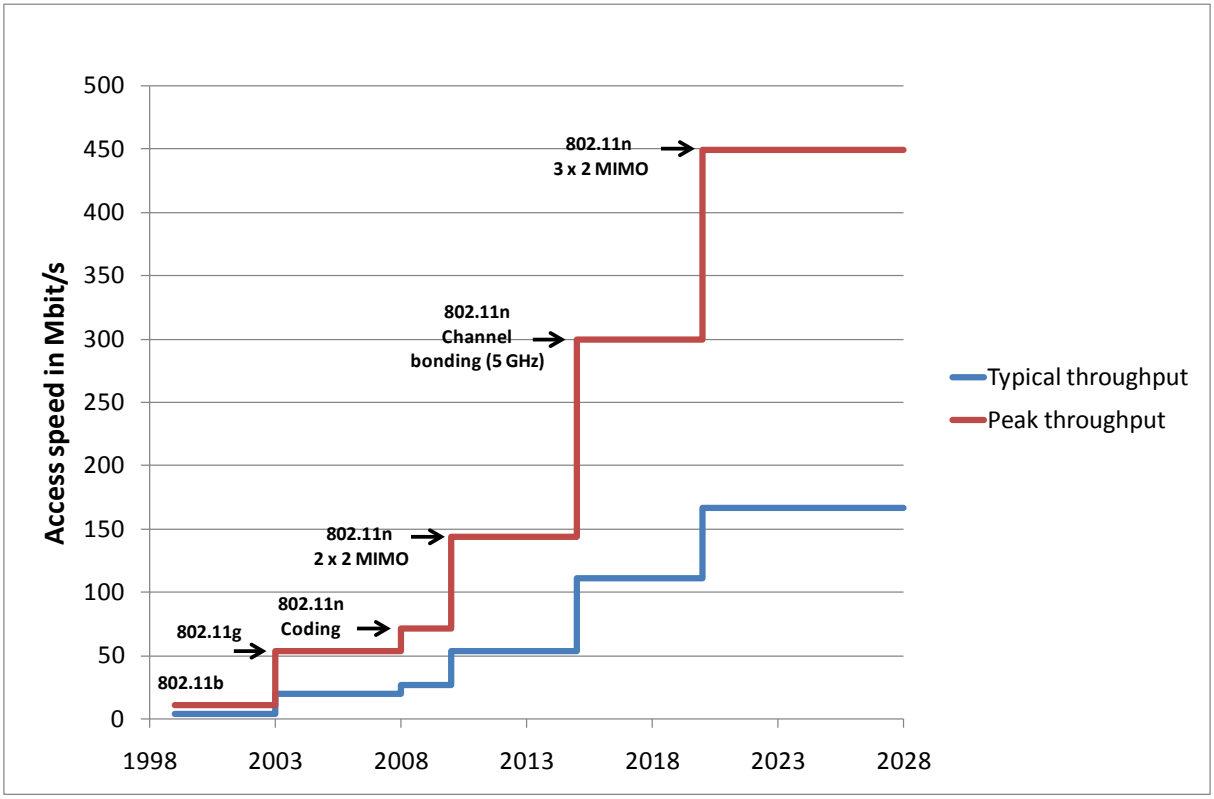
A proposal with potential to complement public wireless hotspot capacity is the “White Space” initiative being promoted by the Wireless Innovation Alliance, supported by Google, Dell, HP and Motorola amongst others. The FCC has decided to allow licence exempt use of the interleaved spectrum in the US by technology capable of detecting and avoiding other users of the spectrum, and Ofcom has made the same decision, in principle, in the UK. If the technology is effective and starts to appear within commercial devices, it raises the potential for wider application as a means of sharing spectrum.

Roadmap for public wireless access

We can expect significant increase in throughput speeds over the next 20 years. Implementations of the 802.11n standard when ratified are expected to support typical download speeds of greater than 50 Mbit/s and a peak data rate of 144 Mbit/s to individual devices using a single non-overlapping 20 MHz channel. It is possible to more than double this peak rate to 300 Mbit/s but this relies on bonding of 2 x 20MHz RF channels. Contention between users in public wireless hotspots means that channel bonding will be unlikely to be achievable in the 2.4 GHz band where there are only 4 non-overlapping channels. By contrast, the 5 GHz band has 19 non overlapping channels which makes it more likely that 2 adjacent channels will be available for bonding.

Development of technology and take-up of 5 GHz devices is likely to be driven by increasing consumer traffic demand of which entertainment traffic is likely to be a major component. A potential capability growth path for the 802.11 standard is illustrated in Figure F11F11. This assumes that major technological improvements will be introduced on approximate 5 year intervals.

Figure F11: Future performance improvements in the 802.11 standard for a single link in an interference free environment



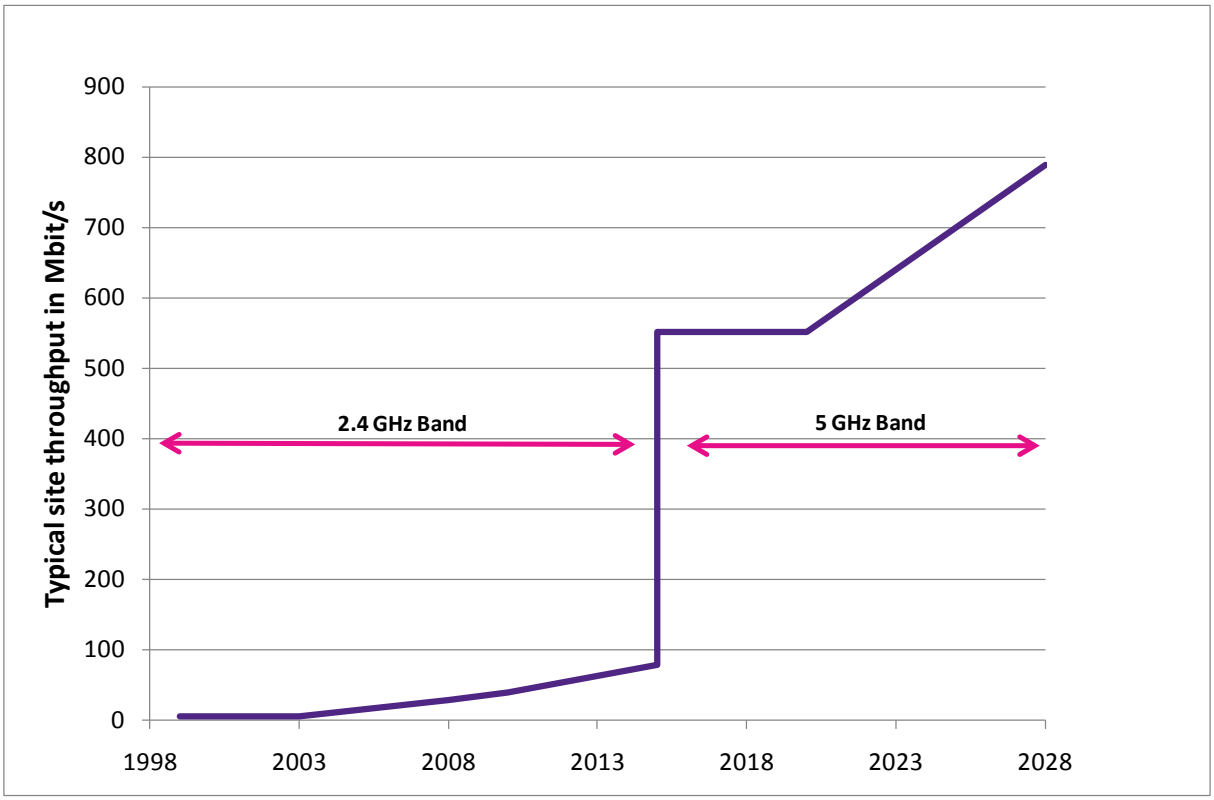
The peak access speeds illustrated in Figure F11 relate to maximum achievable user data rates to a single user in an uncontended environment on non-overlapping channels. In a multi-user environment collisions and retransmissions limit the practical throughput to the more typical levels indicated.

The 802.11n standard provides for greater use of MIMO to a 4 x 4 configuration but the need to implement many antennas with sufficient spacing limits its practicability.

Much of the popularity of 802.11b/g has been its installation within consumer devices, improving ease of installation on laptops and PCs and a desire to utilise the full access speed available over broadband internet connections. This trend is likely to continue and as fibre to the home becomes more prevalent and devices proliferate then the demand for higher access speeds will continue. However, in considering the overall capacity gains we need to bear in mind that there will be legacy equipment sharing the same licence exempt bands that tends to degrade the overall capacity achievable. As the number of hotspots increase there will also be increasing interference from adjacent properties.

Considering the typical throughput rates in Figure F11 and considering the number of non-overlapping channels available in the bands we have estimated the total potential capacity of wireless hotspots as shown in Figure F12. The capacity calculations assume that throughput will be reduced by 50% due to interference between sites.

Figure F12: Estimate of future capacity of a wireless hotspot



The capacity shown in Figure F12 depends critically upon the take up of dual band (2.4/5 GHz) devices in end-user equipment, here assumed to occur in 2015. With 19 non-overlapping channels compared to only 3 in the 2.4 GHz band, capacity is able to increase rapidly once end-user demand stimulates inclusion of 5 GHz within end-user devices. Since the 5 GHz band is little used at present, it is unlikely to be degraded by the presence of legacy user equipment using less spectrally efficient technology.

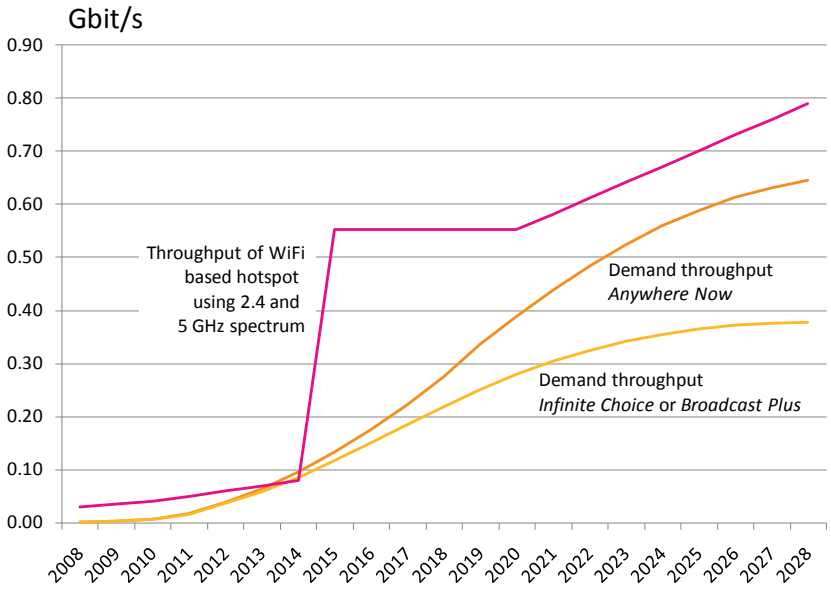
Demand

Demand for public wireless hot spots is a function of both entertainment and non-entertainment applications. We estimate this demand as follows:

- The projections of Section F5 give us the total UK busy hour mobility traffic which is generated in public wireless hot spots
- We assume that the number of public wireless hot spots grows from 15,000 to 50,000 over the next 20 years
- We further assume that a busy public wireless hotspot generates ***five times*** the traffic generated by the average hotspot.

Figure F13 plots the resulting projections and compares them with the capacity of a hotspot which uses WiFi technology and currently assigned spectrum.

Figure F13: Demand vs capacity at a busy wireless hotspot



Demand versus capacity

The plots of Figure F13 suggest that the capacity of hotspots will increase at a sufficient rate to deal with demand, even under the more challenging *Anywhere Now* scenario. There may be a need to bring forward the introduction of 5 GHz-based services by one or two years from the assumed date of 2015. Market mechanisms should enable this to happen.

We note however that the projections of Figure F13 are very sensitive to the assumptions which we have used to calculate demand in the busy hour and that relatively small changes in these assumptions could lead to capacity problems at the busiest public wireless hotspots.

Annex G Core network capacity

This annex addresses the question: can the core IP network of the UK Internet handle the additional video traffic generated in the Infinite Choice and Anywhere Now scenarios?

The estimate of Figure G1 suggests that, by 2028, current levels of video consumption (of 3.6 hours per day per person) would generate:

- 3.5×10^{19} bits per month of video in SD format
- 2.3×10^{20} bits per month of video in HD/3D format.

If we then assume current levels of improvement in the price performance of network components and continuing capital expenditure on the UK Internet at current levels, then we estimate, in Figure G2, the UK Internet will be able to carry 0.9×10^{22} bits per month in 2028.

Comparing the findings of Figures G1 and G2 indicate that current video traffic would represent:

- 0.4% of capacity if transmitted in SD format
- 3% of capacity if transmitted in HD/3D format

In practice it is unlikely that all video will be transmitted in unicast fashion over the Internet. For example our scenarios assume that big live event will continue to be broadcast, so reducing the load on the Internet at peak times.

Figure G1: Current broadcast video traffic in IP format in 2028

Assume

- 3.6 hours of viewing per day per person
- 70 million people[203]
- Download generates 1.5 Mbit/s per second of viewing time in SD format or 10 Mbit/s in HD/3D format

Then traffic per month = 3.6 hours x 3600 seconds per day x 70 x 10^6 people x 1.5 x 10^6 bits per second x 30 days = ***4.1 x 10^{19}*** bits per month in SD format

And traffic per month = 3.6 hours x 3600 seconds per day x 70 x 10^6 people x 10 x 10^6 bits per second x 30 days = ***2.7 x 10^{20}*** bits per month in HD format

[203] http://www.statistics.gov.uk/downloads/theme_population/pp2no26.pdf

Figure G2: Capacity of UK Internet[204] in 2028

Assume:

- EU Internet carried 1,400 Petabytes per month in 2007 (Cisco, *Towards the Zetabyte era*, June 2008)
- UK is 20 % of this capacity
- 1 Petabyte = 10^{15} bytes = 10^{16} bits
- Capacity grows at 50% pa (Cisco assumes 52% cagr; Moore's law assumes 41% to 60% cagr)

Then capacity per month = 1400 x 10^{16} x 1.5^{20} x 20% = 1.4 x 10^{19} x 3300 x 0.2
= ***0.9 x 10^{22}*** bits per month

[204] Figure G2 assumes Moore's Law will not break down before 2028 or that, if it does, developments in optical switching will enable historic improvements in price performance to be maintained.