Annex 6

Mobile broadband services and spectrum

Introduction

A6.1 This annex provides additional background information on the mobile sector in the UK, mobile broadband services and spectrum suitable for mobile service. Accordingly this section:

- provides a brief overview of the mobile sector in the UK;
- provides an overview of the characteristics of mobile broadband services and discusses quality aspects of mobile broadband services.
- examines how frequency affects mobile broadband services;
- reviews how the mobile spectrum has been allocated historically, resulting in the current spectrum holdings of the five mobile operators;
- considers future spectrum awards that might be relevant for mobile services.

The mobile market in the UK

A6.2 The mobile sector plays a vitally important role to citizens and consumers in the UK[1]. In terms of revenue it is now larger than fixed telecoms and broadband combined, with retail revenues of £15.1bn in 2007 (see Figure 1 below). It has also changed significantly in recent years, in ways that have benefited us as consumers and contributed to UK society – reflecting rapid growth, technological improvements and, in part, regulation.

Figure 1: UK Telecoms industry retail revenue

Source: Ofcom / operators

[1] For further detail on the Mobile Market in the UK, please see Mobile Citizens, Mobile Consumers http://www.ofcom.org.uk/consult/condocs/msa08/msa.pdf

A6.3 The sector continues to see increasing subscriber numbers. UK mobile subscriptions exceeded 73.5 million at the end of 2007. We estimate there were approximately 46 million people (unique users or individual subscribers) aged eight and over using mobile services by mid-2007, who comprise 84% of the total population in that age group.

A6.4 The five major Mobile Network Operators (MNOs) are Vodafone, O2, T-Mobile, Orange and Hutchison 3G. Additionally, there are a number of Mobile Virtual Network Operators (MVNOs) such as Virgin Mobile and Tesco Mobile. These companies do not own a network or any spectrum, but instead buy wholesale services from one of the five MNOs. There are also operators such as Cable and Wireless who operate small localised networks in the guard bands 1781.7 – 1785 MHz and 1876.7 – 1880 MHz. Table 1 below presents a snapshot of the major MNOs market positions.

Table 1: UK MNO snapshot

	Vodafone	O2	Orange	T-Mobile	H3G
Subscriptions (millions)	16.5	20	15.7	17.3	4
Retail revenue (billion)	4.1	4.1	3.2	2.7	1.1
Parent company	Vodafone Plc	Telefonica	France Telecom	Deutsche Telekom	Hutchison Whampoa
3G Coverage (%)	Greater than 80	Greater than 80	Greater than 80	Greater than 80	Greater than 80
Fixed Broadband Provided	Yes	Yes	Yes	No	No

Source: Analysys Research and Ofcom estimates where operator data is not reported
Note:
3G coverage denotes population, as opposed to geographic, coverage
O2 subscriber and revenue figures include Tesco Mobile
T-Mobile subscriber and revenue figures include Virgin Mobile
Coverage data from Ofcom

Mobile broadband services

A6.5 A key development in the mobile sector of particular relevance for our analysis of liberalisation is the emergence of mobile broadband services, currently using 3G technology. This sub-section therefore briefly sets out the significance of 3G versus 2G networks, what we mean by mobile broadband, and the key characteristics of these services.

2G and 3G networks

A6.6 Currently 2G networks deliver voice services to a relatively good quality. 3G does not materially alter the voice quality; instead it increases the network capacity available in a material way due to the increased spectral efficiency delivery of standard circuit switched voice. Second generation networks with enhancements such as General Packet Radio Service (GPRS) or Enhanced Data rates for GSM Evolution (EDGE) also deliver a basic data service that can support lower data rate applications such as e-mail, limited web browsing and smaller file downloads. An EDGE enabled 2G network can typically deliver data speeds in the general region of 25 to 100kbps depending on the signal quality.

A6.7 Considering 3G networks, the typical data rates currently available are in the region of 100 to 300kbps and have moved towards speeds of 1Mbps and beyond with deployment of High Speed Packet Access (HSPA) evolutions. This allows services such as video streaming, normal web browsing and larger file downloads to be provided. Also 3G networks, especially when HSPA upgrades are implemented, have much better control of latency than 2.5G and applications such as Voice over Internet Protocol (VoIP), video calling or interactive gaming become viable.

A6.8 It is generally accepted that 3G systems provide a more spectrally efficient solution than 2G. By spectrally efficient we mean that the amount of traffic (often referred to as throughput) a fixed quantity of spectrum can handle is greater for 3G than 2G. This efficiency becomes an issue if mobile broadband demand increases as 3G will be much better placed to handle increasing numbers of users requesting higher speed services.

Mobile broadband characteristics

A6.9 The term 'mobile broadband' in this document refers to high speed mobile data services which can only be provided, or are best provided, using 3G technologies and beyond, for example UMTS, HSPA, WiMAX and LTE. Mobile broadband includes provision of services to any type of device, including mobile handsets and laptops with USB 'dongles' or embedded modems.

A6.10 From a user's perspective the key characteristics of mobile broadband which might differentiate one *network* (i.e. excluding the pricing and non-network related customer service) from another are:

- its **coverage**
- whether the network has sufficient **capacity** to provide a service to the consumer at the time they want to use it
- its **speed**, in terms of the data rates consumers actually experience (considering only the speed of the mobile network itself, rather than any limitations of websites and the wider internet etc); and

A6.11 We use the term mobile broadband 'quality[2]' in this document to generically refer to mobile broadband coverage, speed and capacity, as from a user's perspective these factors make one mobile broadband network better than another. In other words the likelihood of a consumer being able to practically use the service, at any particular place and time, depends on having coverage, available capacity and an adequate data rate for what they want to do. So higher quality mobile broadband simply means better coverage and higher speeds with sufficient capacity to provide this.

A6.12 However, coverage, capacity and speed are not straightforward concepts, as they have a number of aspects and are related to one another.

[2] This is distinct from a narrower definition of quality of service which is sometimes taken to indicate technical performance indicators such as dropped and blocked call rates, handover failures, bit error rates etc.

Coverage

A6.13 From a user's perspective, there are two high level aspects to how good coverage is for a mobile service:

- Coverage breadth
- Coverage depth

A6.14 From a user's perspective, coverage breadth determines whether or not the service is available in a particular geographic area at all. They may need to go outside or round the corner, but they will recognise that they are able to get a service in the area. At the moment, the coverage breadth of 3G services is such that networks cover at least the areas in which over 80% of the UK population live, defined in terms of the availability of some 3G signal in outdoor areas.

A6.15 From a user's perspective, coverage depth captures how good the coverage is in any particular area. The better the coverage is in an area, the more likely a user is to be able to use the service wherever they happen to be, particularly indoors, in densely built-up areas and perhaps in other hard to reach places such as railway cuttings and subways. Deep coverage means that users can consistently use a particular service wherever they are – they do not have to wander around the room or building or outside to find a good signal. With shallower coverage they might only be able to use the service near the window and very patchily in other parts of the building, or not at all in some buildings.

A6.16 For mobile broadband services, the depth of coverage also affects the speed of the service that can be provided in any particular location (see below). So instead of shallower coverage meaning that users lose service altogether, it may result in a slower service than could be provided with better coverage.

Capacity

A6.17 For the end user, the availability of a service also depends on there being sufficient network capacity available to them. Users must share the limited amount of spectrum and network resources[3] with other users on the cell. This is particularly evident during busy hours where the network may become congested and the speed available to each user will decrease and the latency of services will increase. Ultimately a mobile broadband user could be denied service if resources are unavailable at the time they attempt to access the network.

A6.18 Additionally, the presence of a large number of users on the network creates interference amongst the users, even those in different cells. This interference will also degrade the service quality available. The interference can be spread to minimise interference if the amount of spectrum and/or base stations is increased. Delivering a given quantity of data more rapidly – e.g. via HSDPA – can also reduce the number of users who are accessing the network simultaneously and hence decrease the impact of interference.

[3] 'Network resources' refers to other capacity-limiting elements of the network, such as the available power and the level of interference.

Speed

A6.19 From a user's perspective, the 'speed' of mobile broadband is likely to mean how quickly web pages appear, how long it takes to download emails, documents, music etc, and maybe, whether it is fast enough to play videos. However, it is important to distinguish two aspects of speed in relation to mobile broadband services:

- **Maximum rate.** The maximum data rate that the device and network can support with a given technology (e.g. HSDPA). This is what is commonly advertised by operators (e.g. up to 7.2 Mbps), but in practice can only be provided when the user is very close to the base station and there is no one else nearby using the service.

- **Throughput.** This is the data rate that the user can actually get on their mobile device at any particular place and time. Throughput may vary depending on location, as a result of variations in coverage, and over time if the network becomes capacity constrained at certain times of day. In our analysis of the differences between bands we primarily consider the throughput of mobile broadband networks, since this relates more closely to the service experienced by users.

A6.20 Note that there are other factors (other than the mobile network) that can affect the throughput experienced by users. These include congestion on the wider internet, in the backhaul capacity from cell sites and in the MNO's core network and perhaps limitations in the processing power of handsets, e,g. for handling complex web pages, compared to a PC or laptop.

The advantages of lower frequency spectrum

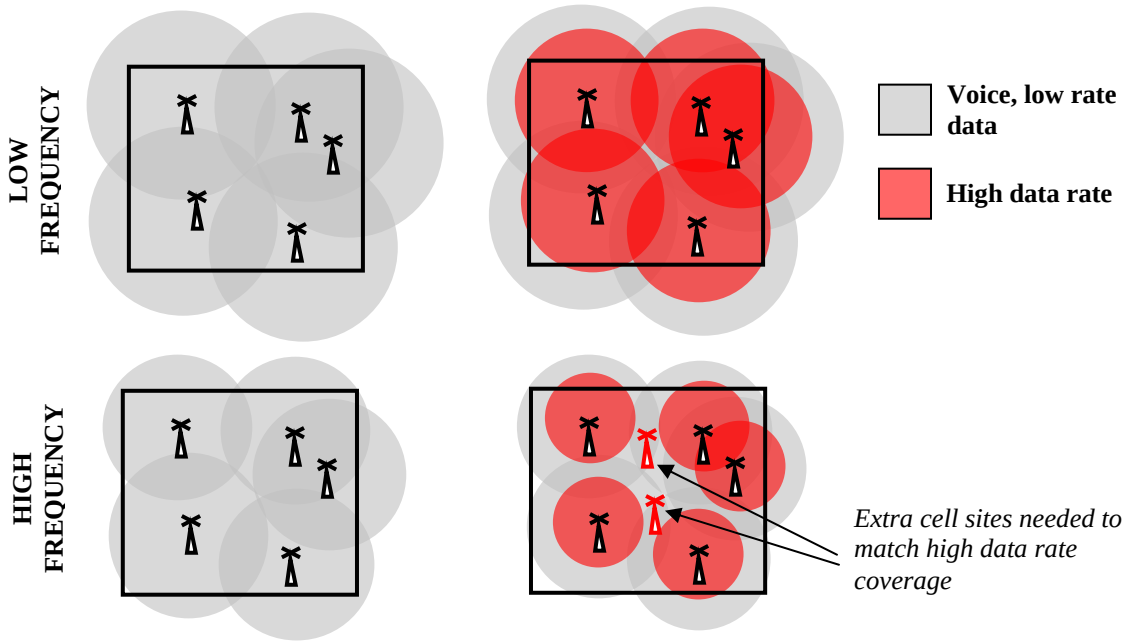
A6.21 Lower propagation loss at lower frequencies means that the signal travels further compared to higher frequencies and can provide better coverage compared to higher frequency signals. This will result in a larger coverage area for networks deployed using lower frequencies for a given number of sites, all other things being equal. Similarly, operators with lower frequencies will require fewer sites to achieve the same level of coverage and service than an operator using a higher frequency.

A6.22 As well as having differences in coverage generally, variations in frequency also have specific impacts on the coverage and data rates of mobile broadband technology.

A6.23 Figure 2 below illustrates how this principle applies in urban and suburban areas. Practically, this means that operators using higher frequencies will need to roll out additional cell sites to match the data rates and coverage of operators using lower frequencies, or equivalently that lower frequency networks can provide higher capacity and data rates for a given number of sites than higher frequency networks (assuming the same quantity of spectrum in each case).

A6.24 But in theory these advantages can reduce, or even disappear, as an operator requires higher capacity. Each site operates at the same frequency, so when more traffic is carried interference between the sites increases and eventually becomes the limiting factor on the cell size. This interference actually travels further at lower frequencies and is therefore more challenging to manage. In principle, therefore, at very high demand and well after initial coverage is established, the advantage of the lower frequency networks could diminish.

Figure 2: 3G operators at higher frequencies need additional cell sites to match coverage for high data rate services



With similar cell site distribution basic services can be offered with similar coverage at both low and high frequency

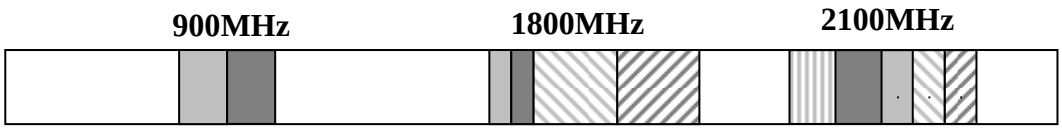
High speed data suffers more at higher frequency and extra cell sites are needed to match coverage of operator using lower frequency

A6.25 We have undertaken extensive analysis to quantify these effects. Annex 13 outlines the technical details of this analysis.

Existing spectrum holdings of the 2G and 3G mobile network operators

A6.26 In the UK operators require a Wireless Telegraphy Act licence to operate a mobile network. The way that licences were awarded for mobile services has varied over time. The first and second generation licences were awarded by the government by a process known as comparative selection. This took place in 1985 and 1991. 3G licences were awarded by an auction process in 2000. The current distribution of spectrum holdings is the direct result of this series of awards and is illustrated in the diagram below.

Figure 3: Summary of ownership of bands and dates of spectrum assignments



	900MHz	1800MHz	2100MHz
Who	**O2, Vodafone**	**O2, Vodafone, Orange, T-Mobile**	**H3G , Vodafone, O2, Orange, T-Mobile,**
When	**Mid 1980s**	**Early to mid 1990s**	**2000**
How	**Comparative selection**	**Comparative selection**	**Auction**

NB - Diagram indicative of actual spectrum holdings – not to scale

A6.27 Table 2 below shows the actual quantity of spectrum held by the major mobile operators, including amounts of paired and unpaired spectrum. The 900 MHz and 1800 MHz spectrum is currently used for the provision of 2G mobile services, and is unevenly distributed amongst the five mobile network operators. The entirety of the 900 MHz spectrum is held by Vodafone and O2 only. Orange and T-Mobile hold over 80% of the 1800 MHz spectrum, with the rest split between Vodafone and O2. All five operators hold 2100 MHz spectrum, which is currently used for the provision of 3G mobile services using UMTS technology.

A6.28 The terms ‘paired’ and ‘unpaired’ spectrum refer to whether or not the spectrum consists of matched bands that allow uplink and downlink transmissions to be carried out in separate frequencies. An entry in the table of “2 x 5.8” means a total of two blocks of 5.8MHz, one designated for uplink and the other for downlink. The blocks may not be contiguous and may be fragmented across the band. This distinction has been made as although in the UK 2G and 3G networks currently make use of paired spectrum, there are some air interfaces that also allow operators to use unpaired spectrum such as the TDD mode of UMTS, which has been little used commercially but has been suggested as a means of offering mobile TV services.

Table 2: Current mobile operator spectrum allocations for paired and unpaired spectrum

	Vodafone	O2	T-Mobile	Orange	H3G
900 MHz paired	2 × 17.4	2 × 17.4	0	0	0
1800 MHz paired	2 × 5.8	2 × 5.8	2 × 30.0	2 × 30.0	0
2100 MHz paired	2 × 14.8	2 × 10.0	2 × 10.0	2 × 10.0	2 × 14.6
Total paired	2 × 37.8	2 × 33.0	2 × 40.0	2 × 40.0	2 × 14.6
2100 MHz unpaired	0	5.0	5.0	5.0	5.1
Total unpaired	0	5.0	5.0	5.0	5.1

New spectrum is now becoming available

A6.29 Ofcom has a programme of spectrum awards that will make more spectrum available for wireless services.[4] It is one of Ofcom's statutory duties to make the most efficient possible use of our spectrum resources, and where appropriate to free up more spectrum for new services. Some of these awards are potentially well-suited to the delivery of mobile broadband services which we outline briefly below.

Bands of particular relevance for mobile broadband

2500 – 2690MHz and associated bands

A6.30 This spectrum consists of 190MHz between 2500MHz and 2690MHz (the '2.6GHz band') and one smaller portion of 15MHz between 2010MHz - 2025MHz and provides the possibility of paired and/or unpaired use. The spectrum is available now in its entirety for new uses.

A6.31 We set out our decision for the award of these two bands in a Statement in April 2008. Alongside the Statement, we published an Information Memorandum and drafts of the statutory instruments that will give effect to our decision. The award was due to take place in the late summer of 2008. However, the award has been delayed as a result of a legal challenge brought by two of mobile operators.

A6.32 We have defined the rights for the 2.6GHz band in a technology and service neutral way, with technical conditions consistent with likely uses and our obligations under European regulation. A likely use of this spectrum is to provide mobile broadband services using new mobile technologies such as WiMAX or LTE. There is a European Commission decision that is in force now and identifies the technology and service neutral conditions for use of the band that are suitable for mobile broadband services.

[4] See http://www.ofcom.org.uk/radiocomms/spectrumawards

Digital dividend

A6.33 In January 2003, before Ofcom was established, the Government decided that 14 channels, each of 8 MHz of spectrum, in UHF Bands IV and V would be cleared of analogue terrestrial television as a result of DSO in the UK and made available for new uses. This digital dividend of cleared spectrum, which forms a key element of the UK's digital dividend, would lie in two bands:

- an upper band of 48 MHz at 806-854 MHz (channels 63-68); and
- a lower band of 64 MHz between 550 and 630 MHz (channels 31-35, 37 and 39-40).

A6.34 Through the Digital Dividend Review (DDR), we have subsequently acted to clear channel 36 of aeronautical radar during 2009. Furthermore, the UK authorities responsible for radioastronomy decided that they would vacate channel 38 of radioastronomy during 2012. This will extend the lower band to include the whole of 550-630 MHz (channels 31-40) and increase the amount of cleared spectrum in the digital dividend to 128 MHz in total.

A6.35 In June 2008 Ofcom also proposed to include the interleaved spectrum in channels 61 and 62 (790-806 MHz) in the award of the cleared spectrum to reflect the outcome of WRC-07 and nascent European consideration of a common digital dividend. The award would thus consist of 128 MHz of cleared spectrum and 16 MHz of interleaved spectrum (see Digital Dividend Review: 550-630 MHz and 790 – 854 MHz).

A6.36 Since that time there have been a number of developments in Europe in which other countries have identified a digital dividend which cover 790 – 862 MHz which would be available for electronic communications services including mobile broadband. Ofcom has proposed that it should now reorganise its digital dividend so the upper band matches the frequencies which we expect to be made available in a number of other countries. It has set out its proposals on this in a recent consultation (see Digital Dividend: clearing the 800 MHz band).

A6.37 The consequence of these proposals if implemented would be that the UK digital dividend would make available cleared spectrum covering:

- an upper band of 72 MHz at 790 – 862 MHz (channels 61 – 69) (often referred to as the 800 MHz band)
- a lower band of 64 MHz at 550 - 614 MHz (channels 31 – 38)

Other potentially relevant bands

L-band (1452 – 1492MHz)

A6.38 The L-band was the first major part of Ofcom spectrum awards programme relevant to mobile services. It consists of 40MHz between 1452MHz and 1492MHz. The auction took place in May 2008, in which Qualcomm won the entirety of the available spectrum.[5]

[5] See http://www.ofcom.org.uk/media/news/2008/05/nr_20080516b

A6.39 While the physical characteristics of the L-band spectrum at these frequencies are relatively attractive, it currently does not appear to be a good alternative to either 900MHz or 1800MHz spectrum because of the lack of current standards to support use of this spectrum for mobile broadband.

872 – 876 MHz paired with 917 – 921 MHz

A6.40 This spectrum is currently vacant and Ofcom is considering an award during 2009. We published a consultation on this in 2006[6] and are currently plan to publish a further consultation on the award in the first part of 2009. The spectrum is potentially suitable for delivery of mobile broadband services however the limited bandwidth and lack of international harmonisation mean that it is unlikely to be a good alternative to 900 MHz or 1800 MHz spectrum for mobile broadband services.

Independent audit of spectrum holdings

A6.41 In the medium to long term more spectrum might become available. Professor Martin Cave's 'Independent Audit of Spectrum Holdings' published in December 2005 recommended wide-ranging changes in several areas of spectrum managed by the public sector. The Government, supported by Ofcom, accepted his recommendations and committed to a programme to reform public sector spectrum management with a view to increased sharing with commercial users. This programme is in the process of being implemented. The outcome of this is that additional spectrum, including some spectrum below 2.6GHz suitable for mobile applications might, depending on future decisions by the Ministry of Defence (MOD), become available in the medium to long term.

A6.42 The MOD published a statement on 5 December 2008 on its implementation plan for reforming defence spectrum management in the UK. This stated that it plans to release spectrum below 4 GHz in the 406.1-430 MHz and 3.4-3.6 GHz bands by November 2010 and in various other bands beyond November 2012[7].

A6.43 Ofcom has recently consulted on granting the MOD tradable Recognised Spectrum Access initially in the band 406.1-430MHz as a first step and plans to extend the regulations to enable the MOD's programme to proceed. In addition, the 3.4 -3.6 GHz band was identified at WRC-07 for IMT-2000. The ITU and CEPT have begun work on international harmonisation of this band for IMT-2000 use and in addition the European Commission has adopted a Decision on use of the band for mobile broadband systems.

A6.44 Figure 4 below provides a summary of the spectrum available for mobile services

[6] http://www.ofcom.org.uk/consult/condocs/872-876/

[7] The statement, together with a study of future demand for defence spectrum that was published with it, may be found at http://www.mod.uk/DefenceInternet/AboutDefence/CorporatePublications/ConsultationsandCommunications/PublicConsultations/UkDefenceSpectrumManagement200812.htm.

Figure 4: Spectrum particularly suitable for mobile broadband services