APPENDIX IV. SPECTRUM IMPLICATIONS OF EACH SCENARIO

IV.1 Introduction

This Appendix assesses the broad-brush implications of the four scenarios for spectrum demand. It has been prepared by Intercai Mondiale and discussed with the RA. Its purpose is not to create a precise and self-standing forecast; but rather to provide a semi-quantified context for the review of how the different Convergence Scenarios may affect spectrum management issues for the RA and other interested parties. Any comments or questions on the material presented here will be addressed by Intercai, but should in the first instance be directed via the RA as indicated in the foreword to the main report.

Each scenario paints a broad picture of the way that people will communicate and gain access to information and entertainment in both the business and consumer sectors. The scenarios are essentially qualitative descriptions. They do not lend themselves to a rigorous quantitative assessment of the amount of spectrum that would be required for specific services in the various cases, but provide insights into the general pressures on spectrum use caused by meeting the demand for the major services in each scenario.

Accordingly, this Appendix does not review services at the level of specific technologies. In ten years time, for instance, we do not know whether there will be a 4G mobile service being introduced in addition to UMTS and GSM; or if UMTS will have subsumed all other public wide area mobile services. We have therefore decided to explore the future spectrum requirements in terms of four major broad categories of use:

- Wide Area Mobile
- Short Range Radio
- Fixed Wireless Access
- Digital Video Broadcasting

Even among these broad categories, there is some overlap. HiperLAN for instance, which we would categorise as Short Range Radio, is seen by some as a solution to the last mile problem - which we would place firmly in the Fixed Wireless Access category. Similarly, the provision of a substantial return path in one or more of the Digital TV channels could lead to its classification as Fixed Wireless Access or, if DTV was deployed with the mobile user in mind, as Wide Area Mobile. Such options are being explored by the ITC.

Nevertheless we feel that it is useful to adopt these general categorisations, while recognising that they are not immutable. In essence we are using RF Power, Mobility Requirements and Symmetry as the dimensions of variation, as shown in Table IV-1.

Table IV-1 Differentiation of the Basic Categories of Spectrum Need

	RF Power	Mobility Requirements	Symmetry
Wide Area Mobile	Medium	High	Largely symmetric
Short Range Radio	Low	High	Symmetric
Fixed Wireless Access	Medium	None	Largely symmetric
Digital Video Broadcasting	High	Low	Highly asymmetric

In the following sections we take each scenario in turn, describe the way that it will create demand for services that use spectrum and develop an indication of the scale of that demand.

IV.2 A Review of the Scenarios

Scenario A postulates the comprehensive convergence of communications, computing and entertainment, as well as widespread strong uptake of Internet-based services by all segments of society. IP is the common thread and services are accessed by a variety of means - fixed telecoms, mobile, interactive TV. The most widely used services are Internet-based and multicasting from web servers is a common way of reaching groups of customers. No one route dominates and users choose the most appropriate access method for each session.

In general, there will be significantly increased use of multimedia Internet data services. Thus, all four categories will require additional spectrum over that available today although the Fixed Wireless Access growth is not expected to be great because ADSL will succeed in meeting most users' need for fixed access. Wide Area Mobile will be used extensively when away from home to access those services that have become popular and this will create pressure for additional spectrum. Short Range Radio usage is less than the peak in D, but we can expect some need for additional spectrum as technologies such as Bluetooth come up against the ISM limitations. Digital Broadcasting will grow steadily and, with the provision of a user-friendly return path, will become the access method of first choice for a significant element of the population. This will begin to put pressure on the available TV channels.

We characterise Scenario A as the 'Steady as she goes' scenario in which the requirement for increase in spectrum is fairly well spread across categories.

Scenario B suggests that Digital Islands will gain the ascendancy and the Internet and Broadcast services remain distinct. Nevertheless it can be expected that each island will try to offer a comprehensive package of services, either via a single access route or by alliances. The filtered and focussed content means that the amount of data accessed is likely to be less than Scenario A. This focus makes Digital TV an attractive medium for information access and we can expect a number of islands to emerge from the DTV world. In this scenario users are beginning to be freed from the time constraints associated with broadcast services, either via the digital video recorder (e.g. TiVo) approach or by means of staggered transmissions although these would require additional spectrum to support. Wide Area Mobile and Short Range Radio do not grow extensively and only produce some demand for additional spectrum. On the other hand, as portals vie for control of the delivery channel we can expect increased competition in the local loop and some pressure on the available spectrum for this application. DTV, as a major method of consumer access to digital information, can be expected to require additional capacity to meet demand.

Scenario B is characterised as the Digital TV Scenario

Scenario C creates the most demanding situation for spectrum use. Everything is personalised and people expect to be able to access all their information and entertainment needs, as well as conducting "m-commerce", via their personal mobile terminal. This terminal becomes a thin client, effectively being largely a display and control unit for accessing a variety of servers (eg Internet and intranets) and entertainment sources.

This means that much of the communication need is asymmetric. However video telephony is popular, as is the uploading of pictures, or high definition video, from the user's current location. These applications redress the imbalance to some extent. This Scenario implies a major demand for data transfer in the mobile arena. It is reasonable to expect therefore that some of this demand will be at fixed locations. However, because the wireless approach has dominated, ADSL may not have succeeded in the market and we can anticipate that Fixed Wireless Access will play an important role delivering capacity to the home, office, shopping mall, etc.

A natural complement to the personalised broadband, wide area service will then be the Short Range Radio facility, because users will expect not to be tethered to one receiving point. The personal terminal will remain the medium of access but it will select the wide area service or the short-range access as appropriate. DTV, with continued emphasis on one to many broadcasts, has little to offer in this Scenario, although there will, no doubt, be some digital islands served by the DTV broadcasters. Service provision is personalised and switched. It is likely therefore that there will be no demand for additional spectrum for digital terrestrial TV above that planned today.

Scenario C is characterised as the Wide Area Mobile and Fixed Wireless Access scenario

Scenario D envisages the rapid adoption of broadband services, the bulk of which are delivered via fibre, (with some copper or Fixed Wireless Access) to the home and office. Very high bandwidths will be available by this method and video is used extensively. Video on demand, ubiquitous miniature cameras and 3D networked gaming create much of the demand. New media forms that exploit high performance computing (e.g., detailed simulations) and very high bandwidth networking (e.g., downloading full 360 degree immersive motion image environments) will emerge in this timeframe. We can therefore expect reasonable growth in the requirements for spectrum for FWA.

As in Scenario C, there will be strong demand for Short Range Radio distribution of the data within the home, office and elsewhere. The data carrying capacity of these distribution tails will, however, be significantly greater than in the previous Scenario simply because of the far greater data rates that are delivered into the vicinity. We can therefore expect substantial pressure on the spectrum available for these Short Range

Radio technologies. The Wide Area Mobile demand will not have grown to anything like the level of that in Scenario C, but there will be substantial demand for wide area access to as much as possible of the service received in the home and office. Mobile access will generally be a fallback option however and, in many cases, it will be possible to use Short Range Radio tails in public places. So the pressure for spectrum by the Wide Area Mobile services will, while remaining heavy, not reach that created by Scenario C.

The widespread provision of such high bandwidths means that there is little need for terrestrial broadcast services. In those remote locations where economic provision of terrestrial broadband access is not feasible satellite services are able to provide an adequate alternative. The spectrum need for Digital terrestrial TV is practically non-existent in this scenario because almost everyone receives their services via wireline links.

Scenario D is characterised as the Short Range Radio scenario

Table IV-2 below summarises the broad trends identified in the various Scenarios.

Table IV-2 An overview of the spectral implications of each scenario

	A	B	C	D
Wide Area Mobile	++	+	+++	+
Short Range Radio	++	+	++	+++
Fixed Wireless Access	+	++	+++	++
Digital Video Broadcasting	+	++	0	-

Key

- \- Less spectrum needed than today
- 0 Same spectrum as today
- \+ Some increase in spectrum needed
- ++ Modest increase in spectrum needed
- +++ Substantial increase in spectrum needed

The following sections discuss the spectrum issues associated with each category and develop a rough indication of the scale of the requirement for additional spectrum.

IV.3 Wide Area Mobile

The Wide Area Mobile category encompasses, in today's terms, GSM, UMTS, TETRA (both public access and public safety services), other Private Mobile Radio and Mobile Satellite Services (MSS).

The main pressure on spectrum will undoubtedly arise from the UMTS camp, although we can expect TETRA (and/or any successor) to require some additional spectrum in most scenarios. The needs of the Emergency Services for video communications will grow significantly and this form of communication can be expected to migrate into the civil domain (public and private), as UMTS services become popular and the value of video is increasingly recognised.

In overall terms, however, any increase in spectrum allocation for TETRA is likely to be very small, perhaps a doubling of today's planned bands. Although not explicitly discussed in the workshop it would seem that the need for TETRA-style services is largely independent of the scenarios. It is driven primarily by the emergency and logistics sectors which are largely unaffected by the changes in the scenarios.

The emergency and logistics sectors will, of course, be the major potential users of Mobile Satellite Services (MSS) in the UK - because comprehensive geographic coverage is a critical element of their business. While there may be a very small take up of MSS by conventional business and consumer users we anticipate that the terrestrial coverage, in a country as densely populated as the UK, will prevent any significant demand for MSS services. While there may be minor differences in the use of MSS between the scenarios we do not see these as significant.

The UMTS domain is the area where the most significant differences between the scenarios will be experienced. As we have seen, Scenario C is the one that places most demand on the UMTS services. In the following section we develop an indication of the possible scale of the demand and translate this into spectrum requirements. In the absence of any knowledge about the characteristics of any future 4G technology we have taken today's UMTS radio and channel structures as a proxy for the way that services will be delivered.

IV.3.1 Spectrum demand for UMTS services

It must be recognised that, even if we were to establish an accurate measure of the demand for UMTS services, the amount of spectrum required to meet it is not a simple function of the demand. Frequency re-use and base station density are complicating factors that have significant impact on the economics of supply. This is especially true for the situation represented by Scenario C, where the density of use is expected to be distributed significantly differently from that experienced in today's cellular systems.

This occurs because the heavy consumer use for entertainment and video-telephony will be in the urban and suburban areas rather than the much smaller dense urban business districts. Meeting hotspot demand that extends over an area many times larger than today's business districts will place heavy demands on the base station deployment or, alternatively, will require significantly more radio channels than would otherwise be the case.

IV.3.1.1 Demand estimation

We take the penetration of service to be 100% for business users and 75% for consumer users; this gives 11.8 and 44.3 million subscribers respectively. In this scenario we assume that, because the handset is such a personal portal on the world, a business user will create significant traffic in both the business and personal modes so he appears in both subscriber counts. We have not ascribed any significant cost constraints to the services at this point.

Services are divided into two types - delay intolerant and delay tolerant. They are further divided into 4 speeds - low, medium, high and very high, representing roughly 8, 64, 256 and 2048 kbps. For each service we have made an assumption on the proportion of the subscriber base that will use it and their typical monthly use. These estimates are shown in Tables IV-3 and IV-4

Table IV-3 Business Demand for Wide Area Mobile

Service	Speed	Prop of subs taking service	No of subs	Usage			Symmetry down/up
		%	m	outgoing calls	incoming calls	units	
Low Tolerance Services							
Voice	Low	100	11.8	332	332	mins/month	1/1
	Mid						
Video Conferencing	High	25	2.9	66	66	mins/month	1/1
	V. High						
High Tolerance Services							
Messaging (eg SMS)	Low	100	11.8	3	3	Mbytes/month	1/1
Email, Internet	Mid	50	5.9	240	40	Mbytes/month[1]	2/1
Still video, remote LAN	High	50	5.9	100	50	Mbytes/month	1/1
VoD	V. High	1	0.1	5	0	Mins/month	1/0

[1] To put this in context, 240 Mbytes/month supports 20 e-mails, (10 of which have attachments, 8 of 50 Kbytes and 2 of 500 Kbytes), 5 file downloads of 100 Kbytes each, and 10 Mbytes of web download, every working day for a month.

Table IV-4 Consumer Demand

Service	Speed	Prop of subs taking service	No of subs	Usage		Symmetry down/up
		%	m	outgoing calls	units	
Low Tolerance Services						
Voice	Low	100	44	154	mins/month	1/1
Video Games (VR)	Mid	10	4	60	mins/month	10/1
Video Conferencing	High	25	11	30	mins/month	1/1
High Tolerance Services						
Messaging	Low	100	44	2.4	Mbytes/month	1/1
E-mail, Internet	Mid	50	22	100	Mbytes/month	5/1
Still video, Games	High	50	22	30	Mbytes/month	1/1
Video on Demand	V. High	5	2	90	mins/month	1/0
Automation demand						
Remote metering	Low	200	88	0.7	Mins/month	1/1

Naturally, these figures are open to much debate. We have started with the typical voice usage figures that pertain in today's cellular markets and developed our estimates from there. For the delay-sensitive streaming services such as video telephony we have assumed a usage based on a proportion of today's voice use. We have split the Games services into two types, those that we have called Virtual Reality, which will require streaming services (akin to video telephony), and those that are more tolerant to delay. For the more conventional data-oriented services, such as LAN Access, Internet Browsing, we have taken the upper ranges of our UMTS business modelling case but significantly increased the number of users taking the service.

It is also important to understand the symmetry of the communication because this will have an impact on the capacity required. We therefore provide an estimate of the ratio between the download and upload data needed for each service. In the Business User case much of the usage is symmetric - as much is sent to the LAN or by e-mail as is received - but there is, of course, an imbalance in the service when browsing the Internet. And the small amount of Video on Demand is wholly asymmetric. In the consumer case we see the imbalance in the mid-speed services to be greater because there is expected to be less use of e-mails and greater browsing use. In the games world we anticipate that the Virtual Reality games will consist largely of download while the less delay sensitive games will be somewhat more balanced.

Scenario C presumes comparatively low prices for video-telephony and so we have assumed a high penetration of this service among both business and consumer users. A substantial proportion of both business users and consumers will use E-mail and Internet access and we have assumed that the former will create a greater data load. LAN access will be predominantly a business activity although some consumers will remotely access web cameras in their homes. The high-speed services will be used by consumers for still images and games. We see very limited demand for VoD by business - maybe downloading short clips for review. We have included an automation line for completeness although it has very little impact on demand. In this case we assume that there are two remote monitoring points for every consumer subscriber but they generate only a small amount of data each month.

Table IV-5 Total Traffic Demand

Wide Area Mobile Services	**'Users'**	**Monthly Usage** Million Mbytes/ month		**Peak Traffic Demand** Mbit/sec	
	M	**Download**	**Upload**	**Download**	**Upload**
Voice	56	650	650	4800	4800
Personal Info	56	40	40	320	320
Internet Browsing	28	2,500	920	18,800	7,000
Remote LAN	28	1,850	1,850	14,100	14,100
Video games	4	95	10	725	72
Videophone/conferencing	14	1,835	1,835	13,900	13,900
Video on Demand	2	24,500	-	186,000	-
Automation	89	30	30	235	235
Total		31,500	5,300	239,000	40,000

Table IV-5 consolidates the traffic from the business and consumer users to give the total monthly traffic generated. From this we estimate the peak load by assuming that 10% of the daily traffic is generated in the busiest hour and this gives us the instantaneous traffic demand in Kbps.

Of particular note is the dominant position of the Video on Demand service. Just 5% of the consumer population downloading one 90-minute video a month will create nearly 80% of the demand. In fact, the position is going to be worse than this because we can expect there to be a peak of demand in the evenings and at the weekends giving a higher Busy Hour demand than we show in the simple model. For this reason we suggest that the use of UMTS to provide VoD services is likely to be minimal. In the following we do calculate the spectrum that would be needed for the VoD service, but in practice we would expect it to be delivered by a different means.

V.3.1.2 Spectrum Requirements

As mentioned earlier, the spectrum required to meet the estimated demand depends upon the density of base stations that can be deployed. In the scenario modelled the highest traffic density is seen to occur in the urban regions. If we use the recommended ETSI figure for urban base station range of 1.07 km we find that, to a first approximation, the spectrum required to meet this demand is 2 x 240 MHz + 740 MHz of unpaired spectrum for the VoD service. This figure assumes a frequency re-use factor of 3 and a multi-operator inefficiency factor of 1.5. Remember that we are using the UMTS specification as a proxy here and it may be reasonable to assume that technology developments, akin to the introduction of EDGE in the GSM domain, will allow higher data rates to be delivered in smaller bandwidths thus improving spectrum utilisation.

However, with the current UMTS specification, operators will not, at this range, be able to deliver 2Mbps service to more than half of the users in a cell. It is reasonable to assume therefore that the base station density will be increased to meet the demand that has been identified. The maximum range that would allow the very high-speed service to all users in a cell is of the order of 750m and at this range the spectrum requirement would be 2 x 135 MHz plus 340 MHz. There is, of course, a significant environmental issue to be resolved if base stations are to be placed at intervals far smaller than those used today. Both radiation aspects and visual amenity are high on people's agenda.

If we assume that the VoD service will be delivered by an alternative technology, perhaps deriving from the Digital TV domain, we see that one of the main drivers of spectrum demand in the UMTS case is Video Telephony. We can examine the impact in this by exploring the increase in spectrum required as we increase video telephony use. Table IV-6 shows that if we assume that 50% of voice calls become video calls, for both business and consumer users, the spectrum needed will increase to 2 x 240 MHz using the ETSI minimum range for urban cells (see shaded row).

Table IV-6 The impact of video telephony on spectrum demand

Penetration	Use	Spectrum Demand	
% of subscriber base	% of voice calls	1.07 km Cell Radius	0.75 km Cell Radius
25	20	2 x 205	2 x 105
	30	2 x 240	2 x 135
	40	2 x 240	2 x 135
	50	2 x 240	2 x 135
50	20	2 x 240	2 x 135
	30	2 x 270	2 x 135
	40	2 x 305	2 x 170
	50	2 x 340	2 x 170

These assumptions, if broadly correct, would support the contention implicit in the UMTS Forum request for additional spectrum - namely that, if operators are to offer flexible high data rate wide area mobile services at tariffs attractive to most users, sufficient spectrum will have to be made available to avoid cell sizes becoming uneconomically small. Note that very "hot" spots would still be supported by small cells (typically in a hierarchical arrangement) and that the amount of spectrum envisaged would provide for hierarchy when required. It must be recognised though that the combination of reducing equipment prices and the use of emerging technologies such as HiperLink (see section IV.4.1.2) should go some way towards ameliorating the cost problem.

IV.3.2 Network Infrastructure spectrum requirements

Discussions of wide area services usually concentrate upon the deployment of cell sites. Such sites must be connected to the main network however and this problem will become acute with the substantial increase in cell sites envisaged for UMTS. Both cost and time factors militate against the use of copper or fibre links where new sites must be deployed and, if rapid and widespread deployment of UMTS is to take place, spectrum must be made available for this purpose.

The Information Memorandum issued as part of the recent 3G Auction discussed the need for non-mobile use of spectrum[2]. This concluded that existing capacity, augmented by the RA's plans to "open several bands above 50 GHz for short distance point-to-point links in the next few years", should be sufficient to meet demand. This was based upon the assumptions that;

- Alternatives to radio transmission would be sought in the most congested areas for longer range links using 13 - 14 GHz.

- All transmission requirements beyond the first concentration point would be provided by non-radio means or, if appropriate, by bands above 13 -14 GHz.

It is reasonable to assume that the scenarios envisaged by the study which reached these conclusions were not as optimistic as that characterised by our Scenario C. The requirement to open bands above 50 GHz arises to "avoid congestion in this [the 38 GHz] band from very short links" and it is reasonable to assume that sufficient capacity will exist in these new bands to meet even the significant requirements of Scenario C.

IV.4 Short Range Radio

In all our scenarios we see a growing need for very localised wireless communications capability. Today this need is demonstrated by equipment such as cordless phones, walkie-talkies, TV and video remote controls and garage door controllers. In future it will extend to wire-free access to the high bandwidth services that will be delivered to the premises. It will also be needed for easy and flexible interconnection of equipment such as computers, hi-fi audio, video systems, web cameras, etc and we anticipate substantial growth in the use of wireless for remote communication and control purposes.

In general the requirements are for localised, high mobility, communications, to support medium rate symmetric to very high rate asymmetric uses, and this implies low power, flexible, easy to use and yet cheap equipment. Solutions that are emerging today are Bluetooth and HiperLAN and we use these as models for the capability of systems in the future.

Despite this great increase in the use of short-range radio the technology has the advantage of being a very efficient user of spectrum. The low power means that the same frequency can be reused many times in a small area and the self-organising nature of most modern equipment allows degradation of communications to be only very gradual as use increases use in a locality.

In **Scenario A** we envisage a significant increase in the use of low-power short-range devices and a consequent need for extra spectrum. The development of IP as the common protocol for multi-media services means that the short-range equipment can connect easily and ubiquitously to a variety of services. Bluetooth, or its successor, is used extensively to allow control signals and comparatively low bandwidth data, including voice, to be sent between personal handsets and domestic equipment. It is also one of the main enablers of

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[2] UK Spectrum Auction, The Next Generation of Mobile Communications, Information Memorandum, section 2.2.5

the electronic wallet by virtue of its ability to communicate with Point of Sale terminals. Higher bandwidth communication is supported by the Wireless LAN (e.g. HiperLAN) and this allows entertainment and Internet services to be delivered to personal portable display terminals.

Scenario B is, we suggest, somewhat less demanding of the short-range radio devices, although we still envisage some growth in the need for spectrum for such technologies. Services in the Digital Islands scenario grow more slowly than in the other scenarios and the emphasis on DTV implies a slower evolution away from today's lifestyle.

The need for extra spectrum for short-range radio in **Scenario C** is, we suggest, much the same as that in Scenario A as both are effectively technophile scenarios. The personalisation of equipment in this scenario indicates that the handset will become the focus for a variety of services. Communications between the handset and other equipment, whether they be nearby or at the other end of a wide area communication path, will be common. Similarly, flexibility of equipment use in the home and the office will be an important attribute.

It is **Scenario D** however that we believe will create the greatest demand for short-range radio spectrum ("short broadband tails"). The provision of very high bandwidths into the home or office, coupled with the need for flexible deployment of equipment, suggests that there will be a great need to deliver the incoming traffic to the point of use by radio means. We can also envisage public access points for these very high bandwidth services in the high street, shopping malls, sports stadia, etc.

IV.4.1 Spectrum Requirements

Bluetooth and HiperLAN, which we are taking as our example technologies for the short-range radio requirement, operate in bands shared with other technologies. Bluetooth uses the ISM (Industrial, Scientific and Medical) band and HiperLAN has to share with some radar users. More critical though is the fact the two variants of HiperLAN (1 and 2) cannot coexist in the same area. These factors mean that it is not possible to establish a hard limit on the capacity that will be available when these technologies are mature. Most commentators believe that if the use of these devices become widespread it will be necessary to allocate dedicated spectrum to them.

We can develop an indication of the upper limit of traffic density supportable by Bluetooth and HiperLAN on the assumption that there are no other users of the spectrum in the vicinity.

IV.4.1.1 Bluetooth

Bluetooth has 77 usable channels in the 2.4 GHz ISM band (2.4 - 2.438) and the traffic capacity of each channel is 500kbps. Bluetooth operates by setting up self-organising piconets to allow communication between two or more devices. In a given pico-net at any one time only one of the devices in the net will be transmitting. The highest density of traffic will be achieved if pairs of devices form pico-nets. Bluetooth minimises interference between pico-nets by frequency hopping and, because the hopping sequences are not synchronised, the loading should not be allowed to exceed about 30% of the channels. This means that 23 pairs of devices can be accommodated, each within range of the other. The range of each device is typically 10 m. The total traffic carried by this configuration is thus 30% of 23 x 500 kbps = 3450 kbps and the area covered by it is 314 sq. m. Thus the traffic density that can be supported is approximately 10 kbps per sq. metre.

IV.4.1.2HiperLAN

ETSI's HiperLAN specifications come in two variants, HiperLAN 1 and HiperLAN 2. They both operate in the same 5 GHz band. The former offers data rates up to 20 Mbps over a medium area - typical ranges are 50m and so the applications can include campus coverage and public access services. HiperLAN 2 offers higher speeds up to 54 Mbps. It can be considered as the short-range variant and has 48 channels available for data. The data rate available on a carrier is variable and depends on the interference conditions.

No figures have been published for the supportable traffic density of either HiperLAN variant. To a first approximation, and taking Bluetooth as a baseline we can infer traffic densities based on the available spectrum and the range of a typical device. Using this simple approach we estimate that:

- HiperLAN 1, which has a range of 50 m and an available spectrum of 150 MHz, would offer $150/38\ (10/50)^2\ x10 = 1.5$ Kbps per sq. metre.

- HiperLAN 2, which has a range of 10 m and an available spectrum of 200 MHz (taking the low power part of the CEPT allocation), would offer 200/38 x 10 = 53 Kbps per sq. metre.

In addition to sharing with each other they will also have to share with radar systems, some of which are mobile, and this could add a further restriction on the capacity. A further important restriction is the inability of HiperLAN 2 to coexist with HiperLAN 1.

ETSI is also planning to specify the following variants on the HiperLAN specification:

- HIPERACCESS, which is a long-range variant targeted at providing access at 25 Mbps by residential users and SMEs to UMTS, ATM and IP networks. Spectrum allocations are being discussed in CEPT.

- HiperLink will provide a very short-range interconnection (point to point) capability at speeds of the order of 155 Mbps to connect HiperLANs and HIPERACCESS systems. Spectrum for HiperLink is available at 17 GHz.

IV.4.1.3 Demand

An idea of the potential demand for the Short Range Radio devices can be achieved by considering a typical office LAN. The user density will be of the order of one per five sq. m (i.e. 50 sq. ft per person). Simple experiments have indicated that web browsing can create a download requirement of say 10 Mbytes per hour and perhaps this figure would be doubled for frequent access to a local server. At 20 Mbytes per hour per user we find a traffic density of 20 x 8 /3600 x 0.2 = .009 Mbps or 9 Kbps per sq. metre.

On the other hand, if we are considering a domestic situation in which two people are accessing the Internet and one is watching a TV programme (at 2 Mbps), all using short range radio, the total demand would still be little more than 2 Mbps. This would be required in the area of, say, 50 sq. metres (a typical small apartment) and so, the traffic density is 40 kbps per sq. metre (assuming that the neighbours had similar usage patterns). Note though that the more sophisticated HiperLAN 2 would be needed for this application because Bluetooth does not, today, offer speeds sufficient to carry high quality video. This would stretch the HiperLAN 2 capability, especially if other devices were using the band in the vicinity.

These figures suggest that the spectrum allocated to Bluetooth and HiperLAN 2 may be sufficient to meet the anticipated need for most scenarios <u>if it were dedicated to those technologies</u>. But Bluetooth shares spectrum with other ISM users and HiperLAN 2 shares with HiperLAN 1. This, together with the increasing noise floor created by non-radio equipment, can be expected to significantly limit their capacity. We anticipate therefore that dedicated spectrum of the order of 50 MHz for Bluetooth and 150 MHz for HiperLAN 2 will be required.

In the case of Scenario D the situation becomes more critical with the ubiquitous use of technologies such as HiperLAN 2 for entertainment delivery in the home. In this case the spectrum allocated to such a technology may have to be twice that indicated for the other scenarios, i.e. 300 MHz.

IV.5 Fixed Wireless Access

Although Fixed Wireless Access services have not made any real impact in UK to date it is generally accepted that they have potentially an important role to play in the opening up of broadband services. The extent to which spectrum should be made available for such services is, however, dependent upon the success of alternative access methods, such as ADSL, Cable Modems and fibre to the home, and on the growth of demand for such services. In our four scenarios we have identified Scenario C as the one that is likely to generate most demand for a fixed wireless complement to a pervasive broadband mobile service. Scenarios B and D also suggest significant demand for Broadband FWA.

The point to multi-point FWA offers a number of significant advantages over the wired alternatives. These include

- Speed of deployment. This is especially important where time to market and speed of provisioning are critical competitive factors.

- The ability to share resources between a number of customers. While Cable Modems also offer this ability they are constrained by the maximum data rate that is available to be shared.

- Flexibility in channel structure. The balance of capacity between uplink and downlink can be chosen to reflect the market demand

- Depending upon the bandwidth made available to an operator, and the equipment he chooses to deploy, the total capacity of a channel could exceed 100 Mbps.

One of the factors that have limited market growth so far has been the cost of the customer premises equipment (CPE) which, today, is at the several thousand pounds level. It is widely accepted that there must be an order of magnitude reduction in this figure if the critical markets of the SMEs and, eventually, Consumers are to be successfully served. Manufacturers have indicated that it is not unreasonable to assume that such a reduction will be achieved.

IV.5.2 Service flexibility

The provision of a FWA service presupposes some form of supporting trunk infrastructure, and this could be provided by radio or fixed means. The latter approach is only economically viable where the traffic is high and the distance is comparatively short. This may well, of course, be the case when an operator's network is mature and the success of the service has been established. In the business growth stages however the use of radio infrastructure can be expected to be preferred.

It would seem sensible therefore to allow an operator to use his licensed frequencies for either role and for him to change the balance of use as his network matures. This would also facilitate the provision of meshed networks if an operator wished to adopt such an approach. A meshed network is one in which the infrastructure is an integrated part of the access network. Instead of the standard cell-based architecture, in which traffic is concentrated at a point to multi-point base station before being transported onwards, a mesh approach passes traffic from subscriber unit to subscriber unit, using point-to-point connections, until it reaches a common distribution point.

This is claimed to be more spectrally efficient but complex network modelling would be needed to justify such a claim. By allocating spectrum to an operator while not restricting its use, market forces can be left to establish the most appropriate architecture and infrastructure provision method.

A further issue where flexibility is important concerns the nature of the demand. We cannot predict the degree to which services will need to be asymmetric. As mentioned earlier, FWA can adapt to varying degrees of asymmetry but, in the extreme, the service would become effectively a download service and we can envisage an element of broadcast creeping in.

IV.5.2 Spectrum requirements

Equipment to support Broadband FWA is generally still at the trial or early deployment stage and this, coupled with the great uncertainty about the level of future demand, makes it very difficult to estimate how much spectrum may need to be made available. If a conventional cell based architecture is envisaged network capacity will be subject to factors much like those faced by the cellular operators and discussed in the preceding section. These revolve around the ability to re-use frequencies and the costs of deploying a dense distribution of base stations. Unlike cellular however there is little re-use experience to call on although the theory developed by cellular experts can be used to guide the FWA network designers. The problem for the FWA network designers is also helped by the lack of an inherent need to provide full contiguous coverage, although business imperatives may make this important.

It seems to be generally accepted that a full service operator offering high data rate services to a variety of customer sectors would require about 1 GHz of spectrum[3]. Our figures would support this contention, as follows:

- As in the Wide Area Mobile case we find that the greatest pressure on the spectrum comes in the urban areas. Dense urban areas will typically have a variety of alternative access services available, including Metropolitan LANs. In the suburban areas the density of base stations, caused by the limited range of the signals at 28 and 40 GHz, will inherently create substantial over-capacity.

- In the urban areas of the UK the subscriber density is 4500 / sq. km. If we assume 3 people per household and a penetration of FWA service of 10% this gives a customer density of 150 subscribers per sq. km.

- If we assume a 3km range for a base station, the area covered is 28 sq. km and the number of subscribers to be supported is about 4000. Note that for these purposes we do not need to explore sectored cells and other refinements.

- If each subscriber uses 4 Mbps for 5% of the time during the busy hour this equates to 800 Mbps at peak loads. Allowing a 33% loading figure for Quality of Service purposes gives us a capacity target of 2400 Mbps.

- Today's trial equipment can typically support 2 bits per Hz. Although we might expect some improvement in this figure the increased interference caused by re-use will militate against a substantial increase.

- Thus, to achieve 2400 Mbps we need about 1.2 GHz. A symmetric two way service at this rate would require 2.4 GHz and there will also be some inefficiencies caused by having more than one operator.

Of course, the services provided are unlikely to be wholly symmetric. As an indication we can explore the impact of potential services such as Video on Demand. If the whole spectrum were assigned to a VoD service the 2.4 GHz would support 60% of the subscriber base simultaneously with a switched video streaming service at 2Mbps. Note that, in this case, Erlang comes to our rescue and allows us to avoid most of the 33% loading factor used above.

IV.5.3 In conclusion

The potential for Broadband FWA to fulfil an important role is high. If, as is generally expected, broadband services become relatively cheap and popular, and ADSL does not meet expectations, we can envisage the gap being filled by Cable Modems and FWA. The former will be limited in its capacity thus placing significant load on the latter. However, the need for flexibility in the way the spectrum is used (symmetric or asymmetric, access or infrastructure, etc) coupled with the introduction of interactivity into Broadcast services, suggest that it will be increasingly difficult to restrict the nature of the services delivered by an operator.

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[3] A Way Forward for Broadband Access. A report for the Radiocommunications Agency by Quotient Communications Ltd, March 1999.

Within this context, the figure of 1 GHz per operator is a reasonable working assumption. If demand exceeds those levels discussed here, there still remains potential for operators to increase the re-use levels and in such circumstances the commercial rationale would allow it.

These figures indicate that the 28 GHz band, to be offered later this year by the RA, will not, in the long term, be adequate. This will be aggravated if the LEO operators, such as Teledesic, do end up using the band. Consequently the 40.5 - 43.5 GHz bands will need to be made available in a manner that allows each licensee a substantial bandwidth and significant flexibility in its use.

IV.6 Digital Broadcasting

Within the broadcasting context the major use of spectrum is for television. The advent of Digital Radio has opened up some flexibility in that area but it is not expected to have a significant impact on demand for spectrum. In the following therefore we concentrate on the Digital TV domain.

The introduction of Digital TV services has ushered in a transition period where both analogue and digital signals are broadcast. Much interest has been generated in the spectrum that would be released once the analogue transmissions are switched off. The four Scenarios we have explored suggest the following:

Scenario A implies that DTV will probably require much of the current analogue spectrum, perhaps allowing some to be released for other uses. This is effectively the position being explored by the industry in its Genesis Project. Interactive DTV is used as a simplified form of Internet access for a large portion of the population that may be intimidated by PCs or not want to allocate additional space to one in a crowded dwelling. However, if a significant demand grew for staggered transmissions of, say, films, it is most unlikely that any of today's broadcast spectrum could be released.

Scenario B will require a significant expansion of DTV services and consequently spectrum. Some of the increased capacity will arise through the provision of additional transmitters, allowing greater frequency re-use, and some will need new spectrum. The services requiring this increased capacity are largely interactive and may include Video on Demand. These services may best be delivered via MVDS at, say, 40 GHz. This, of course, blurs the distinction between Broadcast Services and Fixed Wireless Access.

Scenario C postulates that Wide Area Mobile will, to a great extent, replace today's broadcast services by carrying them on multi-casting channels. This would imply that the DTV service need not grow beyond the number of channels available today. All the analogue spectrum would thus be available for other uses. As we have seen however there are significant problems with the delivery of a VoD service using UMTS.

Scenario D suggests that most people will receive their video services via cable or fibre. In this case there is very little need for terrestrial DTV. Those few remote users who can't justify a wired solution will receive video via satellite. In this scenario we can see the need for terrestrial DTV spectrum shrinking to zero.

IV.6.1 The Spectrum Release Problem

Managing the transition from a wholly analogue service to a wholly digital one is not a simple task. The problems are aggravated by the ubiquity required of the service, the comparative low cost and the political need for universal service, including free-to-air channels.

There are significant spectrum implications in the political decision, which is yet to be made, about which channels should be subject to the Universal Service Obligation on broadcasters and on how the term Universal Service should be interpreted in the digital domain. The Genesis Project has identified three possible scenarios, which differ in the geographical extent to which universal service is provided for 'free-to-air' and pay TV services. Table IV-7 defines these scenarios.

Table IV-7 UK Population Coverage in the Genesis Project Scenarios

Scenario	% Coverage of UK population	
	Free to Air	Pay TV
1[4]	94	92
2	98	92
3	99.4	94

It might be assumed that the lower the coverage required the less spectrum would be needed. Unfortunately, it does not work out this way. The spectrum requirement is determined by the acceptable level of interference between the high-powered transmitters. Providing further lower powered transmitters to cover the additional population is a cost issue rather than a spectrum issue.

In addition to the coverage issue broadcasters must decide on the services that they want to offer in the digital bands. These could include the straightforward delivery of service to rooftop aerials, support for portable TVs, support for mobile TVs, HDTV, and a range of interactive services extending up to Video on Demand. The mix of services and the type of receiver supported will also have an impact on the spectrum demand.

There is a further complication associated with re-farming. The extent of the TV UHF band (470 MHz to 854 MHz) made it difficult to design a single aerial to receive all transmissions. In order to avoid requiring people to use two or more aerials it was decided to divide the band up into 3 sub-bands, known as A, B and C/D. In any given area all terrestrial transmitters operate in only one of the bands so that a single aerial can receive them. A consequence of this is that, in different parts of the country, different aerials are used. If the industry is to avoid the cost of replacing at least a third of the aerials in the country it must continue to use the three bands, making it more difficult to release large blocks of spectrum.

Figure IV-1 illustrates this situation and presents a possible outcome of the transition planning process.

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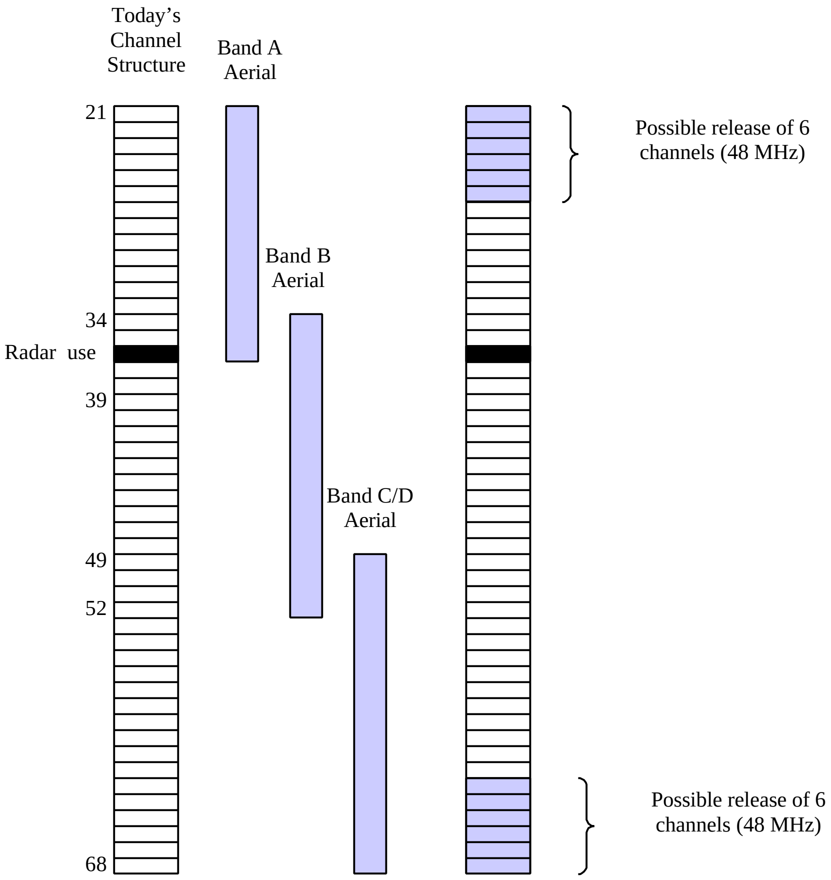
4 Note that the Genesis Project refers to these scenarios as A, B and C. We have numbered them to avoid confusion with our scenarios

Figure IV-1 UHF Channel Structure

Channels 21 - 68 occupy the band 470 MHz to 854 MHz



By making use of the overlap between the aerials it will be possible to reassign channels between aerials and release channels at the top and the bottom of the band. In this proposal a total of 96 MHz would be made available in two contiguous units, although guard band requirements would eat into this.

Clearly a more radical solution is possible, such as re-planning the whole of the broadcast frequencies across the UK and funding any re-tuning of TVs and aerial replacements. This would allow the provision of considerable extra flexibility into the UHF band, enabling for example the better support of portable and mobile units and the introduction of more advanced services. The route is complex however and would require significant international co-operation. It would free up additional spectrum however and, if the re-planning were undertaken in the light of the needs of other potential users of the spectrum, significant benefits and spectral efficiencies could be realised.

IV.6.2 Possible Uses of Released Spectrum

There was discussion during the Workshop on the need for allocating released UHF spectrum for UMTS services. Clearly the greater range at this frequency would significantly enhance operators' ability to provide universal coverage. There are reservations about this use of the spectrum however. The main concern is that it is far removed from the 1900 MHz UMTS band and it will be very difficult to produce dual band handsets economically. Antennas and radio front ends will be significantly different. In addition to the cost there is likely to be a noticeable size difference and we can foresee that most handsets will be single band, creating a lack of economies of scale for the UHF version.

It has also been established that in-car use and, to a lesser extent, in-building coverage, is not as good at the lower frequencies. This is due to the smaller window apertures causing greater attenuation at these longer wavelengths. It must be recognised however that a version of GSM at 450 MHz is being deployed today. A further problem would arise if the channels released by the TV operators could not be structured to provide two bands with a separation suitable for UMTS. The proposal discussed above by the Genesis Project for instance would not be appropriate for UMTS.

Within the Wide Area Mobile domain the current technology that would best benefit from release of spectrum in the UHF band is TETRA, which has been designed so that it can take advantage of small bands of non-contiguous spectrum. We cannot see that it would require a significant amount, however, even if the emergency services were to take up video transmission in a big way.

TV Broadcasters are exploring the use of these bands for novel (to them) services. These include high data rate transmissions to fixed and mobile terminals. They could even extend to include a symmetric two-way high-speed service that could compete with UMTS; trials have already been conducted which show the viability of transmitting 12 Mbps to vehicles travelling at 200 Kph and 30 Mbps to fixed receivers. Such data rates would occupy a whole channel, however, and capacity would rapidly become an issue if switched services - as opposed to broadcast - were to be offered.

IV.6.3 Additional Spectrum for Digital TV

Scenario B postulates a substantial increase in the use of DTV as a means of delivering flexible, interactive services, including Internet browsing and, possibly, Video on Demand. It implies that the service needs are largely highly asymmetric and broadcast style technologies are best suited to this. Where switched high data rates are required, as would be the case for a VoD service, very high capacities are required and it is suggested that this could only be provided at the frequencies above 40 GHz that are now becoming usable. This is one of the bands allocated for Fixed Wireless Access. While a Microwave Video Distribution System (MVDS) is likely to have different characteristics from the more symmetric conventional FWA, the similarities are clear and demonstrate yet again the convergence between telecoms and broadcasting.