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A Common European Spectrum Policy

Barriers and Prospects

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Authors:	Prof. Erik Bohlin (project leader), Chalmers University Dr. Colin Blackman, Editor, *info* Dr. Simon Forge, SCF Associates Ltd Prof. Andrea Renda, CEPS & LUISS
Contracted by:	ETEPS NET Contractor's contact details: ETEPS NET c/o ETEPS AISBL For the Secretary General GOPA-Cartermill S.A. Rue de Trèves 45, 1040 Brussels, Belgium +32 2 280 17 37 (General) +32 2 280 19 12 (Fax) wkoehn@gopa-cartermill.com www.eteps.net
Administrator:	Karin Hyldelund Policy Department Economy and Science DG Internal Policies European Parliament Rue Wiertz 60 - ATR 00L012 B-1047 Brussels Tel: +32-2-2832234 Fax: +32-2-2846929 E-mail: karin.hyldelund@europarl.europa.eu

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EXECUTIVE SUMMARY

This briefing note considers the European Commission's proposals for a common European spectrum policy through reviewing adopted legislation as well as recent communications and other initiatives. The report was produced against the background of the review of the regulatory framework for electronic communications and the recent World Radio-communication Conference.

Radio communication, both broadcast and 'two-way', is one of the great technologies to emerge during the 20th century. The promise of radio spectrum technology, however, is still largely unrealized. Innovation has been limited by large politically connected players, mainly broadcasters and incumbent telephone companies. Policy has been driven by well-intentioned regulators with restricted vision of the possibilities, encouraged in some cases by vested interests and governments in need of new sources of taxation. The result is a wasteful use of the spectrum based on an artificial scarcity.

Looking at the history of spectrum management in Europe over the past sixty years or so, the national, regional and international system has been a good basis for managing the spectrum in times of limited demand. However it is institutionally biased towards the incumbent users of the spectrum. The objective is to protect existing users and their technologies from interference rather than to optimize the economic and social value of spectrum use. The major impacts of such a policy are now restrictions on innovation and growth.

The process of spectrum management in the EU today is spread across the Member States and their NRAs and certain parts of the Commission. There is major involvement of regional and global bodies such as CEPT and the ITU, as by its very nature spectrum management cannot be considered in European or national isolation. In consequence, today's management processes are lengthy, sometimes arbitrary, often politicized and always somewhat fragmented. Based typically on worst-case theoretical scenarios, there is little consideration of the real world, no systematic empirical testing, no economic impact assessment for trade-offs or risk analysis, and no cognizance of future trends in demand for radio services and technologies. The result is a glacial rate of change in policy in the EU and across the world

The development of a coherent EU spectrum policy has become a policy priority only after 1998, though steps had been undertaken to harmonize certain bands for pan-European services since the late 1980s (GSM, ERMES, DECT) with mixed fortune. In the current regulatory framework adopted in 2002, the *Framework Directive* refers to the promotion of 'efficient use', harmonization and effective management of radio frequencies with allocation and assignment, and states that Member States may make provisions for undertakings to transfer rights to use radio frequencies, and ensure that competition is not distorted as a result of any such transaction; whereas the *Authorization Directive* specifies the essential requirement of avoiding harmful interference, the exceptions to the general rule that spectrum use should be only subject to conditions included in general authorizations, not to individual licences; and the imposition of fees for these rights. In addition, the *Radio Spectrum Decision* introduces a complex architecture of decision making, involving the Commission, the Radio Spectrum Policy Group (advising on policy measures), the Radio Spectrum Committee and the CEPT (intervening in technical implementation measures through mandates).

Despite efforts to promote the use of market-based assignment and unlicensed spectrum in Member States through soft law instruments (mostly, Communications), spectrum policy remains mostly subject to national competence. In February 2007, the Commission announced measures to promote flexible spectrum management and the reorganization of some bands.

These include: the accommodation of mobile multimedia services together with broadcasting services in the UHF band; the allocation of 900 MHz and 1800 MHz bands also to 3G services in addition to GSM (e.g. UMTS); the opening of the 1.9-2.1 GHz band, currently allocated to UMTS, also to broadcast services; and the use of the 2.6 GHz band and the *3.4-3.8 GHz* band for broadband wireless access technologies (such as WiMAX).

Most recently, in the recently adopted Communication on the digital dividend, the Commission announced the adoption of a binding Community law instrument to establish 'application clusters' in common spectrum bands in the UHF band, which would form the basis for future national and EU-wide plans. In addition, the proposed Directive amending the 2002 regulatory framework introduces technology and service neutrality as binding principles, and enhances the importance of spectrum tradability, strengthening the Commission's power to take implementing measures via the comitology procedure to coordinate the application of the new principles for internal market purposes. According to the Commission proposal, a newly established European Electronic Telecommunications Market Authority would assist the Commission in facilitating access to spectrum by coordinating or harmonizing the conditions applicable to individual rights of use.

This report concludes that the reforms proposed are good as far as they go, but they need certain changes and some additions. Reforms given in the policy documents cited in Chapters 1, 2 and 3 are aimed at building a new regime for spectrum usage with the key proposals being:

- *A **'harmonized' view of spectrum management***: This means bringing 27 different national spectrum management schemes into line. Why this useful is well explained – a single spectrum regime returns technology and services benefits to users and thus economic and social and benefits (e.g. in volume production of standard equipment, lowering prices and the barrier to entry for new users). How it could be done is yet to be clearly sketched out although it seems that current NRA regimes with a central regulator would be involved. An appropriate overall EU structure is explored in Chapter 1 including a central spectrum management co-ordinator. We also see gaps in defining transition routes that are clear and practical. A progressive transition of the reforms is the most likely to succeed, not a 'big bang' but with Member States being kept in synchronism in a co-ordinated fashion.
- ***Flexibility in assignment of spectrum to a specific technology or services***: This implies that if a band is being used for broadcast, its function could be swapped, e.g. for e-communications. Or, if a licensed band is used for, say, 3G UMTS cellular mobile technology, it could also be used for WiMAX (a metropolitan area broadband technology). At present such flexibility is either non-existent or limited by Member State.
- ***Allocation methods***: The flexibility described above should also be expanded on in terms of the allocation methods. The Commission seeks to add market-based trading with secondary trading and auctions to the traditional method. By traditional we imply a managed administration or command and control allocation for privileged organizations. A key gap here for Europe's future is the progressive addition of far more unlicensed bands, to form a commons for all users based on newly emerging technology. Innovation in radio technologies would benefit from fast and unfettered access to spectrum as they already do for the 6% (or less by country) of the spectrum given over to licence-exempt bands. New uses such as WiFi, BlueTooth and WiMAX depend on this. Ideally what is needed is to establish an unlicensed commons, Europe-wide and internationally. Re-allocation of existing commercial spectrum usages might be combined with Member State governments/international bodies as initial donors. Usage conditions and governance mechanisms for a commons would be light as control for interference relies on equipment tests.

Underlying this challenge to current use of the spectrum by 'single frequency' technologies are several signal processing innovations, some very new, some older but just coming into commercial use. All depend on the availability of high computing power at low cost, which we now see in everyday consumer products such as mobile phones and video game players. The new sharing approaches may employ a range of techniques, either to overlap transparently, or to interleave on white spots, and/or to re-use licensed bands when they are momentarily unoccupied. Approaches to radio communications based on high computational power precipitate a new model of management of the spectrum, which focuses on the right of anyone to communicate and also on the transmitting/receiving device conforming to interference limits. It takes us away from property rights or the granting of permissions to privileged users, and towards the computer industry's form of usage and attitude to the spectrum.

- But more than this, ***Europe needs reforms of the actual spectrum assignments*** among users – the whole of the usable spectrum needs to be reconsidered, but some parts more particularly owing to their advantages in terms of network costs. The Commission's proposals certainly support this reform but are unclear on objectives and concrete proposals. Moreover, the EU has a one-time opportunity with the switchover to digital TV offering the potential for large swathes of spectrum to be re-assigned. This prime spectrum (in the UHF range) offers far longer range propagation and building penetration for high bit rate services.
- From a legal and regulatory perspective, the ***feasibility of the reforms announced by the Commission*** finds important constraints at international (ITU) and regional (CEPT) level, and even more importantly at national level. As regards international commitments, the primary allocation granted to broadcasting services under the GE-06 agreement is currently being discussed in the WRC-07, where the Commission is proposing to grant a co-primary status to mobile multimedia services. This passage would be key to unleash the full potential of the digital dividend, as services enjoying only a secondary status must comply with the interference envelope designed for broadcasting services, nor can claim protection in case of interference with a primary service. In addition, a recent amendment to the MA-02 arrangement has added flexibility to the use of the L-band, currently used for digital audio broadcasting services. At national level, our survey of four Member States revealed the existence of important constraints, especially in those countries where existing, burdensome licences expire in many years from now (as is the case for 3G in some countries), and where the government still uses key bands (e.g. the 2.5 GHz band). Surveyed countries have – to very different extents – taken action towards a more efficient usage of spectrum, with older Member States typically relying mostly on administrative models exhibiting the most significant constraints, compared to countries where market-based models have already been launched, and also new Member States, where the conditions for more flexible spectrum usage appear rather favourable. Overall, our findings suggest the need for coordination between Member States, facilitated by an EU body, to achieve more flexibility in spectrum usage, thorough reorganization of key bands, and establishment of the conditions for a Europe-wide unlicensed spectrum commons.

In summary, the EU needs to rapidly move on to better forms of spectrum management which combine openness, flexibility and harmonization while re-apportioning the spectrum completely. This would be a key step towards the achievement of the internal market for e-communications, as well as a strong driver for European competitiveness and growth. The proposed reforms do attempt to move in this direction to some extent. For the EU to be a competitive contender in the ICT industries, however, better use of the spectrum than is suggested in the reforms so far is vital.

1. ASSESSMENT OF THE COMMISSION'S PROPOSALS ON SPECTRUM REFORM

1.1 Expected impacts of the proposed reforms and chances of success

1.1.1 The history of spectrum usage and future potential significance

Technological foundations for usage of the spectrum

The management of the radio spectrum[1] serves key policy goals for Europe, primarily of delivering the information society, and through that the targets for jobs and growth of the Lisbon agenda. Radio transmission is one of the great technologies that emerged during the 20th century. Spectrum dependent services already directly bring an estimated €250 billion per year to the European economy[2]. Today's spectrum use has grown from early uses of radio transmission for communications by Morse code, by voice from the 1890s and then the first public radio broadcasts in the early 1920s. These applications were all based on 19th century radio research by the likes of Tesla and Marconi, with broadcast television from 1928 led by Logie Baird and others.

A basic principle of spectrum management, until very recently at least, has been that all transmissions need their own specific frequency or continuous band of frequencies (apart from some military applications). Since interference occurs with two transmissions on the same frequency, management of the spectrum is needed to assure one usage over any other. This leads to a doctrine of spectrum scarcity, which means that spectrum must be managed with every wireless system needing an exclusive licence from government to operate. This doctrine has suited most governments throughout most of the 20th century, allowing them to reserve spectrum for military purposes and also to exercise control over radio and television broadcasting. If spectrum is scarce, enlightened governments have a justification for ensuring that broadcasting media are pluralistic; similarly, it is easier for undemocratic regimes to manipulate the media for propaganda purposes.

The historical regulatory landscape

Since the beginning of the 20th century, national regulators for radio spectrum have set national rules. These have been guided by agreements at an international level by the key user bodies: the ITU (telecommunications and other usages), EBU (broadcasting in Europe), IMO (marine communications) and ICAO (civil aviation) with bodies such as CEPT speaking for national regulators and suppliers plus a wider range of concerned bodies and specialists (e.g. Eurocontrol for civil and military air traffic control). In this context of a patchwork of frequency usage, with some EU-wide and international agreements, the public/government services and the military have maintained their hold over large portions of national spectrum.

Policy in Europe has generally been a national concern, driven by well-intentioned but broadly conservative NRAs who have largely maintained the status quo. Traditionally, spectrum has been managed through an administrative process (sometimes known as 'managed or administered command and control') based on the notion of scarcity. The spectrum manager decides on both the use of a particular band and on which users are allowed to utilize each band. This was appropriate when there were fewer uses, and users, plus an establishment that was difficult to challenge, stifling new demands for spectrum.

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[1] The radio frequency spectrum is only a comparatively small part of the electromagnetic spectrum, covering the range from 3 Hz to 300 GHz.

[2] Ofcom, communication, October 2007.

The application of market principles has begun to emerge in some jurisdictions over the past decade or so with spectrum being assigned through auctions. The notion of spectrum sharing, however, has largely been seen as illusory, owing to interference, or has been portrayed as a science fiction of the future.

Growth of spectrum applications

In the 21st century, a major expansion in applications in e-communications is occurring, as radio is the focus of great innovation. The promise of radio-enabled ICTs is finally beginning to emerge. Demand has started to exceed supply under the traditional regime and governments cannot ignore the economic benefits that accrue from efficient use of the spectrum. More responsive spectrum management is now required to ensure Europe keeps pace with technological changes and maintains its place as a world leader in the communications sector. In these circumstances, a growing number of influential voices are recognising that current regulation is the problem, not the solution, including parts of the ICT industry, the RSPG, some NRAs and some members of the ITU. The key question all these groups are asking is: how can we unlock the power of spectrum?

In response to this question, a well-known general concept is taking hold, of a conversion from using the terrestrial airwaves for broadcast TV and radio programming to their use for two-way e-communications[3]. In complementary manner, all forms of broadcast entertainment may increasingly be carried over cable TV and satellite, and perhaps even mobile channels. Some Member States, such as the Netherlands, have moved away from broadcast TV almost entirely into national coverage by CATV networks. Consequently, as we advance into the 21st century, the telecommunications industry as whole becomes the radio-communications industry, whose major service revenue portion is in mobile services.

Future usages and their needs

New applications for radio technology are being driven by expanded use of business and consumer ICTs and their needs to communicate. They are driven by social and economic trends such as the aging demography in Europe and the rising costs of healthcare, as much as the take-up of radio-enabled ICT products. Thus we see the growth of medical applications, for instance the move to accommodate patients in their home, and experiments with sheltered housing for the elderly and frail. Underpinning this is expansion into broadband wireless services. The use of short range technologies (i.e. one to a few metres) is exploding, from Bluetooth and its successors for headsets to ultra wide band (UWB) for home video networks. They include RFID for logistics and retail sectors, with many other future applications. These consumer and business uses are all dependent on unlicensed bands. Thus we may identify future potential demand trends for spectrum resulting from applications in:

- Broadband wireless for media as well as e-communications, both mobile and fixed.
- Healthcare and social service radio networks.
- Enhanced and EU-wide public emergency services for the increasing incidence of natural catastrophes with climate change and large-scale man-made disasters (Bohlin et al, 2006b, Annex 2).
- Low power applications such as RFID for logistics and consumer home networks (ITU, 2005).
- Satellite communications and broadcast.

[3] This principle of bandwidth exchange was sometimes referred to as ‘the Negroponte switch’ in the 1990s.

- Expanded scientific uses.
- Digital TV (both standard and high definition).
- Mobile TV.

1.1.2 Current status and key trends in spectrum policy and its related areas

Where are we in spectrum management today?

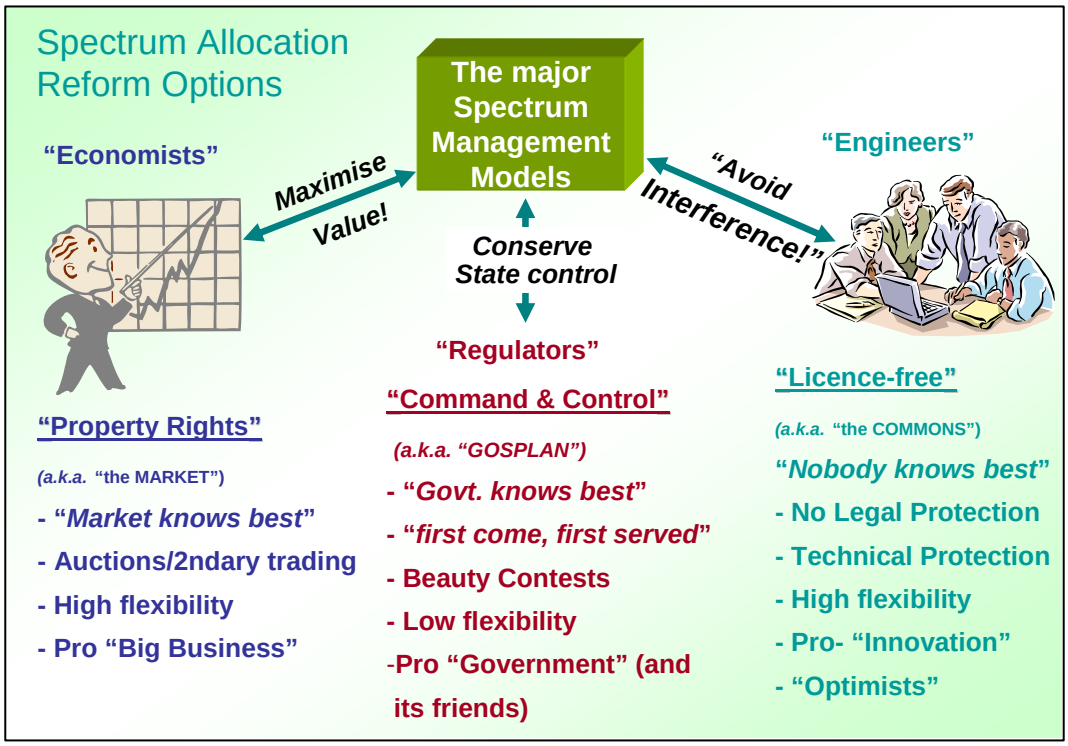
Increased demand, convergence of media and communications and the need to facilitate more rapid access to spectrum to promote innovation and competition are driving more market-based and flexible approaches to spectrum management in the EU. In order to achieve optimal use of this 'scarce' resource, the European Commission is seeking to continue this process. Policy goals are to give spectrum users greater freedom over how spectrum should be used and by whom, by removing barriers to entry and applying only the minimum necessary regulatory constraints.

One approach has been property rights rather than 'permission' for trading slices of the spectrum like land, commodities or other natural resources. Member States such as Germany and the UK have moved the furthest, using spectrum auctions since the late 1990s, following Coase (1959) and later developments (Benzoni, 1993). Trading some of the radio spectrum in specific bands like a commodity is currently permitted in only a few Member States, but would become legal throughout the EU under the Commission's proposals. This would establish a secondary trading market with prices being set by the forces of supply and demand, following on from the primary sale into the market. Liberalising spectrum access through truly open markets would invite new players and current competitors to take market share from the established users. Moreover, the importance of regulators could diminish if such private – and independent – markets can be established to allocate radio spectrum in all Member States.

An alternative and more radical approach is to permit unlicensed spectrum bands for anyone to use – the basis of the 'commons' in spectrum. This concept and its variants such as the 'supercommons' hold that spectrum is not a commodity, and is certainly not scarce, but rather is just misallocated (Werbach, 2004). So regulatory proposals based on the spectrum being a physical asset, defined in bands of frequencies, artificially constrain exploitation as a common good. Extensive use of a commons approach depends on new radio technology to enable far more sharing of the spectrum and so refocus radio regulation away from the spectrum itself and towards the devices used for communication – the position of the computer industry rather than the telecommunications sector.

The commons approach considers that real ownership is not possible as spectrum is not concrete – there is no such tangible thing as spectrum, it is only an intellectual construct. Analogies to land or to natural resources eventually break down and should be replaced by a universal communication privilege. Limits should be set by technical approval tests and liability mechanisms to effectively prevent interference. These commons concepts could operate in unlicensed bands alongside the property and managed command and control regimes. Allowing unfettered radio communication could theoretically overcome scarcity to maximize capacity. Unlicensed bands, initially for instrument, medical and scientific applications, have expanded slightly in some Member States, but still generally take less than 1% of the spectrum below 1 GHz. The various approaches to spectrum reforms are summarized in Figure 1.

Figure 1: A simple view of the options for spectrum reform



Source: Geiss, 2004.

Key policy t

rends emerging

Expansion of the EU's strongly consumerist economy is putting more and more pressure on policy makers to reconsider spectrum allocation with expansion of market and commons principles.

The telecommunications industry is expecting more spectrum to be available for mobile services and fixed wireless access, released from two sources. First is the TV media broadcast industry, with the switchover from analogue to digital TV. Broadcasting going digital should release 75% of the current analogue broadcast spectrum to other uses, and so it is termed the 'digital dividend'.

A second source is expected to be the 'refarming' of public services and military spectrum, be it in moving to new technology, e.g. for civil aviation radars, and in new positions in the spectrum with narrower bandwidth as well as reducing military requirements. It may take financial incentives to encourage state organizations to value and recycle their spectrum assets, retaining only what they really need when using more efficient new technology.

Progress to a single market in the EU has also driven demands for a harmonized approach to spectrum management across Member States, although that may not be an explicit demand for ordinary citizens, only being expressed in pressure for lower prices. Convergence of different regulatory regimes across the EU means commonality in:

- Freedoms of usage (in service type or in technology – e.g. WiMAX for 3G mobile).
- Rights to usage.
- Bands for each type of usage

Economic significance of spectrum for tomorrow's society

The economic significance to the EU resulting from use of the radio spectrum should not be underestimated. It is now a primary economic input factor on which our technology-based lifestyles and infrastructure increasingly depend.

Over the past decade, dependence has expanded dramatically with focus for communications shifting from fixed to mobile for the majority of the EU population. The GSM market in the old EU-15 generated €15.6 billion in 2004 and accounted for 2.8 million jobs,[4] greater than all agriculture, and also greater than the combined value for the EU-15 of the public utility industries (gas, electricity and water). Table 1 gives estimates for indirect and direct impacts in the EU arising from the use of the spectrum, for the two largest spectrum-dependent user sectors.

Table 1: Economic impacts of spectrum use on the EU economy for mobile and TV broadcasting

		Mobile	TV
Direct	Operators – service provision	€208 billion (2007)	€43 billion (2005)
	Suppliers/distributors – hardware (handsets), software, networks, content	€87 billion (2007)	€30 billion (2006)
	Economic output per MHz at 900 MHz	€168 million (2006)	€28 million (2005)
Indirect	Economic stimulus of mobile working, cumulative driving effect of mobile productivity to 2020	0.6% GDP growth	Negligible
	Indirect stimulus to the economy by spend of direct impact revenues in other sectors: – User surplus, social and economic value, i.e. difference between what paid and prepared to pay – Producer surplus, i.e. difference between margins to stay in business and margins actually achieved	€165 billion (2007)	€95 billion
Jobs	Employment in sector	0.5 million	0.4 million
	Employment stimulated by spend from sector	2.3 million	1.8 million[1]

Source: Forge et al, 2007.

1.1.3 Technical and organizational constraints and barriers at EU and MS levels

Technical constraints – forming the basis for spectrum management today

Technical spectrum management revolves around the principle of avoiding interference. This is mainly applied by allotting one user to one frequency band. However transmission at a single frequency using an oscillator locked to that frequency inevitably produces some effects of both a spread of frequencies and the possible emission of 'side bands' – harmonics of the original centre frequency, both higher and lower up the spectrum. These effects depend on the type of signal generation in use, antenna characteristics and their overall effect of the transmission power.

[4] Ovum, 2004.

To some extent these side effects can be filtered out before the power stage of transmission using various types of slot filter which only give window of passage to the desired frequency.

However, some spread of the centre frequency as 'skirts' may be inevitable, despite the efficacy of modern digital filters. Thus the second key for technical spectrum management is the use of 'guard bands' between different users, a dead space where the interfering spread can decay.

The effect of guard bands is to reduce efficient use of the spectrum enormously – they just add dead space. Their widths are a technical question of how sharply the signal filtering can attenuate the skirt and the sidebands of the desired transmission signal, a transmitter as well as a receiver problem. Understanding how the spectrum is actually used is therefore becoming far more important, as detection of unused licensed regions in even dense urban settings can been measured. This shows that perhaps as little as 5-10% of licensed bands are actually being used at one time, and less in rural areas so that rural flexibility for the digital divide could be envisaged (see Dettmer, 2005, p. 44; McHenry, 2005).

Some tolerance of other signals may be possible, in that they appear as part of the background noise which is present at all frequencies, if their power levels are low. Future directions for regulation have been considered in the USA: in 2003, the FCC sought comment on the feasibility of implementing a so-called 'interference temperature' model for quantifying and managing interference.

Organizational limits and political constraints

Legacy ownership of spectrum and usage restrictions will be exceedingly difficult to shed across the EU. It is reinforced by the international Radio Regulations, agreed both worldwide and at regional level, e.g. by the WRC-07 and the RRC-06 (e.g. its DTV broadcast agreement).

Nevertheless, the major problem for the EU lies close to home and results from the 27 Member States. Each owns and regulates spectrum individually and each NRA is confronted with specific national conditions (economic, cultural, geographic, demographic) and priorities. Furthermore, change is global and moves at a glacial speed – for instance, preparation for WRC-07 began in 2003. Any reforms face considerable resistance from existing users with established services and businesses, as well as from governments themselves. Moreover, the latter may see spectrum in terms of confiscatory taxation, and so may introduce their inertia of political constraints.

However, spectrum policy should not be driven by short-term budget policy, as in the USA, which has consistently set the timing and scope of spectrum auctions to align with potential budgetary deficits (Tramont, 2005). In addition, such revenue pressures cut out any willingness to promote a spectrum policy of unlicensed bands. Thus reluctance to promote a commons by some governments, which they claim are for technical reasons, needs to be viewed with scepticism. One should ask whether it is the finance ministry that is setting spectrum policy. In the UK with £22.5 billion was raised in carefully orchestrated 3G auctions but at what cost? The damage to technology development, roll-out and marketing from tax gathering may be said to have limited, perhaps halted, the whole European 3G industry (Forge, 2004). Moreover, presence of government licensees can also distort spectrum reform effort buy auctions, e.g. in the USA in the 800 MHz proceedings in 2004.

On the pricing of licences for newly released spectrum, there are several models for the initial release. A number of EU Member States price the licence based on the principle of covering administrative costs. Some EU countries such as the UK have been making greater use of incentive based spectrum pricing to set licence fees since the late 1990s. Not only is incentive pricing used for commercial applications but it is also being applied to an increasing amount of public sector holdings of spectrum (e.g. spectrum used for defence purposes).

It is also worth looking at the history of others who have pursued intrusive policies with a market-based approach. For example, in the USA, the FCC may have learnt lessons on how spectrum policy should not be managed from the PCS auctions of the mid-1990s which reserved a 'set aside' of two blocks for small businesses – the legal tangle of the heirs to that spectrum is still being resolved a decade later. Similarly, FCC intrusion has limited distance learning and fixed wireless services.

If a market-oriented approach is taken for some bands then all the rights need to be put in the marketplace as rapidly as possible, and users not charged extra for each degree of flexibility in the licence and ownership rights.

There are also some users with strong agendas who expect no changes, perhaps with justification. For example, civil aviation in Europe, through the Spectrum Frequency Consultation Group (SFCG), co-ordinates spectrum strategy through the WRC-07 for aviation in Europe under Eurocontrol. Safety is of course the priority – overall it must have the bandwidth necessary for air traffic control to function[5] – and so requests adequate allocation. The telecommunications industry itself sees advantages in spectrum reform[6], especially in cheap new bandwidth, although for secondary trading, they see problems of transaction costs.

1.1.4 Substance of proposals – Directives, Communications, relevant policy papers

A number of documents on spectrum reform have been produced covering:

- Building a framework for spectrum management in Europe with a range of proposals, some being fairly simple extensions of today's situation of shared powers at EU and Member State level, some more radical such as a European regulator for spectrum management. With this comes:
  - A harmonized approach across all the EU for regulation of the spectrum
  - Flexibility in allocation by service and technology type for rapid access
- Market-based forms of regulation with secondary trading for spectrum licences, usually first offered through some form of auction
- Future mobile services and their spectrum requirements
- The digital switchover from analogue to digital TV and its digital dividend
- Collective spectrum use in the sense of overlays and interleaving

Discussion of regulatory issues in the area of spectrum is set in a combination of adopted legislation and recently adopted and planned initiatives. The most relevant pieces of legislation start with the R&TTE directive of 1999, the regulatory framework for electronic communication and the spectrum decision. Also relevant are replies to requests for comment on the major reforms as well as some studies carried out for the European Commission[7]. The major relevant documents are listed and summarized in Table 2.

[5] Eurocontrol, Response to request for comments on 'Study on conditions and options in introducing secondary trading of radio spectrum in the European Community', 14 September 2004.
[6] GSM-Europe, GSME response to the final report for the European Commission 'study on conditions and options in introducing secondary trading of radio spectrum in the European Community', 17 September 2004.
[7] Analysys, 2004; Forge, 2005; Mott MacDonald, 2006.

Table 2: The major documents relevant to the spectrum reform proposals.

Document Reference / Title	Substance
Directive 1999/5/EC. Radio equipment and telecommunications terminal equipment (R&TTE) and the mutual recognition of their conformity	The R&TTE directive – initial framework for electronic communication markets and spectrum decisions. Establishes the EU market through a regulatory framework for the placing on the market, free movement and putting into service in the EU of R&TTE conforming technically to standards assuring non-inference over the range 9kHz to 3000GHz, with protection of users and all others. Allows use of mutually agreed EU-wide harmonized standards for all States. Radio equipment for public security, defence, State security excluded.
Decision 676/2002/EC. Radio Spectrum Decision (RSD) on a regulatory framework for radio spectrum policy in the European Community ("The Radio Spectrum Decision")	Key EC policy decision to establish an EU framework to coordinate policy/ legal approaches as harmonized conditions for availability and efficient use of the radio spectrum, as the basis for establishment and functioning of the internal market, in EC policy areas such as e-communications, transport and R & D. Establishes procedures for policy making – strategic planning and harmonization of use of radio spectrum
COM/2007 /50 final, adopted 8 February 2007. Rapid access to spectrum for wireless electronic communications services through more flexibility	Main policy document to establish a more flexible spectrum management approach, reducing spectrum scarcity and costs, termed WAPECS (Wireless Access Policy for Electronic Communications Services). Aim overall is to accelerate access to spectrum, based on efficient management. Changing spectrum usage freely is valued at €8–9 billion per year. The basis for this approach is service and technology neutrality, as defined usages block opportunities for other usages. Notes that 1350MHz of spectrum could be flexibly repurposed, using technical criteria to limit interference (power levels, guard bands, channel ID).
EC Directives 2002/19/20/21/22/and 58. This series of directives establishes rules of operation of e-comms services and networks[8]	19: Freedom of access, or interconnection, without restrictive practices 20: The Authorization Directive – proposes minimal authorization rules 21: The Framework Directive – common regulatory framework 22: Covers universal service, user rights for availability, affordability etc 58: The Directive on Privacy – personal data and protection of privacy
COM(2005)411 final, of 6 September 2005. Second annual report on Radio spectrum policy	A forward-looking radio spectrum policy for the EU to harmonize spectrum for good of EU society. Considers need for common policy and regulation for spectrum markets, transition to DTV etc– in consideration of the high impacts on EU economy – e.g. GSM revenues and jobs. Notes failure of 3G auctions with 109Bn Euro spend. Notes 2 approaches to allocation – markets and commons – and new applications of spectrum
COM(2005)400 final, 14 September 2005 A market-based approach to spectrum management in the EU	Policy document describing how market should decide on use of a spectrum band following Framework Directive 21 (2002) which considers trading. Would apply for selected bands to be owned under a licence – states that a third of the spectrum below 3GHz could be tradable. EC could initiate co-ordination process using the RSD – to have all in place for 2010. Still sees a place for managed command and control for public sector. Notes market based reforms already active in Member States – AT, DK, HU, IT, NL, PT, SK, SI, SE, UK.

[8] Following EC obligation under Art 8 of Directive 90/387/EEC of 28 June 1990 on the establishment of the internal market for telecommunications services through the implementation of open network provision (ONP), OJ L 192, 24.7.1990, p. 1. Amended by Directive 97/51/EC of the European Parliament and of the Council (OJ L 295, 29.10.1997, p. 23)

Document Reference / Title	Substance
COM(2004)507. Radio spectrum policy in the European Union: State of Implementation and Outlook	First annual report on Radio spectrum policy under the RSD. Discusses specific actions to strengthen spectrum policy: on 3G mobile, RLANs, UWB, SRDs, etc; policy for digital dividend, 2ndary trading, WRC-07; international activities; future wireless platforms.
COM(2005)461 final, 29 Sept 2005. Policy for Radio spectrum availability in context of digital switchover and upcoming ITU Regional Radiocommunication Conference 2006, (RRC-06)	Describes EU priorities for the RRC-06 meeting to discuss plans for terrestrial digital broadcasting frequencies (174-230 MHz & 470-862 MHz). Usefully notes that 3 to 6 times less radio spectrum needed – so some 300 to 375 MHz could be freed. Also could make broadcasting bands tradable. Requests EU-wide harmonization of dividend and commitment to swift switchover (by 2012) with need for common action.
"Towards a European policy on the radio spectrum" EP Resolution of 14 February 2007, P6_TA-PROV(2007)0041	European policy on the radio spectrum from EP. Considers EU needs to adopt a sustainable approach to spectrum which will promote competition and the development of innovative technologies, inhibit the hoarding of frequency rights and the aggregation of monopolies and benefit consumers, and that this approach should take into consideration technological change as well as the needs of market players and of citizens. Emphasizes importance of spectrum has increased during recent years and that the growth of the technology sector relies, inter alia, on the efficient use of spectrum. Responded to Commission communications, COM(2005)400, a market-based approach and 2nd annual report COM(2005)411.
Decision 2007/344/EC, adopted 16 May 2007.	Harmonized availability of information regarding spectrum use in the EU – MS to use ERO information system (EFIS) on spectrum data
COM(2007)371 final. The ITU World Radiocommunications Conference: WRC-07 preparation, following Lisbon agenda, i2010, for a European Information Society for 2010.	Call by EC for MS to maintain common negotiating positions during WRC-07 and support positions identified by EC, endorsed by CEC and EP, specifically- consolidation of EU single Market; removal of technical barriers to international trade; promotion of competition between alternative infrastructure platforms; innovation-friendly conditions for new technologies, including via open standards.
RSPG policy input documents, specifically, Opinion of the RSPG on WAPECS – the EU policy for radio access to e-comms services	Describes an EC policy for platforms for radio access to e-comms services for any spectrum band and any technology. Sets out a long-term vision for equitable competition between such platforms offering similar services and addressing similar markets. Aimed at a more flexible spectrum management approach but co-ordinated on an international basis with other regulatory bodies. Proposes removal of constraints on usage of radio spectrum bands where possible. Concerned with spectrum reform in a coherent way for new e-comms bands across the EU with flexibility by all MS. Vague on real objectives and deliverables so far.
EC Decision 2007/344/EC, adopted 16 May 2007	Harmonized availability of information regarding spectrum use within the EC. MS to use ERO information system (EFIS) on spectrum data
COM(2007) 13 November 2007, not final, Reaping the full benefits of the digital dividend (DD) in Europe: A common approach to the use of the spectrum released by the digital switchover	3 main candidates for the DD – 1.Wireless broadband communications 2. Additional terrestrial broadcasting services (somewhat specious argument on participation) 3. Mobile multimedia, (and surprisingly mobile TV). Proposes DD division into sub-bands for Uni-directional services) broadcast and bi-directional (e-communications, e.g. broadband mobile). NO unlicensed reservation.

Source: http://ec.europa.eu/information_society/policy/radio_spectrum/index_en.htm.

1.1.5 Implications of key proposals

Major directions expected for the future of spectrum usage and management in Europe

In these policy papers and directives the EC has made a framework for moving forward to a generally better spectrum regime in terms of allocation and level of management specifically with recommendations that include:

- *A common framework for spectrum decisions*: the general major thrust towards consistency across Europe on spectrum assignments with an expectation of economic penalties if universality is not met, as spelled out in the Markets paper, COM(2005)400.
- *Neutrality on services*: specific services are chosen today for each band – for instance broadcasting has large reserved bands, especially in the range up to 1GHz, the prime region of spectrum that broadcasters wish to retain.
- *Neutrality on technology*: generally when a service has been chosen for a band, the actual technology in use may well be specified, especially for mobile services, such as GSM or UMTS. Liberalization of spectrum away from assigned usage by technology is more efficient. The EC has identified at least 1350 MHz that could be used for new purposes if complete flexibility is permitted (see Table 3).

Table 3: Bands on the run – open to review for neutral service usages

Band for potential re-use	Frequency range, in MHz
Digital dividend, analogue TV	470 – 862 (total of 392 MHz)
GSM Mobile	880 – 915 and 925 – 960, also PCS 1710 – 1785 and 1805 – 1880 (total 220)
UMTS/3G	1900-1980, 2010-2025, 2110 – 2170 (total 155)
IMT 2000/3G still to be licensed, the "2.6GHz" band	2500 – 2690 (total 190)
Broad band to customer premises, also satellite channels in Africa and Russia, at 3.4GHz	3400 – 3800 (total 400)

Source: from COM / 2007/50.

- *A market-based approach to allocation, allowing secondary trading*: letting the market decide on use and values of spectrum. Markets become the major mechanism of spectrum allocation reform, through trade in specific authorized bands. This key proposal is outlined in COM 400, 2005. It suggests assuring efficient coordination at Community level, by introduction of markets for the bands listed below:
    - Terrestrial mobile communication services, including frequencies for public mobile services, such as GSM and 3G, and those for closed user groups, e.g. PMR and PAMR.
    - Terrestrial fixed wireless communication services, including frequencies for Wireless Local Loop, Broadband Wireless Access and microwave links.
    - Terrestrial TV and radio broadcast services – local, regional and national.

It notes that actual bands to trade would have to be validated with a coordination process needing specific legislative proposals, based on impact assessments. Also the costs of having a market-based entry for smaller operators should be considered, especially to avoid spectrum hoarding and/or driving prices beyond the economic value to a small operator (with the aim of limiting competition, after which the market price of services could be revised to recoup overpayments).

Optimistically, the bands listed above might be expected to function on a market basis rapidly. Reassignment of the released spectrum from the digital dividend could boost efficient use of these bands, although the dividend might be far better managed through other models[9]. A commons of unlicensed bands is the obvious solution. Hostility in some Member States to this is likely, due to governments anticipating lost auction fees, or regulatory capture by operators interested in protecting their mobile licence investments, and of course mandated users of the managed command and control portion, who would not wish to relinquish spectrum for a commons.

- *Flexibility*: Neutrality on technology and services means that spectrum could be used for any purpose. But caution may be necessary. In practice, some bands may need to be reserved for one application across the EU (certain military or emergency services, for instance). There may well be bands where a general class of application could be set, but implementation would be open, e.g. for commercial broadcast, implementation might be terrestrial broadcast, but if technically suitable, digital satellite with a restricted footprint might be a contender. Here the notion of sub-bands becomes useful, i.e. division into commonly agreed areas for flexible and non-flexible usage.

- *Harmonization across the EU Member States*: a single EU market for mobile services could create one of the largest markets globally for such services[10]. There is therefore much mileage for the EU in moving to harmonized standards for allocation methods and types of usage of bands in terms of the split between commercial and public/military services and the release and refarming of spectrum. This does not mean that flexibility disappears, just that the same degree and dimensions of flexibility and freedoms should be applied across the EU. This applies equally to public access EU radio spectrum information, with uniformity of access to comparable and accurate information on spectrum use and regulation via a single reference point having been mandated by the EC[11]. It does imply an EU-level of agreement. Whether it implies an EU regulator is a moot point.

- *Management of the regulatory process*: in connection with the latter issue above, the move from NRAs as key deciders to a central authority may make some sense in the case of a harmonized EU spectrum management. For spectrum to be of economic benefit to all, it can no longer be a subject for independent local decisions, especially if a licence-free commons and perhaps markets for licensed bands are to be allowed to operate. Also it would relieve regulators of redundancy and conflicts in rulings while reducing parallel resources and effort to make the rulings. Instead, one central body sets the agenda and the rulings. Impacts of new EU-wide policy are likely to be better supported by strong coordination at a single point, perhaps more so than can be effected by the ERG[12], although this group may be quite adequate, in concert with EC guidelines, for other aspects of telecommunications regulation.

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[9] 'Accelerating the Transition from Analogue to Digital Terrestrial Broadcasting', SEC(2005) 661, p. 10, staff working paper; and COM(2005)204.

[10] A market-based approach to spectrum management in the EU, (2005)400 final, 14 Sept 2005.

[11] EC Decision 2007/344/EC, on harmonised availability of information regarding spectrum use within the Community, adopted 16 May 2007.

[12] European Regulators Group, the collective body of NRAs which currently coordinates policy between Member States, http://erg.eu.int.

- *Overall implications for Europe* – The recommendations for a European strategy to harness the opportunities of spectrum are largely useful as far as they go. Major areas that do need revisiting are now considered, in sections 1.2 and 1.3.

1.2 Who wins, who loses – SWOT analysis of key reforms proposed

1.2.1 SWOT analysis of key proposed reforms

The main impacts of the current proposals are considered in the tables below:

Table 4: Concepts of spectrum assignment in current proposals.

Strengths	Weaknesses
• Continuity with the past • Satisfies current users with conventional concepts of usage – military, TV, emergency services etc and those with single-user licences.	• The conventional view of spectrum assignment as being exclusive usage of a discrete frequency band requires either a managed allocation or a licensed model. This is likely to hinder new entrants and restrict new technologies for sharing spectrum and using it more efficiently.
Opportunities	**Threats**
• A single market for technology, pan EU services and content. • Introduction of neutrality on services and technologies enhances economic potential	• Conventional view of spectrum usage may halt development of new radio technologies for mobile and other non-cellular communications, both in R&D and bringing into service – both sharing and interleaving technologies. So innovators (researchers and service providers) offering novel technologies, infrastructures and services would lose out.

Table 5: Spectrum allocation methods proposed (market-based, with command and control still).

Strengths	Weaknesses
• Opens up usages and owners to the market rather than just officials • Market-based mechanisms of allocation may well be useful for some applications such as DTV, so more flexibility would be introduced for some commercial players and their industries.	• Not looking forward to new types of usage e.g. mobile Internet • Based on yesterday and today's views of allocation. • Secondary market operations in the EU have been limited • US experience of markets in spectrum has been mixed • Secondary trading will require administration of owners, rights and usages updated in real time with trading • Trading could lead to speculation and hoarding requiring regulator vigilance, with an EU and a national level of awareness to protect smaller market players
Opportunities	**Threats**
• Open up spectrum to new uses in some MS through markets and auctions • Establishment of secondary trading markets • Secondary trading could introduce higher competition in some markets	• Only pursuing command and control and market based implies either a mandated privilege or funds to purchase a licence – unfair to smaller players and minority interests (lack of government lobbying power) • Without inclusion of more unlicensed allocation, uses will be restricted to those with resources to compete and those with mandates to use. New technologies using the WiFi model of free and open access would tend to be restricted

Table 6: Impacts of neutrality in technology and services.

Strengths	Weaknesses
• Drives innovation in technologies as they can be deployed more easily. • Enables service providers to enter markets far more easily using the spectrum available	• Reduces chances of EU-wide harmonization. • May lead to market led rather than social-value services. • Technology neutrality may encourage many standards with less chance of economy of scale, interworking and roaming
Opportunities	**Threats**
• Easier entry for service providers with novel offerings will promote a thriving competitive market • Choice for users is greater	• May increase chances of interference unless well managed – e.g. with constantly updated central spectrum registry for the EU

Table 7: Impacts of EU harmonization and centralization of spectrum regulation.

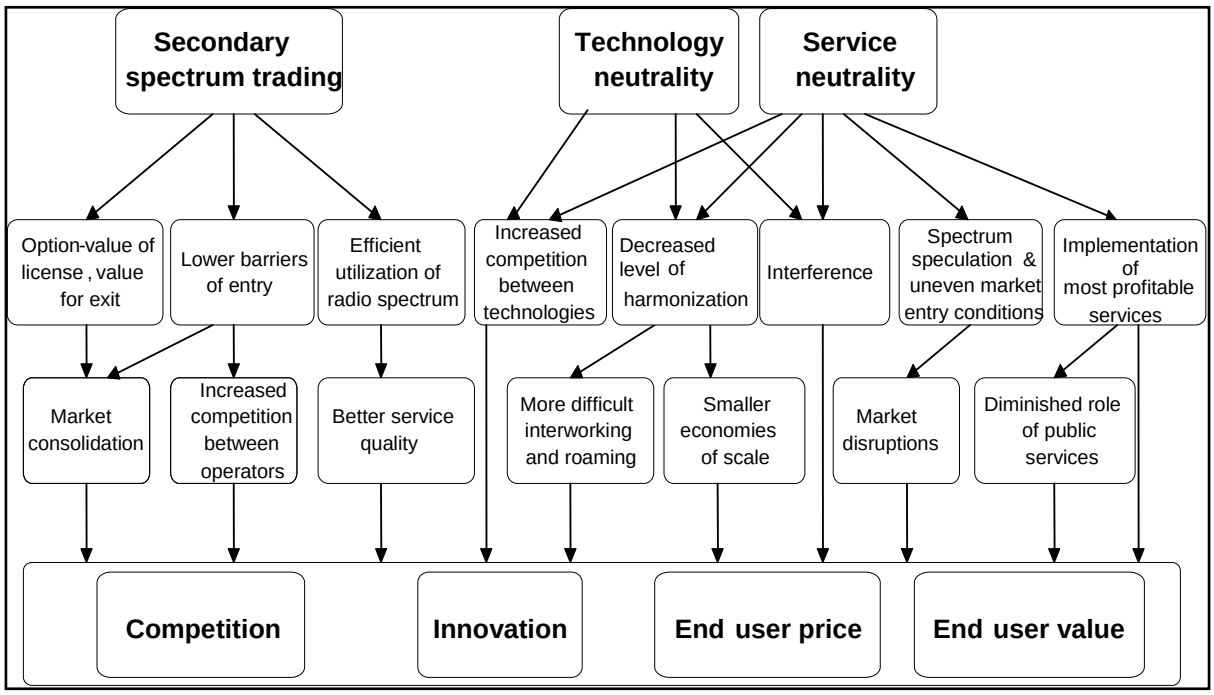
Strengths	Weaknesses
• Gives an EU wide conformity for users and regulators, removing the patchwork of legal, technical and commercial conditions for awarding and using spectrum.	• May require much negotiation to arrive at a suitable balanced structure, with clear identification of roles of each participating body at EU and MS levels – a lengthy process. • Tends to limit role of NRAs to national issues other than spectrum – e.g. forms of universal service in view of national income and needs
Opportunities	**Threats**
• Build an EU-wide market for services and equipment with simplification of support for users – e.g. a single mobile numbering plan	• A strong EU central body, rather than a facilitator and coordinator, would be a single point of pressure for political influence by MS governments lobbying for special interests.

1.2.2 Conclusions from SWOT analysis

The key conclusions

A summary of the major impacts of the policy proposals for trading and technology and service neutrality is given in Figure 2.

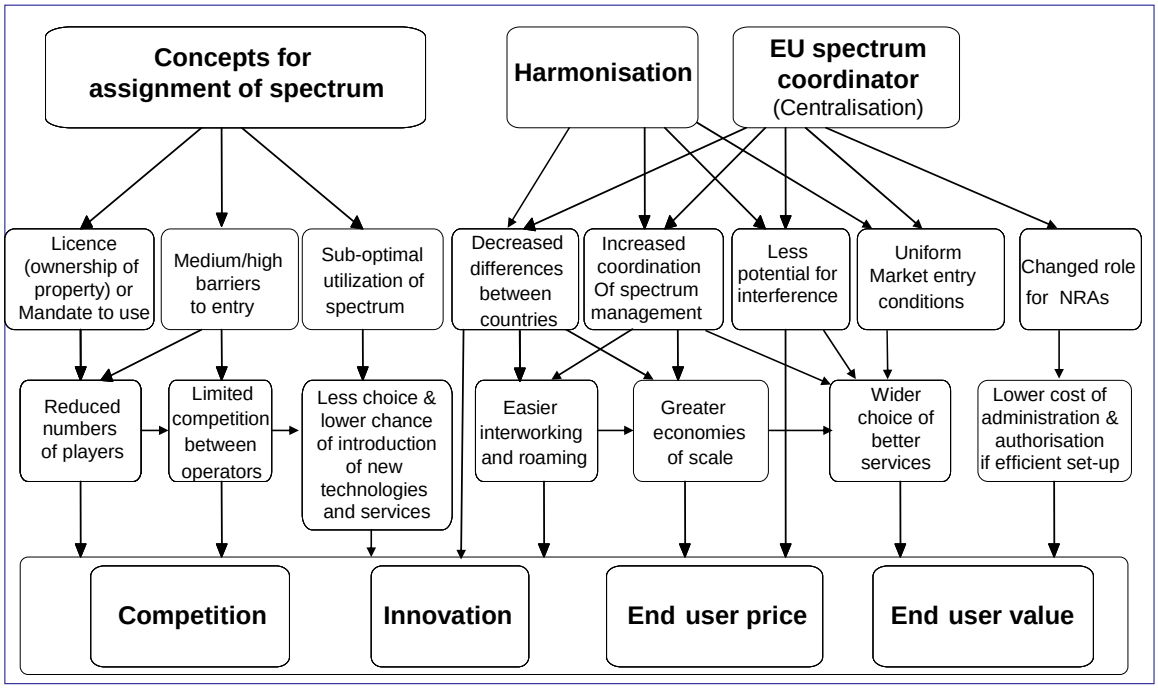
Figure 2: Impacts of policy proposals for trading and neutrality.



Source: Smura et al, 2006.

The implications of the proposed regulatory policy for the basic concepts of assignment with EU-wide harmonization and centralization of spectrum are shown in Figure 3:

Figure 3: Impacts of proposals for harmonization, EU-wide regulation and basic concept



1.2.3 Main implications

Overall the Commission's proposals imply a significant improvement over previous spectrum management. However, several questions remain over whether the proposals go far enough. The first is whether more emphasis should have been given to the potential for unlicensed bands rather than market-based allocations of only a relatively small part of the spectrum. Second, should more spectrum have been considered for re-allocation, especially as a result of the digital dividend? Third is the question of whether this is being carried out at the risk of too much centralization of power in a way that could be performed equally well or better at the local, NRA, level.

On the first two questions, we have to look at the socio-economic implications. The promise of spectrum-based industries for Europe will be realized to a limited extent by the current proposals. Older technologies have already taken most of the prime spectrum, i.e. that at the lower frequencies below 1 GHz with low and questionable future socio-economic value. So there is a crucial need for spectrum reform as the value to society and the EU economy of spectrum has increased dramatically since the first European agreements were made.

1.3 Gap analysis and likely impacts on demand for spectrum

1.3.1 Major areas missing or requiring further attention

New thinking on spectrum usage – a commons in spectrum

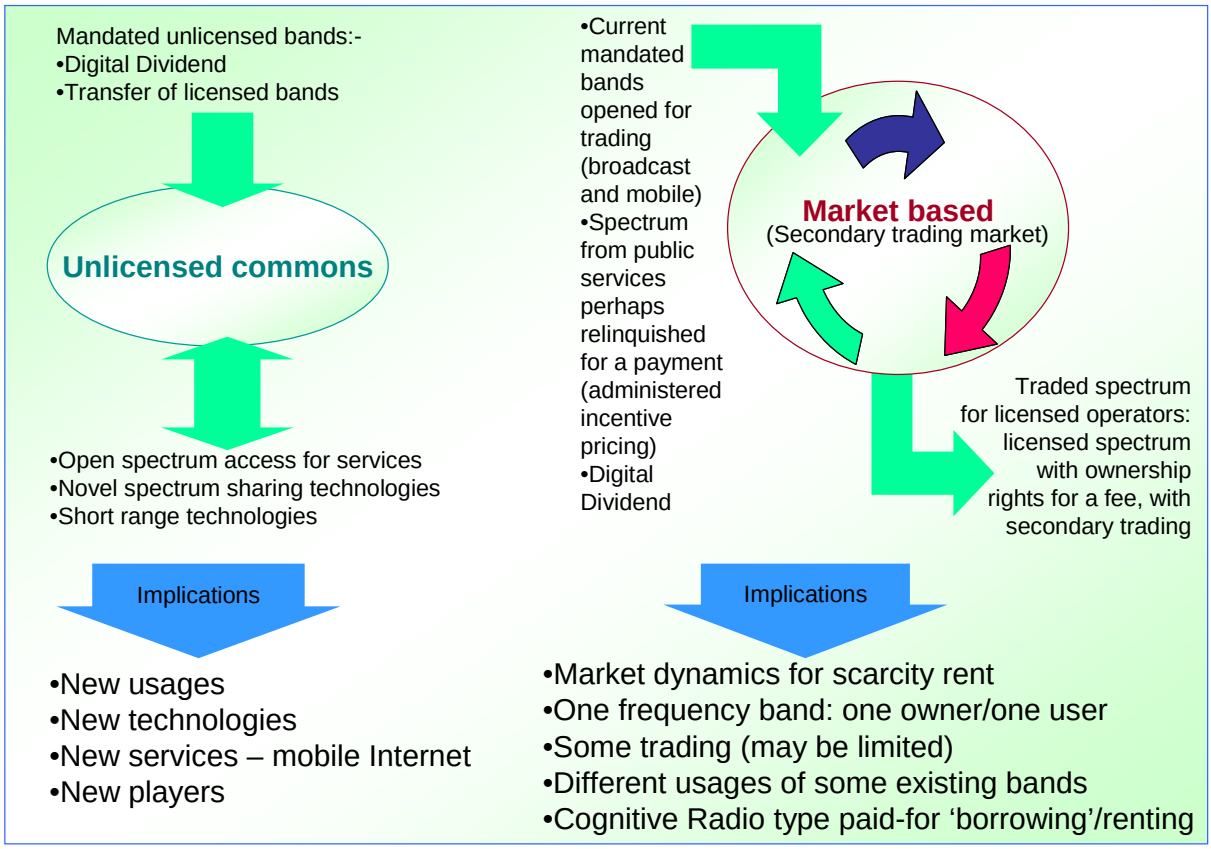
The analysis above implies the need for more than just better mechanisms of allocation. Rather, what is needed is complete reassignment of usages of the existing spectrum. For example, the prime spectrum (in the UHF range) offers longer range propagation and better penetration of buildings for lower cost, high bit rate services. But it is unclear whether current proposals will deliver this. Advanced technologies and their spectrum needs deserve far more consideration than is currently the case.

On the question of centralization, to achieve harmonization with flexibility of the liberalized spectrum, a greater degree of coordination will surely be required. However, a large bureaucracy is not what is necessary. Instead, a central facilitator is likely to be more successful, coordinating the Member States, working with NRAs in a more direct way than today, and above all quickly and decisively to review questions of harmonized authorizations. The aim would be to accelerate the rate of change in regulation at national, European and world levels.

Perhaps the largest area missing is anticipation of technology to expand spectrum usages in the future by sharing using technologies explored in section 1.3.2. This implied that a commons in spectrum is probably going to be required. Using the most advanced technologies (only completely exploited by the military today), each transmission would be transparent to other users, and if allowed, could use already allocated unlicensed bands. For the thinking here it is useful to refer to recent literature on different concepts of the nature of spectrum which see it as an abstraction, not a saleable good so that property rights no longer apply (e.g. Benkler, 2003; Werbach, 2004).

It would accompany a change of model of spectrum usage that has yet to be seriously considered by the European Commission (see Figure 4).

Figure 4: Radio spectrum policy impacts: commons and unlicensed bands against markets



In this concept the future operation of radio networks would converge with the Internet, as conceived by the computer industry. This open mobile Internet access contrasts with the traditional telecommunications operator model. It is based on access by any terminal device to any radio network in a completely free manner, just as any laptop PC with a radio card can access any WiFi network, if permitted, perhaps with payment for usage. Then all mobile services would become like a WiFi model of operation with IP access. This suggests Skype-style forms of low-cost mobile VoIP services will be the future.

Management methods and supporting technologies

New technologies and management models present new challenges. Future spectrum management methods will need to be more flexible and efficient in terms of spectrum usage across the EU in harmony. While assuring harmonization, they should also introduce reduced technical constraints for greater technical flexibility. They must also operate with several management models, not just command and control and market-based (and secondary trading) but also spectrum sharing, commons and unlicensed bands at assignment level. Will traditional spectrum management methods alone suffice for these new technologies? Current spectrum management frameworks to some extent already provide for competing mechanisms and for limited spectrum sharing. But novel definitions of user rights are required to reflect new degrees of flexibility for shared access to frequency bands and for concepts of secondary and primary users. Some technologies considered below may offer novel spectrum sharing between peer users as well as primary and secondary users. Spectrum sharing with secondary users implies that a regulatory spectrum agency would have to provide a novel legal framework for secondary usage and trading secondary rights.

A regulatory agency should also:

- Set technical conditions on secondary use on interference, e.g. spectrum masks for interleaving, or noise levels (e.g. similar to the FCC's 'interference temperature').
- Police the frequency bands for spectrum sharing, having identified them, with a central registry of users and rights for licensed users and trading partners.

In contrast, verification for commons users in unlicensed bands should be performed at the equipment conformance level, simplifying authorization and eliminating the regulator's load beyond type approval testing. However, all such novel sharing techniques are at an early stage, making it difficult to predict impacts on spectrum management and exactly what supporting technologies would be needed. More sophisticated spectrum sweeping equipment will be needed if dense usage of the spectrum is to be maintained. It could provide constant monitoring at low cost as a first step, surveillance of trends and alarms for over power-limits detection, and in some situations, user identification.

1.3.2 Consideration of emerging technical developments and their impacts

What we are seeing is a rapid change in the way transmitted signals are handled as new technologies and techniques for communications via the radio spectrum are brought to market. These all depend on low cost digital signal processing requiring relatively high computing power that has only recently become available at handset level in terms of cost and power. The main technologies and techniques that will change how the frequency spectrum may be allocated are explored briefly here:

Software Defined Radio/Cognitive Radio (SDR/CR): over the last decade, far greater flexible configuration of the air interface has appeared. SDR grew out of the need for far more flexible ('intelligent') radio receivers and transmitters, units whose transmission frequencies and other characteristics could be changed at will, i.e. under software control. Pioneered in Europe and the USA in the early 1990s, initially for digital audio broadcast (DAB). Use of SDR is essential for the next stage of such thinking on intelligent adaptability in which the ambient radio spectrum is tested (or 'sniffed') continually to identify unused areas of spectrum for re-use, perhaps for a very short time. First publicly researched from about 2000 on, this is often termed cognitive radio (CR) as the transceiver is aware of its radio spectrum environment and so can dynamically adapt its transmission/reception behaviour and characteristics accordingly[13]. It allows temporarily free spectrum, or small gaps between used bands ('white spaces') to be re-used. Alternatively in a market-based model the spectrum might be rented for the moment it is used and then released for others[14]. Such techniques depend on the finding that perhaps only 5-10% of the licensed spectrum at any one time is in use, across urban, suburban and rural environments. 'Interference' problems only appear if a CR cannot find a legitimate free band as it jumps from one vacant frequency to another. In summary, this real-time spectrum management of CR is useful at two levels – as part of a general spectrum management regime for higher efficiency in utilization and secondly for deploying a market-based charging approach, with (preferably) pre-negotiated access among co-operating users – those who 'own' the spectrum and those who wish to 'borrow' it, for a short time. It has led to the term 'collective use' implying a licence exempt basis, e.g. for short range devices (SRDs), as well as sharing concepts such as underlay and overlay.

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[13] See e.g., FCC notice, 'Facilitating opportunities for flexible, efficient, and reliable spectrum use employing cognitive radio technologies', Notice of proposed rule making and order, FCC 03-322, ET Docket No. 03-108.

[14] FCC , Comments of Shared Spectrum Company: In the Matter of Inquiry Regarding Software Defined Radios , June 2000, ET Docket N0. 00-47, Shared Spectrum Company, Vienna, VA.

Here users would have no or only partial protection from interference in terms of legal recourse against interfering users. Collective use is open to all applications and technologies if they comply with the relevant technical parameters.

Spatial multiplexing using Multiple-input, Multiple-output (MIMO) systems. Using multiple antennas both at the transmitter and receiver to improve air interface performance offers significant increases in data throughput and link range with no extra bandwidth or transmit power. MIMO achieves this by higher spectral efficiency, i.e. more bits per second per Hertz of bandwidth and better link reliability or diversity – reduced fading. MIMO is a central theme for radio research and standards setting currently. Various radio systems including cellular (3GPP/3GPP2), WiMAX and WLAN (WiFi[15]) exploit it commercially now or plan to in 2008. The next step is to exploit its spatial diversity further, for more users per cell.

Mesh and ad hoc networks. Mesh networks exploit the users' terminal devices acting as a base stations or relay for other users (Forge, 2004). They can thus extend a network or set it up just by the presence of a user who is in range of other users. So mesh networking may create 'new' networks in an ad hoc fashion, a feature making them attractive for emergency services. Moreover their more flexible network architectures may co-exist with like and unlike networks. Their very nature indicates use of shared spectrum, and so licence-exempt bands. They could be used for delivering present services and also could exploit less used and less valuable spectrum (e.g. beyond 5 GHz for short ranges). Moreover, mesh networks could link different licensed operators, acting as a relay between their frequency bands to carry a single service between different spectrum holders.

Spread spectrum: This term covers a range of very different techniques (Sterling, 2007) some of which have been around for over seventy years and have illustrious inventors (e.g. Hedy Lamarr). The concept is to not use one frequency but many in various configurations to avoid interference at one frequency, or detection, or jamming. Its future impacts for radio telecommunications could be fundamental in that 'direct-sequence' spread spectrum substitutes bandwidth for power, transmitting over a wide spectrum, with low power at any one frequency. A simple form is used in the CDMA mobile system based on military research from the 1960s, and is also employed in 3G mobile, under the name Wideband-CDMA in Europe. Ultra wideband communications (UWB) also fall into this category, although many suggested uses are more towards short range, high data rate usage. Such technologies could use unlicensed bands or if truly successful could use any band, in that they are transparent to other users when suitably engineered. Their impingement on other users is then a legal licence infraction rather than technical interference. For truly successful future spread spectrum systems, regulation of their use of the spectrum could be problematic due to their invisibility, except for failures involving amplified signal strength.

Compression: coding of digital signals in less bandwidth is a common practice today. Reduction of bandwidth required can be significant, as long as there is enough computing power in the terminal device to decompress the incoming signal in real time or near real-time, e.g. for display. Current compression (and fast decompression) ratios vary between typically three and up to 10 times and more, highly significant for limiting bandwidth needs and so the demand for spectrum. Standard protocols such as the MPEG series for graphics and video use compression, as do advanced mobile cellular protocols over the air interface. It comes into its own for high bandwidth applications such as a TV programmes (and for download storage).

[15] The 2006 IEEE 802.11n, high-throughput standard.

Bit rate encoding: one of the major decisions over reassignment of bandwidth is how much would be needed by an operator to provide a complete service. Closely linked to the principles of compression above is the encoding form used for digital signals when transmitted. The number of bits per Hertz of bandwidth is always greater than one, and with modern techniques is conventionally five and can go be as high as 25. The impacts of this are crucial for spectrum reform. It means that a 100 Mbps data stream can be encoded in 20 MHz of bandwidth, for a 5:1 ratio and in 4 MHz for a 25:1 ratio.

1.3.3 Digital dividend opportunities

Political agendas of the main protagonists and their relative political power

The switchover to digital broadcasting is as much a political issue as a technical one. Today, analogue broadcasting dominates the radio spectrum – and is inefficient. It uses spectrum as being free or very cheap. Also it uses a key band – the 470-862 MHz band – optimal for both long range of propagation, which reduces network costs, and for penetrating buildings, for better indoor reception and transmission. Switchover to digital TV from analogue promises a saving of at least 75% of its spectrum, possibly more, which could be freed for other purposes. On the re-use of this 75% currently we see a major division in the EU between the public broadcasters and other commercial users. Broadcasters would like to re-use the entire released spectrum for more digital channels, effectively seeing it as theirs of right. The telecommunications world sees it as a key opportunity, for a mobile industry 'mid-life kicker', and as a chance to close the digital divide in the EU with a fixed radio broadband local loop. The use of the 700 MHz UHF spectrum instead of a 2.4 GHz (unlicensed) or 2.6 GHz band would reduce network infrastructure costs enormously. Cell radii at 700 MHz are more than 100% larger than comparable systems at 2.6 GHz. As a result, the required number of base stations is reduced by more than half. Analysis of a wireless internet service provider (WISP) shows that using spectrum below 1 GHz would need about 1/3 fewer base stations and about 50% of the capital investment of a WISP using the 2.4 GHz or 5 GHz bands (Open Spectrum UK, 2007, p 20). Also, indoor antennas are feasible in the digital dividend's bands, enabling a 'plug and play' solution, whereas at 2.4 GHz or 5 GHz professional installation is typically required.

However, broadcasting is a powerful and influential lobby (see Starks, 2007), which governments do not want to upset – touch TV and you touch popular sentiment. And so the political power of broadcasters is enormous, far greater than that of any other player including the mobile network operators (MNOs). Broadcasters argue that their public service role means that they should not be subject to normal market considerations. However, the real question is not the scale of social value from television but, rather, it is whether the airwaves should be the delivery mechanism when alternatives are increasingly available.

The broadcast paradigm of the past is less relevant to the future because a plethora of other platforms can deliver content: cable TV; satellite; also IPTV over fixed xDSL/FTTH; and Internet media downloads for non-IP TV from the Web. Many fixed line operators are investing in NGNs with broadband capabilities. Mobile TV may appear either as cellular channels or as broadcast elements. Fixed wireless broadband and mobile can carry TV. Note that the lead country worldwide for IPTV in 2007 is France, provided by the incumbent telco, France Telecom, with some 0.5 million users, over its broadband networks.

The case for investment of spectrum in broadcast TV is weak on economic grounds. It will not create as many jobs and wealth as investing in mobile spectrum allocation. New mobile TV, IPTV, etc might even drive display devices more. This would include the content and programming as well as technology for: TV products (media recorders/ players, DVD players and disks, MP3 players, etc); network distribution; cable television, etc. Consumer electronics would continue to flourish with mobile usage of much of the spectrum.

Investment in mobile via the digital dividend would seem to be a more promising way forward for Europe. The mobile contribution to productivity and GDP from investment in telecoms and especially mobile is much greater than anything else (see Table 1).

The outcome will depend on discussions between three parties – the Member States' governments, European Parliament and the European Commission on the one hand, the broadcasters, led by the EBU, and the mobile industry, supported by the GSM-E forum and CEPT. As the EBU and individual broadcasters are increasingly firm over the retention of the spectrum for DTV, the opportunity may be missed.

Impact of HDTV on the digital dividend

Several factors affect the bandwidth needs of HDTV. First, compression ratios and the standards available have become more efficient over time and will continue to do so. Compression algorithms in five years time may be expected to be even better than today, and claims of 10 times better than the first DTV standard, MPEG-2, have already been made for proprietary schemes.

Second, the bandwidth demand required by uncompressed HDTV is also a moving target, with estimates of broadcast spectrum required varying with technology, image resolution and time, from 6 MHz up to 20 MHz. Thus claims on bandwidth for HDTV should be treated with some care. Bandwidth required may be set at arbitrary, possibly exaggerated; levels that may not be necessary in future even for the maximum image resolution as technology progresses.

It should also be noted that platforms other than DTT (such as cable or satellite) may be better suited to DTV and HDTV especially. Furthermore, broadband communications to the home (e.g. via radio local links, or fixed) can deliver streaming channels of HDTV, as IPTV or in its original HDTV format, as well as Internet and voice communications. This would reduce the need for broadcast, generally, and broadcast HDTV.

The above implies that with four HDTV channels per analogue channel, the digital dividend could be around 75% of the approximately 390 MHz analogue spectrum, i.e. some 290 MHz[16]. However this figure may be disputed in the knowledge that a future expansion of the number of possible HDTV channels may be expected, as technology advances, if more bandwidth is reserved now for broadcast, and bandwidth per channel shrinks. Arguments that this is needed because the technology is not yet that efficient should be treated with care.

1.4 Flexibility v harmonization and implications for authorization

1.4.1 Flexibility in authorization desired by Member States

The two basic options are a centralized EU level regulator for spectrum and the current system devolved to NRAs. We now consider each case:

The case for delegation to Member States: The case rests on the concepts that the current system works well. The regulators under the European Regulatory Group (ERG) claim to co-operate constructively and are sensitive to encroachments[17].

In many areas they may be correct, such as implementing universal service, or addressing VoIP, although often following common guidelines from the Commission. In some areas such as international roaming charges they did little, however. Perhaps too few are really politically independent, either from governments and/or industry incumbents (fixed or mobile).

[16] This is confirmed in a recent report for Ofcom (ZetaCast, 2007).
[17] See Richards, 2007, and also response from the Commission (Turton, 2007).

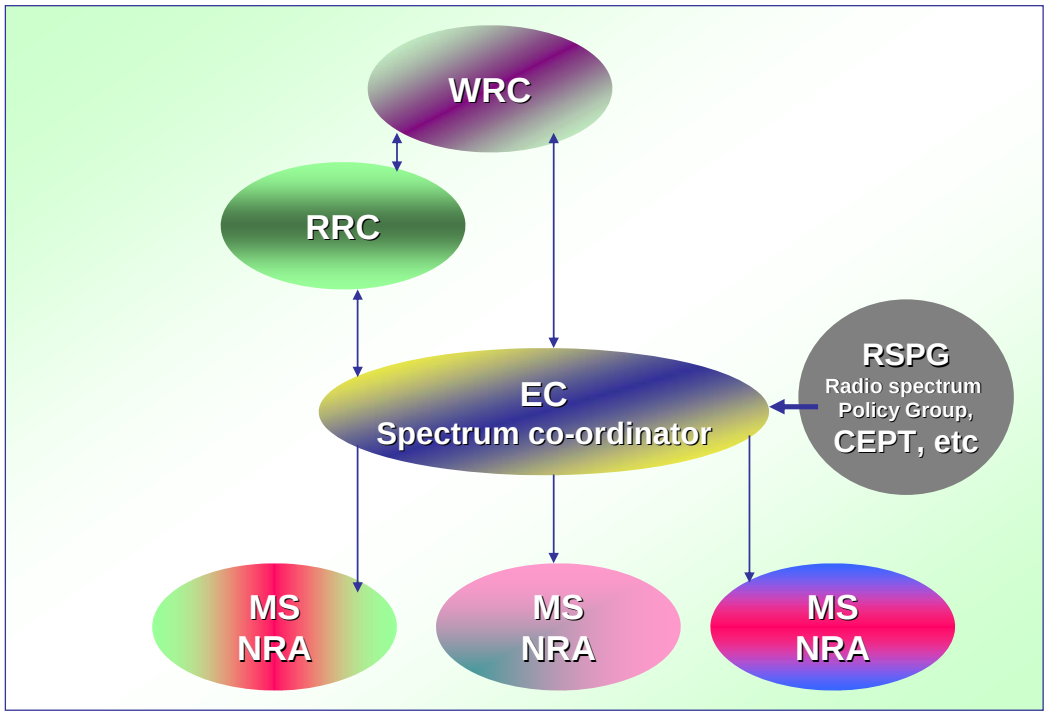
The case for strong harmonization: For radio-based e-communications, a single market would bring the fruits of common pricing, numbering plans, perhaps higher competition and lower prices in services and handsets. From the consumer and business user point of view it would simplify travel and use of services if there were no patchwork of regulations. For common EU emergency services, it would also be advantageous for cross-border working, volume production of equipment etc and compatibility in accessing other ICT resources (e.g. databases of hazardous goods).

Moreover the non-interference model of spectrum usage requires a strong central manager to agree bands across the EU, especially in a market-based system. Here, spectrum rights holders may be of quite different sizes and so will have varied economic and political power – the smallest may get squeezed (out). Independence and transparent rule would be essential for any centralized body but ensuring this is the case is likely to be challenging.

1.4.2 Possibilities for median solutions

What does the median solution imply and what are the potential options? An overall approach may be to use the RRC and WRC to negotiate major guidelines (see Figure 5).

Figure 5: A median solution for a regulatory structure



The European Commission might then set the framework for harmonized bands across the EU within the regional agreements, including unlicensed bands. The commons model would give the maximum freedom in authorization of various usages of spectrum in each Member State – unlicensed bands are the most useful in terms of flexibility and authorization, which would be at a level of technical conformity. Thus political median solutions could turn on technical parameters.

Within the agreed bands, the NRAs then assure the discipline of local users and police conformance. This would place the EC in a coordinating rather than a policing role, which may well suit it best.

Flexibility and the concept of the spectrum commons

Service flexibility will give the chance to let the market decide on which part of the spectrum is used for what. Moreover, technical flexibility does not exclude the possibility of harmonising frequency bands and standardising technology.

However, it leaves the harmonization of services (and frequency bands) and standardization to the market. It is still unclear today as to whether markets will lead to efficient use of spectrum. Their real openness is obscure, as is the market knowledge of potential players.

On the other hand, reduction of technical constraints for greater flexibility may facilitate the evolution of novel e-communications or broadcast technologies from one generation to another. For example, allocation of spectrum for digital broadcasting without specifying the technology makes it possible to improve transmission techniques without delays for regulatory decisions at each stage. What is needed is a balance between a potentially highly regulated new world of more complex spectrum sharing and the ideal of no regulation. The latter case is where the unlicensed commons has much to offer. We now look at these options:

Collective use

The technical summary (section 1.3.2), briefly reviewed the collective use of spectrum via CR/SDR technology in the sense of interleaving, low power overlaps and borrowing when no one else is using the frequencies in licensed bands. The collective approach provides a clever way of living with the existing, without disturbing it too much, although some existing users may be perturbed by the concept of temporal or frequency interleaving and borrowing, even under regulated market (paid for) conditions. This approach is also highly relevant for short-range applications. But it does not go as far as what may be required for the enormous expansion in radio-based applications we can expect over the coming decades.

Significance of the spectrum commons in regulatory and innovation terms

As noted, the present regulatory framework for radio spectrum management needs to be revised for new technology. Shared spectrum in a commons could provide far more users with access, with many different services and at minimal cost in that no spectrum licence fee is paid – the computer industry model. Different uses would be able to share the same spectrum, effectively overlapping, combining the flexibility of advances such as CR/SDR with new techniques for spread spectrum.

This is a far more flexible approach than a licence to use spectrum. It draws on usage privileges that do not presuppose ownership but a universal communication right instead. It simplifies regulation enormously. Such a regime also allows freedom to innovate within technical limitations on interference. The commons approach refocuses wireless regulation away from the ether as scarce transmission medium and towards the devices used for communication. It rests on a more forward-looking, non-discriminatory spectrum management, which is effectively passive. It thus encourages innovation both in the underlying technology and in content of all kinds, through the freedom in carrying content.

Implications for the future European economy

In such a situation, with part of the spectrum freed for unlicensed use, competition could thrive between mobile and other actors and technologies in these unlicensed bands. This assumes that new technology for overlapping usage is developed and takes off across global markets, not just the EU, to give the pricing of volume production.

Strong competition could then ensue in every sector – TV/radio, mobile, etc – but the range of applications may increase. Market forces with no obligations on operators to conform to market and service definitions for radio spectrum use and conditions of operation (e.g. coverage and bandwidth definitions) would result in advantages for all end customers, removing market distortion by powerful incumbents. Operators would have greater freedom to introduce innovative services. Greater competition would drive universal coverage of new services, such as mobile broadband, avoiding ‘cherry-picking’ of dense urban sites which increases the digital divide. Such a scenario of freedom of use fits well with mobile as the broadband gateway to Internet services.

This would give a major incentive for European software developers to produce applications and utilities and leave behind the fragmented mobile application and network world of today.

1.4.3 EU wide recommendations on spectrum management

Key recommendations

The proposals set out by the Commission meet some goals that will generally be beneficial for Europe, but that there are some gaps, so that we recommend:

- More centralization of decision making could make sense, especially to assure harmonization by ensuring that Member States follow guidance on neutrality at technology and service levels. This would also ensure flexibility rules in assigning uses are followed. An orchestrated solution for Europe would help to implement the rebalancing of DTV, military, satellite, public services, merchant marine and civil aviation, against mobile e-communications for consumer and industrial purposes.
- The concept of market approaches to allocation should be taken seriously, but as one possibility among several. In some cases, markets may be a temporary mechanism and/or of limited application. The technology now under development will change the sharing possibilities. Governments may prefer auctions as a way of generating taxes while the market mechanism gives a veneer of liberalization. But real stimulus to the economy may come from free spectrum, both in ease of use and cost with newer technology. Competition rules would have to be applied to markets to prevent hoarding, and might have to be streamlined for rapid action. So instead of just markets, wider unlicensed bands at lower frequencies (400 MHz-1 GHz) would enable the establishment of a commons for new long and short-range technologies and for far more innovation, brought to market rapidly. The ISM band (Instrumentation, Scientific and Medical) band could become part of a larger set of commons bands.
- The digital dividend should be used primarily for mobile and radio communications technologies rather than terrestrial or satellite DTV, as it will bring far greater economic leverage for the EU. Part of this could form the commons. The question then posed is how much should this be – the better the sharing technology, the less is needed. But if all technology progresses in this direction over the next few decades, switching over from legacy radio technology would indicate a progression of steps in wider bandwidth, rather than a single big bang. The digital divide could also be addressed by mobile usage of the spectrum especially in rural areas, and wherever development of broadband services is still hindered by limited infrastructure competition.
- Bandwidth should also be earmarked for new collective emergency services for the increasing rates of natural disasters (floods/fires) and man-made (radio-active and chemical leakages/petrol terminal explosions/ terrorism) enabling ad hoc networks to be set up as well as European level networks involving all emergency services, hospitals, disaster centres, etc. Here the notion of equipment using the commons comes into its own as the most flexible way forward for coordinating nomadic, mobile and fixed resources. EU sector policies already act here and should be coordinated, including Public Protection and Disaster Relief (PPDR) for cooperation in civil protection, Galileo positioning satellite for navigation, under a ‘Single European Sky’ and GMES (Global Monitoring for Environment and Security) the core environment and security programme.

2. THE PAN-EUROPEAN SERVICES QUESTION

2.1 The concept of pan-European services

2.1.1 Services across Europe

Concepts

In examining the future of Europe in terms of its spectrum use, the anomaly that crossing a border implies new uses of spectrum is fast becoming questionable. National services are the norm today even for spectrum uses which have a common baseline agreement – such as the 900 MHz and 1800 MHz mobile cellular GSM bands, as national borders rule for implementation of the services. Thus the concept of a single common set of services across Europe is increasingly attractive.

This concept can be seen in two alternative lights:

- First, the need for common *spectrum uses* across the EU, for instance for new e-communications services such as MSS (Mobile satellite services) and mobile communications from aircraft (MCA). This is the conventional view of pan-European services. There may be less opportunity for common terrestrial and broadcast services from one provider across Member States due to language barriers. However standardization of frequency bands for DTV and satellite in technical frequency terms across the EU will become necessary to enable other spectrum users to operate EU-wide services. These are subjects under discussion in WRC-07, and subsequent conferences and will also be a future Regional Radio Conference (RRC) item. Note that certain e-communications and also TV (entertainment) services might be delivered via a broadband fixed wireless local loop not just a mobile network and this will also require considerations for a harmonized approach. The current bands already reserved internationally for WiMAX and the unlicensed spectrum for WiFi are a starting point here, with re-use of UMTS (3G mobile) bands.
- Second, as a common pan-European *implementation of services*, possibly only the most important e-communications services, rather than national varieties. This would apply primarily for mobile services but could also to some extent be for broadcast terrestrial and satellite TV entertainment (if copyright restrictions on the content allow international coverage). This will enable provision of a pan-European network of information services, which will become more important in the future as mobile Internet access ushers in a range of new radio-based usages.

Impacts

The impacts of current national orientation are fragmentation, effectively bringing total market size down to national level for mass consumer services. This gives operators the chance to extract new scarcity rents for their services, while limiting their market reach in some cases. One instance of the manifestation of such inefficiencies is in the excessive international roaming charges for the EU, which the European Parliament struck down in its near unanimous Plenary vote in May 2007. Fragmentation in spectrum usage by Member State means that adopting new EU-wide uses for any part of the spectrum is long, painful and costly.

For mobile services, crossing a border means changing to new numbering systems, new charges, new ranges of services on offer and even in some cases, new user interfaces for advanced services, all of which tends to limit take-up.

Building a single market for radio-based services is thus limited by the regulatory regimes, which the NRA largely decides on. So, interestingly, some national regulators may not see the need for an EU-wide approach as much as end-users.

Requirements

Such a concept requires Europe-wide agreements by all Member States on common uses of spectrum not just for those services that touch consumers but for rebalancing the spectrum across all the types of users, especially military and public services. This would mean not just collective EU agreements for civil marine and aviation uses, as we have had for over sixty years but also for emergency services and most difficult, military.

For the market-based approach to spectrum management, it might introduce the concept of a new type of licensing that covers multiple, adjacent Member States, and may even be EU-wide for the first time. This would tend to displace some of the current licensing for commercial mobile and broadcast service on a national basis – some TV satellites with overlapping footprints effectively do this. It would tend to overturn current spectrum licensing regimes, which enforce national territorial markets.

For this to happen inter-government agreements on licence fee sharing would be required, a minefield that might profit from some central guidance – perhaps an EU framework of fair-to-all financial rules. It also introduces the principle of the use of auctions at EU level to award spectrum for pan-European services – for instance an immediate candidate might be a pan-EU auction to award spectrum for the new service proposed at 2 GHz for Mobile Satellite Systems (MSS). However, removing a national tax harvest and installing a shared EU scheme may well be as problematic as changing the traditional scheme and its players' attitudes: it would be quite difficult.

It also raises the question of an EU-wide regulator to manage and monitor EU-wide services and spectrum alignments. But this may only become necessary if agreements at NRA level are impossible to reach effectively, so that either a 'light touch guiding hand', or alternatively, a strong regulatory body is seen as necessary to effect change.

Use of pan-European services at EU-external borders

With coordination of Member States more as an EU entity, the EU will slowly form a sizeable block of common spectrum uses, which neighbours may wish to join. Certainly at the outset of a spectrum replanning exercise for common EU spectrum policies and usages, the impacts on neighbour states should be evaluated. In general, there are two reasons for the neighbour states to be interested in a changing EU regulatory regime and its spectrum assignments:

- Interference with their existing services due to signal coverage overlap beyond borders, interrupting national services, perhaps owing to new frequencies and higher signal powers being used, especially for mobile services. The impact may occur up to 20 km or even more into the neighbour state, depending on technology and frequency of propagation.
- The arrival of pan-European services, which might be of interest to neighbour states. They may have a wish to benefit from pan-European services, especially if they offer cheaper international rates and more advanced services. This is more likely to be the case, wherever there are strong trading ties (e.g. Norway, Switzerland, accession states to the EU such as Croatia and Turkey, some of the former Soviet republics, and North African states such as Morocco).

Naturally the existing international regulatory bodies should be the fora for discussion and resolution of theses issues. Thus there are two major policy options:

- Bilateral agreements, which are effectively commercial deals, extending pan-European services using carriers on either side who agree to reciprocate on relaying services. Networks could either be at different frequencies for the same service, or the neighbour state could revise its spectrum assignments. For users, this would mean either that common spectrum agreements on assignments must be in place beforehand, or multimode handsets are made available, probably mostly in the neighbour state.
- Or, negotiations on interference resolution and/or for pan-European services extension may occur through the Regional Radio Conference, and also perhaps the ITU (WRC series). A single agreement with all neighbour states at once would be optimal, if at all possible. As always this depends on the willingness of neighbour states to act in concert.

2.1.2 Service provider types and opportunities

Market contexts and types of service provider

Tomorrow, if trans-EU services become the norm, then the build-up of supra-national operators offering common services across all Member States could become more likely – if licences became available on an EU basis, a seemingly unlikely premise today for the reasons given above. But it could introduce a new type of MNO – truly integrated across Europe – rather than separate licences and services by Member State. It would remove the handover between mobile service providers and the accompanying series of financial and technical changes between national territories.

Opportunities across the EU for service providers

Thus the commercial context could change from national-only coverage to multi-Member State, up to EU coverage, for all types of commercial radio services. Trading could also introduce arbitrageurs, depending on licence resale rules. If secondary trading of spectrum received a common EU–wide set of rules, or even light guidelines, then their market in buying and selling spectrum could well expand. Special interest vehicles, perhaps financed by those with excess capital such as private equity players, may appear as such a business is essentially capital intensive.

The major markets that could evolve in such an EU-wide eco-system would be of several types. Primarily there would be markets in value added mobile services, as explored further below, and second would be provision of the content for such services. The model for such a mobile market could be the Internet but transcribed into the mobile world with users able to access mobile-enabled websites for transactions, entertainment, communications, navigation, etc, and perhaps even services with social value such as health and education.

Impacts of new services in economic terms

The impetus of mobile working could act as a strong catalyst for the EU economy owing to the externality effects of its workings on all sectors of the economy. Table 1 showed the various impacts which could produce a progressive increase in the EU economy driven by the mobile productivity factor of an estimated value of €330 billion by 2020.

2.1.3 Selection process and authorisation of pan-European services

The selection process for pan-European services must come from the market – it is not for the EC or the NRAs to define commercial offerings. Governments have a poor track record picking winners in a fast moving commercial market.

However, there may be a role in applying certain attributes for efficient market operation such as:

- support for a Europe-wide numbering scheme for mobile services
- setting limits on common call termination charges between carriers, especially where a distorted market may arise
- assuring common tariffs across Europe for pan-European services (i.e. they do not differ by Member State), which could also eliminate supplementary roaming fees – the inter-operator termination charge for interconnection would be all that would be required
- assuring privacy and security measures for such services are implemented.

Authorisation of pan-European services could well be a discussion between regulators at EC and NRA level:

- to authorise EU-wide operation by assuring that the bandwidth required is available in order to operate
- to assure that there is competition in this market segment.

However, against this is the argument that assuring that there is competition poses a dilemma, as perhaps no other offering will be made. Thus the alternative seems preferable, that pan-European services are entirely market-driven. There is no interaction by the regulator in their authorisation per se. The regulator's role is passive because the market decides.

The key issue associated with a passive role for the regulator is that spectrum may not be assigned and there are several options here, shown in Table 8.

Table 8: Options for spectrum allocation for Pan – European Services

Option	Advantages	Difficulties
Reserved bands of licensed spectrum common across all EU Member States	Licenses can be auctioned (or beauty contest- less desirable for a healthy market)	Difficulty of arriving at agreement on specific band - long term negotiations may be required (2-5 years), especially if at RRC and WRC levels also Difficult for new services and entrants to enter if all taken Entry process for new service may be lengthy
Reserved band of unlicensed commons across all EU	• Easy to enter • Easy to start new service • Fast entry once set up	Difficult to get agreement on specific commons band Must have strong rules on technical specifications over interference

2.2 Types of services and their requirements

2.2.1 Overall classification

Main types of services today and tomorrow (to 2020)

A study for the Commission on future mobile services and markets (Forge, 2005) looked at applications for consumer and business (i.e. civilian) radio-based services at the level of needs, most of which could fall into the pan-European category. It then converted them into demands for spectrum by analysing their content and network characteristics, with the aim of mapping them to the ITU traffic classes for the WRC-07 deliberations. The study identified over 130 services including internal mobile operator services, which could be formed into about 30 sub-groups. The sub-groups formed components of a super-group. Traffic figures were deduced from these using a statistical measure of the most commonly occurring bit rate. For application services the major super-groups were identified as being:

- Communications and enabling services (i.e. used within other applications, or standalone, such as search, or navigation, or message generation).
- Entertainment.
- Lifestyle support including e-government services to citizens.
- Business services, including m-commerce based trading and public sector services.
- Operators' business support services.

Many of these services could be supplied to a fixed location – either to a mobile terminal such as a handset, or to a fixed transceiver in home or office, over a wireless local loop. In both cases, use of the radio spectrum is called for.

Rise of new categories

One major area for future services is between non-human communicants, i.e. communications and mobile services aimed at sensors, servers and robotic or automated machines to carry out some task, now sometimes referred to as the 'Internet of things' (ITU, 2005). It is especially driven by the use of RFID devices attached to mobile objects and their sensor networks. This has widespread application in health care (Srivastava, 2006) and elderly care as well as logistics and physical security. Wireless LANs in general are expanding in use and bandwidth also from slow rates for data monitoring to video speeds for surveillance. We are now in an initial phase of fairly simple goods tracking in logistics networks and retail. In a second phase, a far more complex radio infrastructure may be used, driving machine to machine communications both in the business sector (especially industrial process usage) and in the consumer segment (smart home/domestic devices and entertainment centres).

Further areas for progress are extensions of existing mobile services with richer and more focused uses, often depending on the mobile Internet. These include location-enabled applications, dependent on location-based services (LBS) which use satellite geographic positioning systems (GPS), or some form of base-station triangulation. We now look at certain categories in more detail.

2.2.2 Lifestyle services

Concept

Lifestyle support includes all those service whose advantage is in ubiquity (such as m-commerce transaction consumer services) to support a richer lifestyle, especially for those who suffer from time poverty.

These services may well be used more by those balancing several worlds, of family, employment and organization of their personal life, and so may well appeal to women more than men in making everyday life more convenient and safer. The move towards lifestyle services using wireless communications such as m-commerce and m-banking will only become widely taken up services if *secure* wireless communications can provide a trusted transaction environment for the consumer. All such sophisticated services would benefit from EU-wide markets for both investment in the quality of the services and the potential volume of sales.

Major services

Major types of services in this category could include[18]:

- Physical security and protection.
- Lifestyle organization including identity and data security.
- M-commerce and m-banking.
- Personal financial and insurance services management.
- Location enabled applications such as location and navigation.
- Specialised needs for the disabled, with targeted lifestyle support services, including smart home (*domotique*) services – surveillance, commands and alerts for interworking for domestic appliances, entertainment centres and security centres.
- Health for the citizen.
- Education – distance learning and supports for education – may require broadband, possibly via mobile or fixed local loop.

2.2.3 Business services

Concept

The business use of radio is not new, i.e. use of radio-based services to enhance business productivity, through mobility, and so create new business processes and whole new business models. Analysis by numerous researchers on the firm's productivity with mobility has highlighted the major advances that can be made (Maliranta et al, 2006; Aral et al, 2006). The advantages of having common services with standard user interfaces EU-wide, identical costing, naming and addressing across all Member States will both aid users and make sales by suppliers easier. Pan-European access creates a far larger market for business models that might not work on a set of national scales varying from the very large to the tiny.

Major services

Major types of services in this category could include:

- Business-specific communications and applications access, use of mobile access to databases and key applications, mobility based business processes, e.g. on site house survey reporting, remote insurance assessments, warehouse operations, etc.
- Ubiquitous office functions – mobile email, mobile videoconferencing, etc.
- Business transaction applications (with some form of customer interface).

[18] For a detailed breakdown of the component services for each service type, see Appendix C to the FMS study report (Forge, 2005), at http://fms.jrc.es/pages/documents.htm

- Business infrastructure services including machine to machine and logistics.
- Business training programmes.

2.2.4 E-government, other public and emergency services

Concept

Most e-government services in place depend on a user interface with an Internet-connected PC. However, if such services are to become a standard part of every citizen's life, then a more ubiquitous interface is required. With some 400 million mobile handsets in the EU today, the lesson of Japan – that the mobile Internet is the major mass platform for Internet access – indicates its ubiquitous appeal. Future applications of spectrum use could include many government interactions for citizens, from paying taxes to voting. They would benefit from having a common EU root design, especially for an intuitive human interface and templates for national variations (e.g. local tax systems). The concept depends on the services' security levels and their perception, to gain the users' confidence for transactions over two hazardous environments – the air interface and the Internet. It also needs MNOs to offer open Internet access, not just 'walled gardens' of their own mobile Internet products.

Main types of services expected across the EU

Major services in this category could include:

- Voting with authentication, using some form of identity code with biometrics.
- Tax and registration forms processing and follow-up.
- Central government national and local government alerts.
- Access to local government services for community services, policing, education, jobs, disabled support and social services, town planning, etc.
- Calls for tender for publicly financed projects with all communications with bidders.

2.3 The demand side

2.3.1 Consumer demand for services, today and tomorrow

The hierarchy of need

To understand future uses of spectrum we should first examine real underlying needs by looking at the demand side, with a socio-economic approach[19]. Disposable income determines consumption – what is bought and how it is bought. Failure to understand the real utility to the user of a service, combined with affordability and accessibility, has led to too many errors in estimating demand for telecommunications services in the past. Too often, a technocentric view of new communications services has resulted in demand being vastly overestimated – or underestimated. Thus while some of the biggest product launches in communications services over the past 20 years have failed, seemingly trivial services have exploded. For instance, forecasts for the take-up of wireless access protocol (WAP) for mobile web access to rich data services were greatly overestimated. By contrast, the impact of a simple radio-based service, SMS, was greatly underestimated and was largely unforeseen by the industry.

[19] Demand for services by a needs analysis is examined in detail in the final report and especially the Appendices in the Future Mobile Services study, available at: http://fms.jrc.es/pages/documents.htm

We should also note that in wireless services, a regional market such as the European Union will be increasingly shaped by a global market. In 2020, there could be of the order of five billion mobile users, shaping technology, services, content and pricing.

In estimating consumer demand it may be useful to employ tools such as the hierarchy of need (originally due to Maslow) which implies the basics such as security come first in consumer demand, followed by lifestyle support for convenience of organization and entertainments last. This would indicate that entertainment services such as DTV come after more primary needs such as work and personal lifestyle organization, so that demand for such support services is likely to be high. This has been verified somewhat with the take-off of mobile generally, first as a business service, from 1995 in Europe. It has been also driven by pricing – the efforts made to ensure that it is widely affordable via pay as you go schemes, for example, that have made Italy and Portugal early leaders in penetration of mobile services – because disposable income limits were met.

Changing needs, changing services

What we see as necessary today was not even considered as part of our lives 20 years ago – our mental model of use of radio-based services dependent on spectrum has moved on considerably since then. For instance, consumers increasingly demand services that they can use when they travel wherever in the EU or overseas. Equally, the telecommunications industry would like and benefit from similar common rules of engagement and a level playing field for competition across the EU, while profiting from a larger market for each service. There is a demand for a more harmonized, liberal approach to spectrum management, which will enable the mobile industry to create those pan-European services that are in demand.

2.3.2 Business demands, today and tomorrow

The business use of radio

Business and public services will expect to expand their use of the radio spectrum over the next twenty years. First there is an industrial explosion in needs for radio communications services in enabling technologies for novel business processes, be it in managing whole container ports to tracking patients inside a hospital and assuring correct treatment with links to the patient administration system, to replenishing supermarket stocks on shelves. Globalization of business will drive innovative uses of radio, being a major factor in mitigating some of its more difficult impacts. Migratory work, working across time zones and maintaining business continuity, with videoconferencing, messaging and document exchanges as well as access to key applications that may operate the business remotely (e.g. a customer or a production database) will be the main drivers. Access from home or the other side of the world will increasingly use some form of radio-based access, for nomadic or mobile working and increasingly there are pressures for this to be broadband access.

Main trends in future usages

More vertical applications may be expected while general usage across factory areas, offices, public areas such as meeting and conference centres usage expand with radio LANs. New ways of organizing work will be based on mobile working, especially as physical transport becomes more expensive both in environmental terms and in the cost of time consumed in travel such as commuting.

Although metropolitan area radio and expansion in rural radio local loop broadband for e-communications may be thought to be the major trend to overcome the digital divide, short range uses will also be important to form a connectivity infrastructure at close range (1–10 metres especially for consumer ICTs) and may be an equally important growth area, to cellular-type ranges of networking.

Successors to WiMAX for broadband will only appear if the spectrum is available. This tends to imply unlicensed bands rather than licensed (e.g. as in the recent decision to allow WiMAX operations at 3G UMTS frequencies) as it takes so long to assign licensed bands. Moreover more flexibility in spectrum assignment is needed to launch new radio technologies. Only unlicensed bandwidth gives this freedom. This implies the model of 'passive regulation', of the device being enabled to use radio technology by the manufacturer, rather than an operator being licensed to allow users to connect.

2.3.3 Converging business/ consumer demands in new lifestyles

Concept

A major premise now changing much of European society is more flexible working with mobile, nomadic and remote teleworking. Moreover we have growing communities that socialise over the Internet. The ideal of juggling several social and work worlds will come to even greater importance as the workforce becomes more equal in gender so that women move higher up the scale of management in all industries and require the communication tools to support family and working lives. Thus social forces will drive a melding of business and lifestyles. Radio is an essential tool in this social development.

Converged services and their implications

Converging work, social functions and entertainment into one environment, and perhaps one device could enables access to any service from anywhere. This does require reasonable bandwidth, to accommodate Internet access and is more than is currently available. Either a re-apportioning of bandwidth or the use of new sharing technologies may become far more necessary in a future Europe. The chosen spectrum should also offer good penetration of buildings. This makes spectrum refarmed from the digital dividend ideal, in the frequency ranges from 800 MHz down to 500 MHz or lower. Their propagation range is also especially attractive for a low cost infrastructure.

2.3.4 Overall spectrum demands, for current and future services

The main mobile application-level services outlined above have different spectrum demands.[20] Some of these applications are quite different to conventional cellular mobile communications, e.g. sensor networks for the Internet of Things and short-range devices including near-field communications with a range of under a metre.

To these future mobile services must be added other current users – broadcast, military, civil aviation, civil emergency communications, marine uses, etc – but perhaps in new forms. Such advances include the digital broadcast services for TV and radio, DAB and DTV as well as digital satellite services for broadcast TV. Delivery channels for mobile other than terrestrial are also here – specifically mobile satellite services, probably using low earth orbit satellites (LEOs). Spectrum bandwidth requirements for uses other than TV and mobile – military, etc – may take up to half of the total in certain prime regions of the spectrum, e.g. from 200 kHz to 1 Ghz. Reducing their generous allocations and moving them to newer (digital) technologies (e.g. for radars, navigation beacons and radio direction finding) may reduce their bandwidth needs to perhaps 30% of the prime spectrum regions.

[20] See Appendix C to main FMS for definitions, technical attributes such as bit rates and type of communications (e.g. voice, video, data file etc): http://fms.jrc.es/pages/documents.htm.

2.3.5 Spectrum bandwidth requirements for current and future services

Analysis of requirements by future service type for bit rate (and so bandwidth) is shown in Table 9. The relation between bit rate and bandwidth depend upon the coding type, which may be between 5 bits per Hz, and for the latest technology, over 25 bits per Hz, so that the bandwidth required in Hz is the bit rate divided by that factor. However, as the air interface is unreliable and may require resends, and data packets may have high overheads, net throughput will be lower.

Table 9: Future services demands for spectrum in terms of ITU bit rate classes

Service class	Total	<16 kbps	<128 kbps	<384 kbps	<2 Mbps	<10 Mbps	<30 Mbps	<100 Mbps	Un-specified
Communications and enabling services	17	3	3	5	5	1	0	0	0
Entertainment	31	1	2	14	9	5	0	0	0
Lifestyle support excluding e-Government	44	1	15	10	16	2			
e-Government	9		1		7	1	0	0	0
Business services, including m-Commerce	27	1	7	3	14	2	0	0	0
Operators' business support services	4	0	3	1	0	0	0	0	0

Source: Forge (2005), Appendix C, http://fms.jrc.es/pages/documents.htm.

Most future mobile services will need a link with a bit rate that is less than 10 Mbps, good news for operators fearful of multiple users demanding enormous bandwidth all at once. The impacts of future compression algorithms should also be considered, especially for rich media (e.g. those in the MPEG series) which may even reduce the required bit rates and spectrum demands further.

This implies that mobile broadband for future common services across the EU is viable, with cost efficiency, if a swathe of common bandwidth is made available, be it a commons or in licensed bands across all Member States. With no sharing of spectrum, as in a licensed model, these bit rates would imply at least 10 to 20 MHz per mobile operator or radio local loop operator to supply broadband to multiple users. With shared spectrum using new technologies, this could be an unlicensed band. Here, providing mobile Internet over a broadband bearer will become a prominent demand and the ideas of spectrum usage for IP services at low cost, currently entertained for WiFi and perhaps WiMAX, should be considered more generally.

3. LEGAL CONSTRAINTS AND REGULATORY LIMITS

3.1 Introduction

The achievement of a more coherent spectrum policy in the EU crucially depends on whether proposed new measures at community level would be hampered by legal constraints exerted by legislation and commitments at the international, regional and national level. In this chapter we illustrate the features of the existing EU framework and its existing rules at all these different levels. Section 3.2 surveys the current status of EU legislation, by describing the main objectives of EU spectrum policy, the complex architecture of decision making and the most recent initiatives undertaken by the European Commission in this field. Section 3.3 summarises the existing constraints in flexibility and technology/service neutrality as provided by international agreements, including the GE-06 agreement and the Maastricht Special Arrangement (MA02). Section 3.4 contains a brief description of the legal framework and potential obstacles to spectrum reform in EU member states, and focuses on four national experiences, i.e. Italy, Romania, Sweden and the UK. Section 3.5 provides some concluding remarks.

3.2 Current state of the legal framework

3.2.1 Introduction

Until the end of the 1990s, spectrum rules were mostly defined at national level, with member states coordinating their spectrum policies in international fora such as ITU and CEPT. The development of a coherent spectrum policy had not been a policy priority at EU level until 1998, when the Commission adopted the Green Paper on radio spectrum[21]. However, already in the late 1980s initiatives had been adopted to harmonise some frequency bands, including: (i) *the 1987 GSM Directive*, which reserved the 905-914 and 950-959 MHz frequency bands for a public pan-European cellular digital mobile communications service starting from 1 January 1991, and paved the way towards the extension of this service to the whole 890-915 and 935-960 MHz bands[22]; (ii) *the ERMES Directive in 1990*, which required Member States to designate in the 169.4-169.8 MHz radio spectrum band four channels for the pan-European land-based public radio paging service; (iii) the *DECT Directive*, which required Member States to designate the frequency band 1880-1900 MHz for digital European cordless telecommunications by 1 January 1992[23]; (iv) the Resolutions adopted by the Council and the European Parliament on *Satellite Personal Communication Systems* (*S-PCS*) in 1993 and 1995[24]; and (v) measures undertaken to ensure the coordinated introduction of a third-generation mobile and wireless communications system (*UMTS*) in the Community, which secured the availability of sufficient spectrum as allocated by the ERC to the frequency bands 1900-1980 MHz, 2010-2025 MHz and 2110-2170 MHz[25].

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[21] COM(1999)596.
[22] Article 1.
[23] (Council Directive 91/287/EEC of 3 June 1991).
[24] The EP in its Resolution of 19 May 1995 on mobile and personal communications considered it a priority objective to establish a harmonized licensing approach for satellite-based mobile and personal communications and, on that basis, to initiate procedures for licensing such systems at an early stage; whereas, according to that Resolution, that approach should have been implemented by 1 January 1996 in order to take account of the rapid development of such services at global level and of their potential in both social and commercial terms.
[25] On 30 June 1997 the ERC adopted Decision ERC/DEC/(97)07 on the frequency bands for the introduction of UMTS which entered into force on 1 October 1997.

In addition, *Commission Directive 96/2/EC* extended the application of Directive 90/388/EEC to mobile and personal communication services, thus opening them to competition between industry players[26]. Some of these initiatives were successful (e.g. GSM and DECT); others were not (ERMES).

After the 1998 Green Paper on spectrum, the first step adopted at EU level was the harmonization of technical requirements to telecommunications equipment, achieved with the *R&TTE (Radio and Telecommunications Terminal Equipment) Directive* in 1999[27]. The Directive defines the essential requirements that products must meet (including the obligation to avoid interference) and the procedures manufacturers must apply to place products on the market, in line with Directive 98/34 and thus through a conformity assessment procedure and CE marking. The R&TTE Directive includes some elements of flexibility by: (i) establishing a co-regulation mechanism which gives market players the possibility to influence harmonized standards, thus taking account of new technological developments; and (ii) allowing products to be placed on the market where harmonized standards are absent, or using technologies other than those contained in harmonized standards, provided that the essential requirements – including non-interference – are met.

After the R&TTE Directive and the '1999 Review'[28], the 2002 New Regulatory Framework (NRF) for electronic communications networks and services created a regulatory framework that enabled the development of a more coherent radio spectrum policy for the European Community:

- *Articles 8 and 9 of the Framework Directive* laid down principles for the use and management of radio frequencies for electronic communications services, and refer to the promotion of 'efficient use', harmonization and effective management of radio frequencies with allocation and assignment, based on objective, transparent, non-discriminatory and proportionate criteria. Article 9 states that member states may make provisions for undertakings to transfer rights to use radio frequencies, and ensure that the authority responsible for spectrum assignment is notified of planned transfers. NRAs shall also ensure that competition is not distorted as a result of any such transaction.
- The *Authorization Directive* specifies the essential requirement of avoiding harmful interference: such requirement may justify an exception to the general rule that spectrum use should be only to conditions included in general authorizations to provide services or networks, not to individual licences. The Directive also imposes obligations upon member states on the rights of use for radio frequencies and conditions which may be attached to such rights; it defines the procedures for limiting the number of rights of use to be granted for radio frequencies, and regulates the imposition of fees for these rights.
- The EU *Radio Spectrum Decision* shapes the current architecture of decision making by establishing a cooperation mechanism (Art. 4) which allows the EC to issue mandates to CEPT on the harmonization of frequency use and to make the resulting ECC Decisions mandatory for all EU member states[29].

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[26] Directive 90/388/EEC provided for the abolition of special or exclusive rights granted by Member States in respect of the provision of telecommunications services, but originally did not apply to mobile services. Directive 96/2/EC was preceded by a Green Paper on Mobile and Personal Communications (COM(94)145 final).

[27] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (OJ L 91 , 07.04.1999, pp. 10-28).

[28] COM(2000)239.

[29] Decision on "A regulatory framework for radio spectrum policy in the European Community" (2002/676/EC).

In order to secure efficient spectrum use, the Radio Spectrum Decision provides for the publication, in appropriate databases, of national radio frequency allocation tables and updated information on rights, conditions, procedures, charges and fees concerning the use of radio spectrum.

3.2.2 Objectives of EU spectrum policy

The EU spectrum policy pursues three main overarching goals:

- to support specific policy objectives by ensuring the timely availability of sufficient harmonized spectrum in the EU;
- to contribute to growth, competitiveness, employment and inclusion;
- to pursue EU-level coordination and thus help achieving the internal market for e-communications.

A study conducted in 2004 estimated that even if Member States individually took the most appropriate action to modernise their spectrum management, the effect would be that Europe would fail to realise 30% of the potential benefits unless the EU coordinated its efforts. This also contributes to the representation of EU interests in international negotiations, in relation to existing policies, in key sectors such as electronic communications, transport, R&D or broadcasting (Analysys et al, 2004).

These overarching goals, in turn, are pursued by ensuring an efficient use of spectrum resources throughout the EU, as prescribe by the Framework Directive. This intermediate goal is currently approached through the introduction of *more flexibility* in the management of spectrum resources for wireless electronic communications, while maintaining *harmonization* where necessary. As a result, the way towards optimal use of spectrum resources in the EU passes through a careful balancing of flexibility and harmonization (see section 1.4).

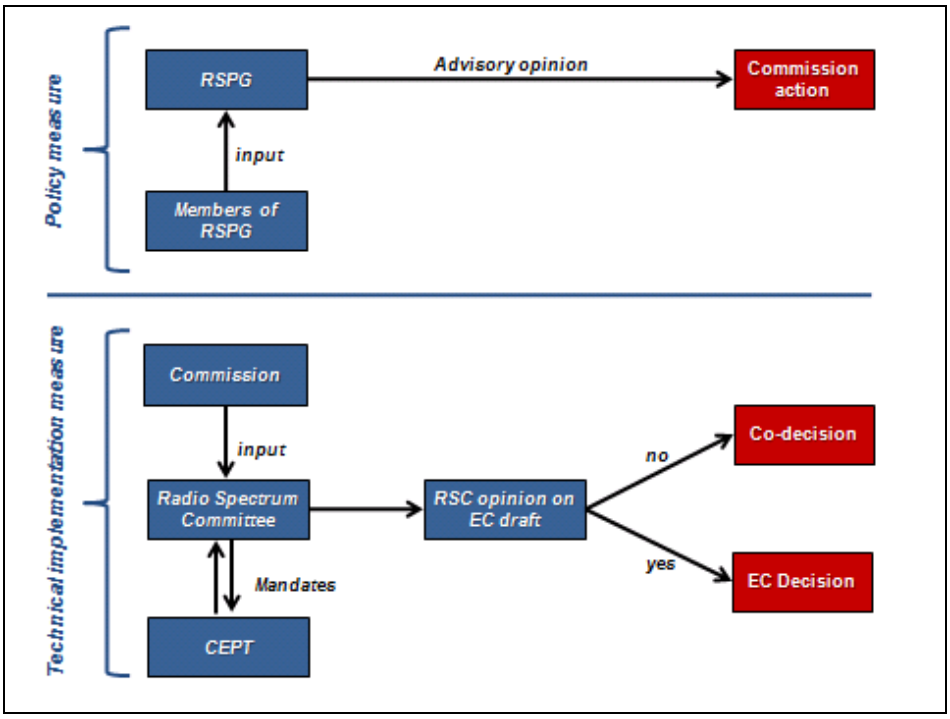
3.2.3 The architecture of decision making

The current architecture of decision making at EU level entails the interaction of many different players, with different competencies. In particular:

- ***Policy measures*** are mostly adopted by the Commission through consultation with the *Radio Spectrum Policy Group (RSPG)*, set up in 2002 and consisting of high level experts from national administrations as well as a diverse set of observers. The RSPG has developed, *inter alia*, the Wireless Access Policy for Electronic Communication Services (WAPECS) concept since 2004, and is advising the Commission in key areas such as the deployment of multimedia services and the future use of the digital dividend.
- ***Technical implementation measures*** are dealt with through the *Radio Spectrum Committee (RSC)*, composed of representatives of the Member States and linked with national authorities responsible for spectrum management. The RSC supported the Commission on specific initiatives regarding, *inter alia*, automotive radars and assisted hearing devices, 2 GHz mobile satellite systems, the harmonized availability of information regarding spectrum use, the proposed harmonization of the use of the 900 and 1800 MHz bands (enabling 3G and other services to be used in the GSM bands) and the Decision on Mobile Communication aboard Aircraft. These measures are interlinked with equipment regulations under the R&TTE Directive.
- ***A third forum for cooperation*** – dealing with the harmonization of frequency allocation, the availability of information and other technical implementing measures – is the issuing of mandates by the Commission (via the RSC) to the *European Conference of Postal and Telecommunications Administrations* (CEPT), which consists of representatives of 48 national administrations.

The procedure is outlined both in the Radio Spectrum Decision (Art. 4 §3) and in the Commission-CEPT Memorandum of Understanding signed in January 2004.

Figure 6: The architecture of decision-making



3.2.4 The evolution of legislation

After the entry into force of the NRF, EU institutions have gradually realised the need for enhanced flexibility, technology and service neutrality, trading and – where possible, unlicensed or collective use. A key step in this respect was the development by the RSPG of the WAPECS concept (RSPG, 2005). The Commission subsequently announced its intention to integrate these principles in the NRF, strengthen the EU dimension in licensing, and clarify technology and service neutrality principles as applied to spectrum. In the 2005 Communication, the Commission proposed to: (i) introduce spectrum markets in the EU by 2010; (ii) reap the full benefits of the switchover from analogue to digital terrestrial broadcasting by setting a target date at 2012; (iii) develop a common spectrum approach for all wireless platforms providing e-communications services without artificially differentiating between technologies[30].

These goals were further elaborated in the 2007 Communication[31]. Actions proposed include the following:

- the identification of spectrum bands used by the broadcasting, mobile and information technology (IT) sectors in which current legal restrictions should be re-examined with a view to permitting more flexible usage, starting from a number of designated bands for a total of 1350 MHz. The bands selected were:

[30] A forward-looking radio spectrum policy for the European Union: Second annual report, COM(2005)411 final, 6 September 2005. In response to this proposal, the European Parliament adopted a Resolution, recognising the desirability of more unlicensed spectrum as one of three spectrum management paradigms (unlicensed, spectrum markets and "command and control"). 2006/2212(INI), 14 February 2007.

[31] Rapid access to spectrum for wireless electronic communications services through more flexibility, (COM(2007)50).

- the *UHF (470-862 MHz)* band (currently used for broadcasting, but potentially usable also for mobile multimedia services and for extending the reach of all types of wireless electronic communication services into rural areas);
- the *880-915 MHz/925-960 MHz* and *1710-1785 MHz/1805-1880 MHz* bands (currently used for GSM mobile services, but potentially upgradeable to UMTS and other technologies);
- the *1900-1980 MHz/2010-2025 MHz/2110-2170 MHz* bands (currently used for IMT-2000/UMTS, but potentially open to broadcasters);
- the *2.6 GHz* band (still to be licensed and available from 2008, and intended for use by IMT-2000/UMTS or alternative broadband technologies such as WiMAX); and,
- the *3.4-3.8 GHz* band (currently used for broadband connections to the customer's premises, and for satellite communications within Russia and a number of African countries).

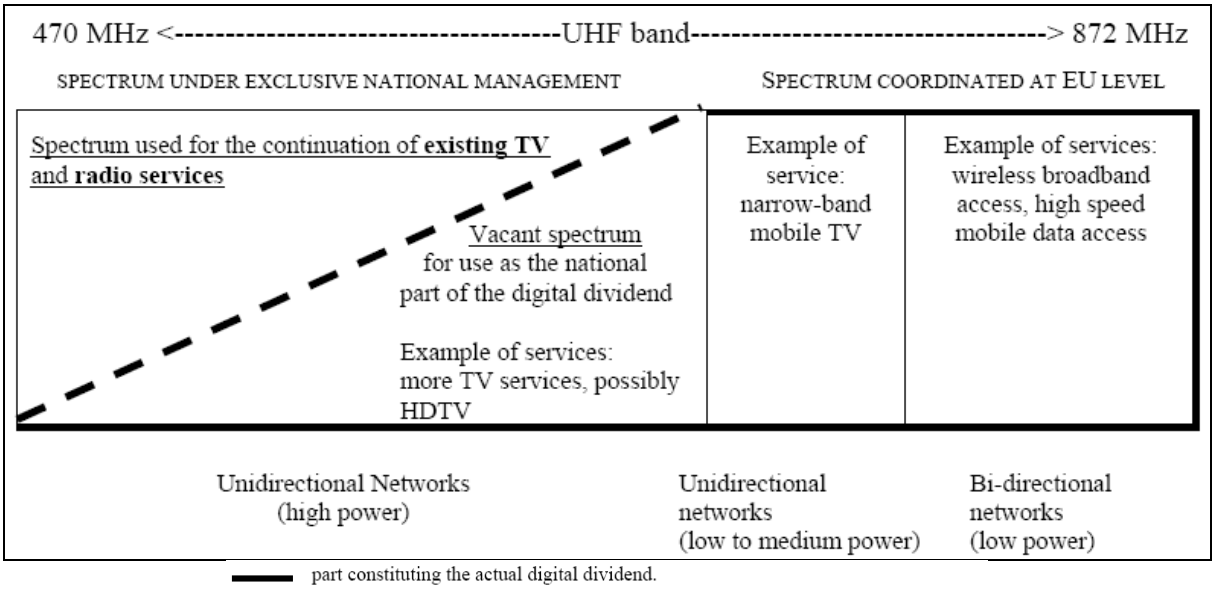
- the review of the validity of the GSM Directive and the application of the new approach to the 'digital dividend'[32].
- the attribution of more power and responsibility to industry players in selecting the most effective and efficient way to use their spectrum rights in a way that avoids harmful interference.

Other initiatives on harmonization of bands include Commission Decisions on: (i) bands to be allocated to Radio frequency Identification (RFID); (ii) use of the radio spectrum for equipment using ultra-wideband technology; (iii) availability as from 1 July 2007 of the frequency bands 1980-2010 MHz and 2170-2200 MHz for systems providing mobile satellite services; (iv) harmonization of the 79 GHz band for the use of automotive short-range radar equipment; (v) the harmonization of the 24 GHz band for the time-limited use by automotive short-range radar equipment; (vi) harmonized use of the 5 GHz frequency band for the implementation of wireless access systems including radio local area networks (WAS/RLANs); and (vii) harmonization of the 169.4-169.8125 MHz frequency band in the Community.

Most recently, on 13 November 2007, the Commission issued a Communication on the digital dividend[33], which forms part of the broader revision of the NRF. The Commission announces the use of a binding Community law instrument to establish 'application clusters' in common spectrum bands in the UHF band. It would constitute a 'top-level' spectrum organization upon which national and EU-wide plans can be developed, defining the bounds within which national flexibility can be exercised by allowing for different levels of EU harmonization for each cluster. Concretely, the clustering should be based on three sub-bands for the three most common types of networks: (i) *Unidirectional high power networks* (i.e. mainly for fixed broadcasting services) to be managed at national level to ensure the continuation of existing TV programmes in digital format and to accommodate new broadcasting needs**;** (ii) *Unidirectional medium to low power networks* (i.e. typically for mobile multimedia services, and newer forms of converged broadcasting and communications services), also to be dealt with both at national level and with optional EU harmonization measures; and (iii) *Bi-directional low power networks* (i.e. typically for fixed and mobile broadband access services), which could also possibly include other applications such as innovative low-power broadcasting services. Figure 7 illustrates the Commission's proposed sub-bands.

[32] This measure was already translated into a Commission proposed Directive, COM(2007) 367 final.
[33] Reaping the full benefits of the digital dividend in Europe: A common approach to the use of the spectrum released by the digital switchover.

Figure 7: Proposed clustering of spectrum.



Source: European Commission, Communication "Reaping the full benefits of the digital dividend in Europe (2007).

In addition, Article 1 of the proposed Directive amending the NRF introduces technology and service neutrality as binding principles (articles 9.3 and 9.4) with the possibility for exceptions to the principle in limited cases such as meeting general interest objectives. The proposed Directive enhances the importance of spectrum tradability, which can be imposed in commonly defined bands (Article 9b); introduces a transitional phase (Article 9a) and allows the Commission to take implementing measures via the comitology procedure to coordinate the application of the new principles (9c) for internal market purposes. Articles 5, 6 and 7 of the proposed Directive calls member states to take measures to stop spectrum hoarding (Article 5(6)); and provides the Commission with strong powers to facilitate access to spectrum for firms needing rights of use in all Member States by coordinating or harmonizing the conditions applicable to individual rights, the selection procedures and the selection of the undertakings, with assistance from the new European Electronic Communications Market Authority[34].

3.3 Impact on international agreements

The initiatives described in the previous sections represent important steps towards the development of a coherent EU spectrum policy. However, the feasibility of implementing these measures essentially depends on the legal constraints existing at international level (ITU, CEPT), and at national level. For this reason, the next section briefly addresses the compatibility of new proposed measures with existing international commitments and agreements. Section 3.4 analyses the constraints existing at Member State level.

[34] Proposal for a Directive of the European Parliament and of the Council of (…) 2007 amending Directives 2002/21/EC on a common regulatory framework for electronic communications networks and services, 2002/19/EC on access to, and interconnection of, electronic communications networks and services, and 2002/20/EC on the authorization of electronic communications networks and services.

3.3.1 ITU and CEPT levels

The coordination of spectrum at a global level is the responsibility of the International Telecommunication Union (ITU), a United Nations agency with the mission to maintain and extend international cooperation for the improvement and rational use of telecommunications. Every three to four years, the ITU-R holds a World Administrative Radiocommunication Conference (WARC, now abbreviated to WRC), a process aimed at adapting the ITU Radio Regulations (RR), the international treaty coordinating spectrum usage globally. At WRCs, frequencies are first allocated to services (referred to as *allocations*); subsequently, individual countries allot frequencies to specific areas or regions (referred to as *allotments*) and assign them through licences to stations (in a process called *assignment*). The allocation of each band within the regions may be to one or more services within one of the two categories: *primary* services or *secondary* services. This is important in light of the current Commission proposals: suffice it to say that if a secondary service suffers unacceptable interference from a primary service, it cannot claim protection. Below, we examine the main legal constraints exerted by existing ITU regulations and CEPT agreements on the proposed new Commission measures aimed at developing a common EU spectrum policy.

Bands III, IV and V

The potential impact of the currently proposed EU measures would be felt mostly in *frequency bands 174-230 MHz and 470-862 MHz*, the use of which has been planned by the Geneva 2006 (GE-06) Agreement. The GE-06 Agreement established a plan containing frequency allotments and assignments for the transmission of DVB-T and T-DAB services in these two bands ('the Plan'). The GE-06 Agreement leaves significant flexibility in implementing the Plan: the concept of *allotment planning* provides a high degree of flexibility regarding the location of broadcasting transmitters within the corresponding service area and interference envelope of the entry in the Plan; whereas the concepts of *interference* envelope and *spectrum mask* offer flexibility for implementing broadcasting services with different characteristics or other applications. If the proposed use exceeds the limits set for the envelope, it requires prior agreement from affected administrations.

As far as these two bands are concerned, the GE-06 seems to allow, in principle, for greater flexibility. However, limitations exist, some of which have already been pointed out in the RSPG opinion on multimedia services, and may constrain the use of the digital dividend:

- The use of bands 174-230 MHz and 470-862 MHz is primarily allocated to broadcasting services, and will continue to be constrained until protection of analogue transmissions has ceased, which is generally expected in 2012, but sooner in some countries in the EU;
- In most CEPT countries, very few allocations for other primary terrestrial services are found in bands III, IV and V. This means that the envelope concept is not feasible for CEPT administrations at present. However, this situation might change as a result of WRC-07 or in the WRC-11, where new allocations for mobile services in bands III, IV and V could be decided.
- In many countries, the implementation of mobile multimedia services may thus require departing from the reference planning configuration (RPC) adopted at GE-06, and hence entail delays and network costs. The limitations of the envelope concept are seen by many countries as too restrictive, and to overcome this restriction, 52 administrations, mainly from CEPT countries, have added a declaration (Declaration No. 42) to the GE-06 Agreement stating that they intend to use the envelope concept for other terrestrial applications (not primarily broadcasting), which in principle would allow for negotiations of the broadcast spectrum by commercial telecommunication operators.

- The flexibility left to administrations for developing the Plan has already led to significant variations in the entries, hence in the ability of harmonizing usage in the future.
- There remain serious technical concerns regarding the practical aspects of co-existence on the same territory of two very different types of transmission networks, namely (i) the traditional broadcasting network, based on high-power transmission sites, and (ii) the dense low-power network, more suitable for implementation of mobile multimedia services, which require higher levels of field strength for reliable indoor reception.
- Another potential source of interference to the traditional broadcasting network could be the uplink transmissions of the other terrestrial services in cases where these are distributed by satellite. If the spectrum for the uplink communication is allocated within the broadcast frequency bands then the interference to the domestic television receivers is likely to be unacceptably high.
- Finally, based on the GE-06 Plan, many licences for digital broadcasting or multimedia broadcasting services have already been granted in European countries for the next 10-15 years. This suggests that, absent new measures at EU level, the Europe-wide harmonization and implementation of a sub-band for multimedia broadcasting services would not be realistic before 2020.

L-Band

An alternative to the immediate search for the digital dividend in the broadcast spectrum consists in exploring the potential of the L-Band, 1452-1492 MHz. At ITU level, the regulatory status of this band is rooted in the ITU WARC-02, which allocates the L-band globally on a primary basis for use by the Broadcasting Satellite Service for the purposes of digital audio broadcasting via satellite. At CEPT level, the Maastricht 2002 Special Arrangement (MA-02) provided for an allotment plan for T-DAB services in the sub-band 1452-1479.5 MHz[35]. In addition, based on the CEPT Decision ECC (03)02, the band 1479.5-1492 MHz is designated exclusively for S-DAB systems.

The MA-02 foresaw the implementation of T-DAB only. Since new, non-primarily allocated services such as T-DMB and DAB-IP use the same bandwidth and have similar technical characteristics as T-DAB, they can already be accommodated in accordance with MA-02 without having to change the rules. In contrast, other systems required a wider bandwidth (up to 8 MHz). There has been growing consensus in Europe that MA-02 should be amended in order to allow for more flexibility. In particular, the RSC has issued a mandate to the CEPT on EU harmonization of the 1452-1479.5 MHz band to allow flexible use by mobile multimedia technologies, requesting CEPT to make an assessment of the technical and regulatory conditions and to issue recommendations. CEPT proposed: (i) the introduction in the MA-02 of an interference envelope concept similar to that in the GE-06; and (ii) a possibility to aggregate T-DAB blocks in order to enable the operation of systems requiring a larger bandwidth. The MA-02 Special Arrangement has been finally modified on 4th July 2007 at Constantza, Romania, so as to allow greater flexibility in the use of the band. A draft 'Commission Decision on the harmonization of the band 1452-1479.5 MHz to allow flexible use by mobile multimedia technologies in the European Community' was prepared by the RSC in October 2007.

[35] 'Special Arrangement of the European Conference of Postal and Telecommunications Administrations (CEPT) relating to the use of the 1452–1479.5 MHz band for Terrestrial Digital Audio Broadcasting (T-DAB)', (Special Arrangement Maastricht 2002 or MA-02), entered into force on 01 September 2002.

The 2.5 GHz band

This band is allocated at ITU level to IMT-2000 services (UMTS), but the question is open to whether the relevant bands should be made available for IMT-2000 exclusively or for new technologies besides or beyond IMT-2000 as well. The majority of Member States have recently stated that the band should be harmonized for IMT-2000 with no deviation at this stage, subject to further review at a subsequent stage. The main problem emerging in the (re)allocation of these bands to UMTS and other services is to be found at national level, as in many Member States this band is still subject to exclusive use for defence or other governmental uses.

Bands suitable for Broadband Wireless Access (BWA) services

In other bands selected by the European Commission for the introduction of more flexible and technology-neutral arrangements, there are no significant constraints exerted by ITU regulations. For the *3400-3600 MHz band*, considered as the most suitable for future sustainable BWA deployment in CEPT countries, existing arrangements in some Member States already exhibit features that favour the development of the BWA market (spectrum assigned in blocks of sufficient size; no registration of user terminals needed; very basic access requirements, rare restrictions on technology or services). Also the *3600-3800 MHz band* and the *5725-5875 MHz bands* do not feature significant obstacles at international level. At CEPT level, the latter band is subject to analysis, mostly as regards technological issues such as sharing between BFWA and other services (e.g. protection of frequency hopping radars).

3.3.2 WRC-07: EU position and outcomes

As the most important international constraints lie in the UHF band and in the 'UMTS extension' band, the European Commission carried out an extensive consultation on the proposals to be put on the WRC-07 table during November 2007. As a result, the Commission proposed to focus on identifying those frequency bands which can promote a convergent telecommunications environment in the long term.

- *'Co-primary status' in the UHF Band.* The Commission proposed to achieve more flexibility by upgrading the status of mobile multimedia services in the UHF band to the same status as broadcasting services (so-called "co-primary" allocation).
- *Interference in the 2.5–2.69 GHz (UMTS extension) band*. The Commission proposed to devote every effort to minimize the risks of interference to IMT-2000 networks operating in the EU in the UMTS extension band from satellite services.
- *Technical sharing solutions in the C-band* (*3.4-4.2 GHz*). The C-band is currently used as a backbone broadband network by satellite services, notably in developing countries. The Commission thus proposed to identify technical sharing solutions accommodating mobile requirements: this implied a *prioritization of sub-bands* for satellite and terrestrial services within the C-band, which would give both of them adequate long-term guarantees of operating within this frequency band without undue interference.

The EU was successful in meeting most of these aims. The key outcome of WRC-07 was the identification of bands for 3G and 4G mobile service, now collectively referred to as International Telecommunications Services (IMT). Two global IMT allocations were agreed: 450-470 MHz, currently used for broadcasting and land mobile services; and 2.3-2.4 GHz, currently used for satellite and wireless broadband. In addition, the Region 1 (countries including Europe) agreed to harmonized spectrum use for IMT in the 790-862 MHz and 3.4-3.6 GHz bands.

3.4 Overview of Member States' licensing regimes

In this section, we briefly illustrate the existing conditions for spectrum reform in four Member States – Italy, Romania, Sweden and UK – chosen with the aim of highlighting the range of approaches across the Member States and the differences that have resulted.

3.4.1 Italy

In Italy, competence for spectrum allocation is shared by the Communications Authority (Agcom) and the Ministry of Communications. Spectrum assignment in Italy has traditionally relied on the command-and-control method; licences in key bands have been assigned through administrative decisions, with the exception of the 3G auction and the upcoming WiMAX auction. Italy can be considered as a highly peculiar country in Western Europe as regards spectrum policy: a so-called 'battle of frequencies' some thirty years ago led broadcasters into a race to occupy frequencies on a 'first come, first served' basis – a situation which was termed 'Wild West' by some commentators. Reportedly, national regulators still struggle to get a clear picture of actual assignment of broadcasting frequencies today (Piacentino et al, 2007). Italy today features a high concentration of frequencies in the hands of Rai Radiotelevisione and Reti Televisive Italiane (Mediaset Group) – which hold about 80% of total frequencies currently available for analogue TV broadcasting nationwide[36]. This problem was not solved by the advent of digital terrestrial TV services; Law no 66 of 2001 set the switch-off date at December 2006, then delayed to 2008 and recently to 2012. Law no 66 allowed for broadcast spectrum trading to allow tests of digital switchover, but deplorably restricted the purchase of frequencies to broadcasters who already had an authorization to provide the same type of service, thereby blocking entry for new competitors.

As a result, the Italian regulator acknowledges that the prospects for real spectrum liberalization in Italy leave little room for hope[37] – the market is de facto and de jure closed to players that do not already operate as franchisors of broadcasting services.

As regards the possible future allocation of bands in given frequencies, the following information describes the existing constraints and opportunity in Italy:

- *UHF band.* The analogue switch-off is likely to free up approximately 100 MHz (probably in the upper UHF band), which will be released gradually. The digital dividend is likely to be initially available through non-adjacent sub-bands, and on a non-interfering basis. Thus, services such as DAB/DMB or DVB-H (for radio uses), Mobile TV or HDTV seem favoured over UMTS, HSDPA/HSUPA) and WiMAX.
- On July 13, 2007, the Ministry of Communications freed up the frequencies in the *865-868 MHz* band – partly used for military applications – for primary use by RFID devices, following Commission decision 2006/804/EC.
- *900 MHz band.* These bands are currently used for GSM services, but may be subject to refarming to accommodate 3G services. At the end of 2005, 5 MHz of prime spectrum in the 900 MHz band became available following switch-off of Tacs mobile phones. There is a growing interest for reallocating spectrum in the 900 MHz band to accommodate UMTS services: in particular, Agcom recently proposed to refarm the 900 MHz band, and proposed two options: (i) short-term partial re-farming to allow for use of the band also by 3G system, after a transitional period;

[36] AGCOM – Analisi del mercato dei servizi di diffusione radiotelevisiva per la trasmissione di contenuti agli utenti finali, sulla valutazione di sussistenza del significativo potere di mercato per le imprese ivi operanti, Annex B, Decision no. 61/2006/CONS, Feb. 1, in http://www.agcom.it.
[37] Ibid.

(ii) longer-term total refarming, when the existing GSM licences will expire (between 2015 and 2018). The Agcom has clearly expressed its preference for the former solution, which would be implemented by making available two blocks of 5 Mhz of spectrum, with an overall spectrum cap per operator of 25 MHz. The two options are currently under consultation following the Delibera Agcom n. 343 of 28 June 2007. Accommodating 3G services in the 900MHz band could facilitate the allocation of (part of) the 2.5 GHz band to WiMAX.

- *The L-Band* and adjacent bands could be freed up for a total of 100 MHz *(1.429 – 1.530 MHz)*. This band was licensed for T-DAB applications following the MA-02 special arrangement, but these services are not yet operational in Italy. Adjacent bands are currently allocated to the Ministries of Communication and Defence (1.429-1.452 MHz and 1.492-1.530 MHz) for radio communications.
- *1800 MHz band.* This band is also allocated to GSM. A block of 2x20 MHz is currently unused and could be soon assigned to a new entrant. In June 2007, Agcom has also proposed refarming in this band: the proposal is currently subject to consultation.
- In the *2.1 GHz band* (so-called UMTS 'core band'), spectrum was initially allocated to UMTS through an auction, which ended up being extremely burdensome for operators, generating more than €12 billion in revenues. In 2000, the duration of licences was extended from 15 to 20 years. Currently, 10 MHz in the 2010-2020 MHz band are unused. A 5 MHz portion of spectrum was recently claimed back from the consortium Ipse2000, which had not made any use of it after the award.
- *The 2*.5-*2.69 GHz band* is currently used by the Ministry of Defence, although in principle it should be assigned to IMT-2000/UMTS technologies, and could be used also for WiMAX is the latter enters the family of IMT-2000 technologies. This band, once free, has to be assigned through a licence, and is strongly demanded by mobile operators for MBMS or 3G services.
- *The 2.7-2.9 GHz band* (internationally indicated for WiMAX services) is currently used for air navigation and meteo services, and highly congested. For this reason, it seems unlikely that WiMAX could be accommodated in that band in Italy in the future.
- As regards the *3.4-3.6 GHz band*, the relevant spectrum was used by the Ministry of Defence until the end of December 2006, when the Ministry of Communications and the Ministry of Defence finally agreed on a plan whereby 2x75 MHz would be available for WiMAX in the 3.4-3.6 GHz band from June 2007[38]. The auction was launched in October 2007. The Ministry of Communications launched an auction, which will assign 3 blocks of at least 2x21 MHz (paired) for each geographic area (whereby one usage right is reserved for new entrants). Licences will last for 15 years, can be renewed for 10 years and will not be transferable to a third party without government authorization. The expected revenue for the Italian government is estimated in the range between €100-200 million.
- As regards *higher bands*, the 'Stanca decree' liberalized usage of the 5 GHz band in 2005 for the point-to-point connections based on the ETSI-HiperLan technology. In addition, the 2005 'Landolfi decree' eliminated all territorial restrictions for the installation of WiFi access points in the 2GHz and in the 5.47-5.75 GHz bands, at the same time opening the 5.15-5.35 GHz band for indoor applications.

[38] The two ministries also agreed that twice as many frequencies will be allocated to enable a nationwide spread of broadband services within five years.

These decrees led many local administrations to deploy wireless networks to bridge the digital divide. However, use of WiMAX in the 5.7 GHz band (125 MHz are available) would not be the best choice for WiMAX applications, as the band is extremely congested and does not allow for indoor reception.

In summary, the Italian situation portraits a mixed picture, especially as regards the existing constraints relevant for the implementation of current Commission proposals. On the one hand, refarming proposals may lead to entry of at least one new player and the conversion of 2G into 3G technology in the 900 MHz and 1800MHz bands, and the WiMAX auction could lead to increased availability of spectrum for broadband wireless access in the 3.4-3.8 GHz band rather soon. However, significant delays and competition problems exist in the UHF bands, which jeopardise Italy's potential to reap the benefits of the digital dividend. At the same time, significant constraints exist in the L-band and in the 2.5 GHz band. The need to preserve legacy rights in UHF bands and 3G licences (on which operators invested enormous resources) may significantly affect the government's agenda.

3.4.2 Romania

In Romania, the Ministry of Communication and Information Technology (MCTI) establishes the policies and strategies for the efficient usage of frequency spectrum and issues the National Frequency Allocation Table. The National Authority in Communication and Information Technology (ANRCTI) is responsible for the management, allocation and assignment of the radio spectrum for non-governmental usage.

In April 2007, ANRCTI took over the rights and obligations of the former institution responsible for spectrum management, namely the General Inspectorate for Communications and Information Technology (IGCTI) which was dissolved. The EU policy regarding radio spectrum was transposed even before accession, through Emergency Ordinance no 79/2002.

Romania is currently in the process of defining and introducing a set of flexible rules for spectrum management, to clarify technology and service neutrality principles as applied to spectrum, issues related to the liberalization of spectrum, the rules for spectrum trading, as well as issues related to switchover from analogue to digital terrestrial broadcasting, having as target date 2012. However, currently there is no general and coherent strategy for spectrum management at national level.

The situation of frequency allocation in key bands in Romania is as follows:

- the *UHF band* is mostly allocated to non-governmental use, mostly to broadcasting (analogical/terrestrial TV) and radio microphones, but some sub-bands are still used for military purposes. Importantly, the band 479-862 MHz will soon be reviewed for possible future applications after the introduction of DVB-T.
- the *900 MHz and 1800 MHz bands* are allocated to GSM usage[39]. Two GSM licences were awarded through beauty contest in 1996 to Mobil Rom and Mobilfon, each for a total of $50 million. Cosmorom was the first GSM-1800 operator, launched commercially in March 2000 (later re-launched as Cosmote in 2005). Cosmorom's licence in the 1800 MHz band will expire in 2009.
- in the *1.9-2.1 GHz bands*, two players (Vodafone and Orange) secured 5-year 3G licences in November 2004. In October 2006, RCS & RDS and the CDMA450 operator Zapp (Telemobil) won two additional 3G licences. The cost of the 3G licence awarded by IGCTI was set at the equivalent of $35 million, for a duration of 15 years.

[39] Telemobil operates a CDMA network in the 450 MHz band, offering mobile voice and Internet services.

Operators have to pay a yearly fee for spectrum usage, and have to cover three development stages with the following deadlines: June 30, 2008, December 31, 2009 and December 31, 2011.

- The *2.5 GHz band* is currently used for military applications, at least until there will be requests for UMTS use of these bands. It is not clear how long would it take to free up these bands should these requests arrive.
- *3.5 GHz and 3.7 GHz bands.* As of October 2006, seven operators held 10 national licences for services in the 3.5 GHz band, while five operators held 175 local licences. The Romanian government has launched a national broadband plan to deploy technologies such as WiMAX in Romania, by setting precise steps: these include auctioning two national licences in the 3.7 MHz frequency band, with duration until 2013. It is interesting to note that if the winners of 3.7 GHz licences also happen to hold licences in the 3.5 GHz band, they would have to renounce these. Holders of the 3.5 GHz licences have been invited to issue proposals to reorganize spectrum in that band: IGCTI launched a public consultation in October 2006 to test the interest of operators for new technologies using these frequencies. In mid-2007, two national 'advanced services' licences in the 3.5 GHz band in 2007 were auctioned. In the medium term, IGCTI (now ANRCTI) plans to adopt the EU and ITU decisions and regulations regarding the 3.5 GHz and 3.7 GHz frequency bands. Moreover, it was announced that after 2013 there shall be only 3-4 national licences in the 3.5 MHz frequency band (compared to the current ten). In any event, no licence holder in the 3.5 GHz and 3.7 GHz frequency bands will be allowed to hold a cumulated spectrum larger than 2x28 MHz (*spectrum cap*); and no licence holder for these frequency bands shall be entitled to simultaneously own local and national licences in both the 3.5 GHz and 3.7 GHz frequency bands.

In summary, current developments in Romania suggest that, due to a limited centralization of spectrum in the past years and the absence of a coherent and rigid national spectrum policy, there may be sufficient spectrum available to deploy advanced technologies in the future, and legal constraints at national level do not seem insurmountable. The pro-competitive provisions adopted by IGCTI in the past year leave room for hope as regards the feasibility of implementing Commission proposals. Thanks to this approach, by mid-2008 Romania will have two operators in the 410-450 MHz band, three operators in the 900 MHz band, three operators in the 1800 MHz band, four 3G operators, broadband services in 3.5 GHz and 3.7 GHz frequency band[40]. The reorganization and refarming of spectrum in the UHF band will be an essential step as regards Commission proposals on the digital dividend; whereas the conditions to access the 2.5 GHz band have to be clarified.

3.4.3 Sweden

The National Post and Telecom Agency (Post- och telestyrelsen/PTS)[41] is the authority that monitors the electronic communications and postal sectors in Sweden, with 'electronic communications' covering telecommunications, IT and radio. PTS is a public authority reporting to the Ministry of Industry, Employment and Communications.

[40] See speech by Mr. Catalin Marinescu (president of IGCTI), *European Communications in Romania*, 17 October 2007, available at http://www.anrc.ro.
[41] http://www.pts.se.

The authority is an independent agency according to the Swedish public authority model, such that the government is not allowed govern how PTS should apply an act[42].

The authority aims to administer spectrum so that it provides the greatest possible level of use and social benefit, to promote innovation, the development of technology and a broader range of wireless-based services. A number of points have been formulated with the aim of achieving this, among others, that[43]:

- Licences to use radio transmitters shall be as technology and service neutral as possible
- When selection procedures are required, an auction should be applied in the first instance
- Second-hand trading (transfer of licences) shall be promoted
- Licence exemption should be introduced where there is little risk of harmful interference and there are no other impediments
- The rights and obligations of the licence holder should be clear and not be changed without notice and good reasons
- A minimum of administrative burdens shall be imposed on licence holders
- The application procedure should be simplified through the use of relevant IT tools, for example, web applications
- Spectrum allocation shall be harmonized with other countries as far as this is possible

Thus PTS agrees with the European Commission that central planning of the spectrum often fails to satisfy the principles of the greatest possible social benefit, accessibility and promotion of innovation. Examples of exceptions to this, where central planning or variants thereof will continue to be required in the future, include radio use for public safety (for example, the police, the armed forces, emergency services) and certain international harmonized radio use (for example, civil aviation, maritime traffic, space/satellite communication, research). PTS must also, in accordance with Swedish Law, consider to the greatest possible extent freedom of expression (use of broadcasting) and the needs of prioritized users (the armed forces and the police).

For many other – not least commercial – services, society's benefit from the use will be greatest if the spectrum is used for the services for which demand is the greatest. Therefore, PTS considers that technology and service-neutral licences, auction assignments, second-hand trading and licence charges in proportion to the use of the resources should be used to a greater extent.

Sweden supports the Commission’s proposal on spectrum trading[44]. However, it appears that the Commission limits the proposal to refer to certain frequency bands identified by the Commission and Member States. Sweden takes the view that it is possible to go even further and state that the general principle, in all bands, is that it should be possible to transfer licences.

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[42] The Swedish constitution prohibits against interference by a government minister in a government agency - see Regeringsformen SFS 1974:152, Chapter 11, §7.

[43] See *PTS Spectrum Policy*, PTS-VR-2006: 2, 10 December 2006, http://www.pts.se/Archive/Documents/EN/Spektrumpolicy_eng.pdf.

[44] See Swedish Reply to Public Consultation on the Review of EU Regulatory Framework for Electronic Communications Networks and Services, http://ec.europa.eu/information_society/policy/ecomm/doc/library/public_consult/review_2/comments/swedish_input_e_com_review.pdf.

Current and possible future allocation of frequencies in key bands include:

- *In the 450 MHz band*, PTS awarded a 15-year licence to Nordisk Mobiltelefon in 2005 to build a digital mobile telephone network, following an auction and a winning bid of about €9 million.
- *Regarding digital switchover*, Sweden is one of the most advanced countries having switched off analogue signals on 15 October 2007. PTS has concluded that at least 189 MHz can be released through the switch-off of analogue television broadcasting, with 112 MHz available in the attractive 470 – 862 MHz band. Nevertheless, PTS has not rushed to decide how to allocate these frequencies, believing that it would be beneficial if European countries can coordinate use of parts or all of this spectrum.
- The *900 MHz and 1800 MHz bands* are allocated to GSM. Three licences were awarded in 1992, now held by Tele 2, Telia Sonera and Vodafone. A fourth licence in the 900 MHz band was awarded in 2004 to the sole bidder, Swefour, to set up a network and offer capacity to companies and operators that lack their own mobile networks.
- *In the 1.9G Hz-2.1 GHz bands*, PTS awarded four 15-year 3G licences in 2000 through a 'beauty contest', licence winners being charged a nominal fee of about €11,000 each plus 0.15% of annual turnover. The successful applicants were Europolitan, later Vodafone, the Swedish operations of which were later acquired by Telenor, HI3G (now 3), Orange and Tele2. Telia and Tele2 gave notice after some time that they would share Tele2's licence through a venture now called SUNAB (Svenska UMTS Nät AB). Europolitan (now Telenor) and Hi3G (now 3) also decided to collaborate on the rollout and to build parts of their network together. In 2004 Orange withdrew from the market and its licence was revoked following unsuccessful attempts to sell its licence. The original license requirement was that, by December 2003, 99.98% of the Swedish population should have access to 3G signals, according a specific technical formula, which later was revised. All licence holders have struggled to meet their roll-out obligations and by 2003 coverage was between 67.5 and 74% of the promised population coverage. Amended technical requirements mean that operators have now met their coverage obligations.
- PTS has been conducting an 'interest survey' and consultation regarding licences in the frequency bands 1900–1905 and 2500–2690 MHz and intends to issue national licences for future wireless applications through an auction planned for the first half of 2008.
- *In the 3.6-3.8 GHz-band*, PTS plans to assign 1,160 licences in a web-based auction in November 2007. There are four licences per Swedish municipality; two FDD licences of 2x20 MHz each and two TDD licences of 40 MHz each. The licences are technology and service-neutral and do not contain any rollout obligations. The purpose of this assignment is to create opportunities for operators to build broadband networks, to increase supply and competition in the broadband market.

In conclusion, Sweden could be viewed as having adopted a wide range of spectrum management principles and methods, but in recent years it has moved increasingly toward market-based solutions (auctions, trading) and supported service and technical neutrality.

3.4.4 United Kingdom

Ofcom[45] is the regulator and competition authority for the UK communications industries, and is responsible for ensuring the optimal use of the electro-magnetic spectrum. It was established in December 2003, assuming the duties of five separate industry regulators, including Oftel and the Radiocommunications Agency[46]. Ofcom has a statutory duty: a) to further the interests of citizens in relation to communications matters; and (b) to further the interests of consumers in relevant markets, where appropriate by promoting competition. The Wireless Telegraphy Act 2006 (WT Act) brought together into a single statute the legislation under which Ofcom now manages the radio spectrum[47].

Although Ofcom is responsible for the management of all spectrum, whether used by the public or private sector, a standing Cabinet Office committee, the UK Spectrum Strategy Committee (UKSSC) has the lead responsibility for coordinating government spectrum policy. UKSSC is jointly chaired by the Department of Trade and Industry and the Ministry of Defence and comprises representatives of interested government departments. Ofcom is not a formal member of UKSSC since it is not a government department but it is generally represented at committee meetings. Ofcom is not obliged to abide by UKSSC decisions but most seem to be implemented on a consensual basis[48]. The UKSSC also coordinates international spectrum policy between government and Ofcom.

Historically in the UK, almost all spectrum was managed through a traditional 'command and control' method. In recent years this has been relaxed in three ways, following its Spectrum Framework Review (SFR) in 2004[49], which built on the earlier independent Cave review of Radio Spectrum Management for the Department of Trade & Industry and the Treasury in 2001[50]. First, auctions have been used to assign spectrum, notably in the case of 3G licences[51]. Ofcom now uses auctions as the principal means of assigning spectrum, where demand for the spectrum is likely to exceed supply. However, occasionally, for strong public policy reasons, Ofcom may choose a different method such as comparative selection.

Second, the introduction of secondary trading in December 2004 enables holders of WT Act licences to transfer all or part of their rights and obligations to another party. Also, since January 2005, spectrum liberalization has allowed licence holders to request a variation to certain licence conditions. Perusal of the Ofcom secondary trading web pages, however, shows that there have been very few genuine trades so far[52].

Third, some new allocations have been set aside for licence-exempt use, for example at 5 GHz. Ofcom must exempt radio stations, equipment or apparatus where interference is not likely or is contrary to an international obligation. Figure 8 shows the weighted use of the spectrum, with defence and fixed services dominating overall usage.

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[45] http://www.ofcom.org.uk.

[46] Ofcom assumed the duties of Office of Telecommunications (Oftel), the Broadcasting Standards Authority, the Radiocommunications Agency, the Independent Television Commission (ITC) and the Radio Authority.

[47] The new Act replaced the Wireless Telegraphy Acts 1949, 1967 and 1998, the Marine etc Broadcasting (Offences) Act 1967, Part 6 of the Telecommunications Act 1984 and certain provisions of the Communications Act 2003. Acts of Parliament can be found at http://www.opsi.gov.uk/acts.htm.

[48] Independent Audit of Spectrum Holdings, Emerging Issues: A Consultation Document, July 2005, p.8.

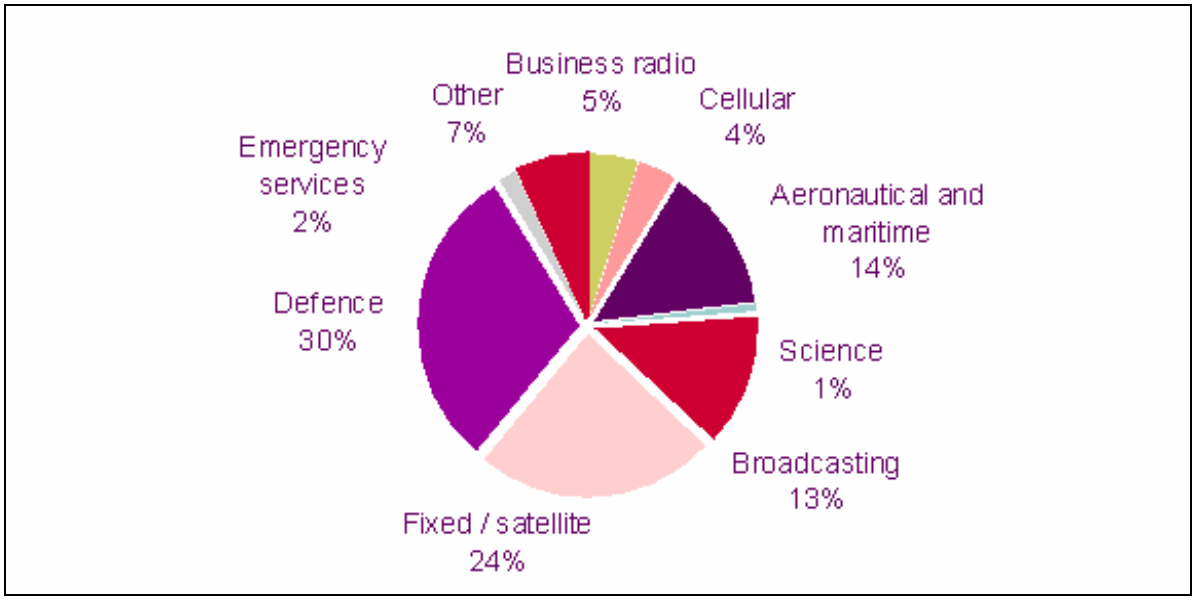
[49] http://www.ofcom.org.uk/radiocomms/sfr/.

[50] http://www.ofcom.org.uk/static/archive/ra/spectrum-review/index.htm.

[51] The five 3G licences auctioned in 2000 raised £22.5 billion for the UK treasury.

[52] See http://146.101.202.225/public-tnr/tradeDetails.do. Of the 20 transactions listed on 13 November 2007, 7 were withdrawn and 6 appear to refer to a minor change to the licence holder's name.

Figure 8: UK spectrum use weighted by frequency.



Source: Ofcom,

Note: 1MHz allocation at 100MHz is given equal weighting to a 10MHz allocation at 1GHz.

Current and possible future allocation of frequencies in key bands include:

- *In the 412-414 MHz and 422-424 MHz bands*, Ofcom awarded a licence to Arqiva through an auction. The auction was for 4 MHz of spectrum in four lots; Arqiva won all four lots with a bid of £1,500,025. The licence, which is effective immediately, is technology and service neutral; this means that the licensee has the freedom to use the spectrum how it wishes, within certain technical limits.
- *UHF band*. In December 2006, Ofcom's published its *Digital Dividend Review*[53] setting out proposal to use the spectrum released by digital switchover in the sought-after UHF band in the frequencies 470-862 MHz. Ofcom has already reserved 256 MHz of this spectrum for digital television broadcasting, meaning that about 128 MHz is available for a variety of potential uses, including advanced wireless services and more digital TV (including high definition TV). Ofcom is currently considering responses to its consultation and the next steps but is broadly committed to a market-based approach through auctions for this spectrum.
- the *900 MHz and 1800 MHz bands* are allocated to GSM, four licences being awarded to Vodafone, BT Cellnet (nowO_2), Orange and One2One (now T-Mobile) between 1992 and 1994 with no expiry date. More recently, in 2006 Ofcom awarded 12 licences for cellular spectrum at the top end of the 1800 MHz band for low power pico-cell GSM, total fees for all licences only reaching £3.8 million.
- *in the 1452-1492 MHz (L Band)*, Ofcom plans to award spectrum by auction, existing fixed link services being obliged to vacate the band by 31 December 2007. This spectrum has a wide range of potential uses including mobile multimedia (using DVB-H or DMB), broadband wireless access (using TDD-IP and WiMAX), terrestrial digital broadcasting (T-DAB), special events (PMSE) services and satellite digital radio (S-DAB). Uncertainty caused by concern over interference has delayed the award.

[53] http://www.ofcom.org.uk/consult/condocs/ddr/ddrmain.pdf.

- *in the 1.9G Hz-2.1 GHz bands*, five UMTS 20-year licences were awarded by auction to five operators (Orange, Vodafone, O_2, T-Mobile, and Hutchison 3G) at a total cost of £22.5 billion. Operators were obliged to ensure 80% national coverage by December 2007, a target that seems unlikely to be met by all operators as they focus attention on covering metropolitan areas.
- *2500-2690 MHz and 2010-2025 MHz*, Ofcom has publishes a discussion document with updated technical and auction design proposals for the award of the 2.6 GHz and 2010 MHz bands. It is proposed to consider the band 2290-2300 MHz separately.
- Ofcom also expects to make a number of awards in bands over 3 GHz during the next few years. These include the possibility of further awards at 3.6-4.2 GHz (part) 10 GHz, 28 GHz, 32 GHz, and 40 GHz.

In summary, Ofcom has been in the forefront of application of a market-based approach to spectrum management and has been influential in shaping thinking in the European Commission. Perhaps because it considers it is 'leading the field', Ofcom and the UK generally tend to pursue its own course to the detriment of European harmonization.

3.5 Legal limits of the proposed reforms and future models

As we can see from the examples we have described, spectrum management regimes vary considerably in the EU-27. Some countries have made significant steps towards a market-based approach and assignment through auctions, whereas other still rely almost exclusively on administrative methods and beauty contests. In addition, some countries are more advanced than others in use of unlicensed spectrum.

The most significant legal constraints for the implementation the Commission proposals towards a more coherent EU spectrum policy are found at national level, especially due to:

- *legacy issues*, mostly arising from the method chosen to assign individual usage rights (e.g. beauty contest, auction, hybrid models), which results in differing economic values for frequency bands and networks;
- *lack of flexibility* in some existing licences, particularly because of long duration of licences or excessive technological prescriptions;
- *the protection of certain public policy objectives*, e.g. for services of general economic interest, which include Public Service Broadcasting, as well as emergency or safety-of-life services;
- *current use of bands by non-communications services*, e.g. governmental, military or scientific use.

Understandably the heterogeneity across the Member States limits the ability to harmonise policy across the EU. **Error! Reference source not found.** summarises the options and constraints for harmonization across the EU in key spectrum bands. The potential for spectrum fragmentation across the Member States is highlighted by the difference in approach to the digital dividend. Although digital switchover is due to be completed by all Member States by 2012, the process is characterized by Member States moving at different speeds, with different views on how much spectrum will be released, what it should be used for, and how it should be allocated. Using some of this spectrum for pan-European services would require a harmonized approach that will not materialize without much greater central coordination.

The Commission's package on reform of the regulatory framework for e-communications includes a new European Telecom Market Authority to support the Commission and national telecoms regulators.

However, with regard to spectrum regulation, what might be more appropriate is a European-level facilitator or coordinating body to help assure a common approach to spectrum requirements across the EU, as outlines in Chapter 1.

On the question of best spectrum management model for the future, the EU and the Member States are still at the beginning of a process of reform and liberalization. It seems likely that in the future there will not be one single approach that will be best in all circumstances and that more likely is a mix of traditional administrative assignment combined with both more market orientation as well as an unlicensed/commons approach wherever feasible. The challenge for future spectrum management in the EU is how to achieve the appropriate mix of these approaches. This is explored in more detail in Chapter 4.

Table 10 Existing options and constraints for EU-wide spectrum harmonization

Frequency band	Advantage	Timing of availability	Existing constraints	Possibility of EU-wide harmonisation	Current/proposed action
174-230 MHz	Coverage	**Long** *Many years needed to release TV spectrum in many MS* *T-DAB spectrum: early for countries not having introduced T-DAB or for systems operating within T-DAB data capacity*	**National level** *T-DAB assignment/ allotment limits technologies* *Existing T-DAB licences and analogue and digital TV: licences in some countries* *WRC-07 relaxed some of these constraints*	**Low** *(at least until 2012)*	**ITU level** *Low constraints in GE-06.* *WRC-07 assigned band III (ch. 61-69) to DTT.* **National level** *Member states should take action to increase flexibility in licences.*
470-862 MHz *(Band IV/V)* *(upper limit changes in some MS)*	Coverage. Potentially significant amount of spectrum	**Long** *Several years in most countries*	**WRC/RRC decisions** *Proximity of higher channels to 900 MHz 2G spectrum for dual band handsets.* **EU level** *Soon to be partially harmonised by binding EU legislation (3 sub-bands, neutrality).* **National level** *Existing analogue and digital licences for TV.* *Coexistence of fixed-roof top and indoor portable reception.*	**Low** *(until 2012)*	**ITU level** *WRC-07 assigned the 430-435Mhz, 435-438Mhz, 450-450Mhz and 790-862Mhz to IMT.* **EU level** *Communication on dig. dividend: two thirds of the UHF band coordinated at EU level.* **National level** *Need for national action to make licences more flexible.*
865-868 MHz	Use for RFID	**Early**	**EU level** *Harmonised for RFID use by Decision 2006/804/EC*	**Harmonised**	
1452-1492 MHz *(L-Band)*	Availability. Significant spectrum amount	**Early** Unused in most countries	**ITU/CEPT level** *MA02 limits to T-DAB (or systems within that mask); some licensed T-DAB use but very limited;*	**High**	**ITU/CEPT level** *Confirm mask approach; review possibility of accommodating wider-band*

Frequency band	Advantage	Timing of availability	Existing constraints	Possibility of EU-wide harmonisation	Current/proposed action
	Suitable also for indoor reception		*ITU satellite allocation and existing filings in the band 1467-1492 MHz.* *CEPT ECC/DEC (03)02 decision for satellite use in the band 1479.5-1492 MHz.* **National level** *Restrictions from other countries outside EU limit possible use of this band in some Member States.*		*technologies within Maastricht framework or consider more radical review.* **EU level** *Mandate to CEPT for EU harmonisation of the band 1452 – 1479.5 MHz (lower part of the L-band) for mobile multimedia services.*
1800 MHz *(1785-1805 or part thereof)*	Availability	**Early** *(At least for 1800-1805)*	**EU level** *Lower part of the band (1785-1800 MHz) harmonized for SRD.* *Limited amount of spectrum, if constrained to top 5 MHz.*	**High** *(at least for upper 5MHz)*	*Avoid limitations on use.*
IMT-2000/UMTS "core band" *(1900-1920 MHz and 2010-2025 MHz)*	Availability	**Early**	**CEPT/EU level** *CEPT ECC/DEC/(06)01 decision on UMTS/IMT-2000* **National level** *Existing UMTS licences.*	**High**	*To be opened for broadcast services.*
2GHz MSS	Significant spectrum amount		**CEPT/EU level** *CEPT ECC/DEC/(97)03 decision on MSS* 1980 -2010 MHz (earth-to-space) and 2170-2200 MHz (space-to-earth) harmonised for MSS by Commission decision 2007/98/EC.	**High**	*Harmonised.*
2.5 - 2.69 GHz	Availability by 2008, internationally harmonized, large amount	**Early** *(2008, subject to market demand and national licensing schemes)*	**CEPT/EU** *CEPT ECC/DEC/(05)05 on UMTS/IMT-2000 identifying harmonized utilization of spectrum in the frequency band.* *2500 – 2690 MHz for terrestrial IMT-2000/UMTS (after WRC-07, IMT includes WiMAX).* **National level** *Some countries prefer to constrain to IMT-2000, others prefer a technology neutral approach. Rules regarding in-band cross-border coordination and out-of-band compatibility to be developed.*	**High**	*Accommodate WiMAX and MBMS services.*

4. ORGANIZATIONAL FACTORS AND TECHNICAL LIMITS

4.1 Technical neutrality and spectrum usage

4.1.1 Demand for services, today and tomorrow, by radio protocol

Today's demand for radio- based services is changing faster than it has done for a hundred years. Signalling protocol types are one of the major areas of development as the new services enter. Principal entrants are the following:

WiFi: the IEEE 802.11x standard can run at various frequencies (often in unlicensed bands at around 2.4 GHz) and has grown ubiquitously globally and especially in the EU, as the preferred Internet link of choice for wireless LANs, with hubs in public spaces as much as homes and offices. Volume production has bought the cost of such radio hubs down from over €500 to under €30 for the simplest in some Member States. This is complemented by radio interface cards and now radio chips inside PCs, and almost all laptops. It is so important that all microprocessor chip manufacturers now include a WiFi chip in their standard chipset, while its data speeds have increased from 10 Mbps to around 100 Mbps. They increasingly form the basis of office and public building/ campus networks for millions of users.

WiMAX: The new longer range technology at the level of a metropolitan area, WiMAX IEEE 802.16, has been driven by the chip manufacturers (principally Intel) to open new microprocessor markets and offers over 100 Mbps over a simple spread spectrum coding. National and city-wide networks are likely over the next decade. It can operate in the unlicensed bands. But with technology neutrality it could operate in other bands – for instance this year the ITU agreed that it could operate as an alternative over certain 3G UMTS (IMT - 2000) licensed bands. This is may well be a major new standard for longer range networking, challenging established cellular mobile protocols. New standards in the WiMAX area may appear, especially if there are intellectual property conflicts over its technology, linked to algorithms with patents owned by Qualcomm (Flash-OFDM – orthogonal frequency division multiplexing). These new protocols might use licensed bands but roll-out would be far faster without waiting for international agreements on a suitable slot but instead operate in an unlicensed band.

Short-range networks: At the low-range end of the protocols, industrial sensor networks are now appearing with standards for low-rate data transfer – principally ZigBee (IEEE 802.15.4) using unlicensed bands, in the ISM range – and also the proprietary ZWave. Other networks are the RFID protocols at a range of frequencies that change by global region, for logistics and retail mostly today, and also the emergence of consumer devices from MP3 player headsets to mobile phone networking using the Bluetooth protocol with 1 Mbps transfer rates. There are also newer developments in the short-range market, with various UWB protocols being launched over the next few years. Many of their applications will be in medical environments for vital signs monitoring etc, using personal area networks (PANs). All of these will use the unlicensed bands as the shortest route to market, even they later won an agreed slot place in the spectrum.

Other developments include convergence of fixed and mobile networks using a 'next generation network' (NGN) designed for this, with all-IP traffic. Also small area coverage hubs (Femto cells) for a house or small office which integrate various protocols are appearing. They integrate various mobile protocols (GSM, CDMA, UMTS and WiMAX, WiFi, or other) with fixed line access. Their aim is to act in a repeater or extender mode as mobile communications become an indoor phenomenon –half of mobile calls are being made indoors and more for data applications.

Increasingly they will be seen as bridge from fixed mobile convergence (FMC) towards fixed to mobile substitution. Some market indications are that 20% of Western Europe has already opted for mobile only, while 18% more users are considering mobile only and two-thirds of EU citizens would use mobile at home if price was the same as fixed (Airvana, 2007).

4.1.2 Promises today and tomorrow

Mobile cellular protocols have not advanced too far, following the 3G debacle aggravated by the IPR difficulties of both 3G-WCDMA and CDMA. Higher data rates have come with enhancements (HSU/DPA – high speed up/down link packet access) for 3G, and for 2G with GPRS and EDGE enhancements, all in their various ITU-agreed GSM and UMTS licensed bands. Really we await the new technologies mentioned above to succeed these cellular technologies in some form. That may be a type of 4G mobile 'mesh' or ad hoc networks which could run over any support protocol, be it WiMAX, WiFi or a new contender, with a software layer on top (e.g. that from UK-based LocustWorld). Enormous research efforts are going on in this area[54], in China and Japan as much as the EU or the USA. What is clear is that unlicensed bands would benefit these technologies, for reasons of freedom to start up and experiment, and time to market.

Thus future spectrum demands are for technical and service neutrality, so that we may exchange existing protocols for new ones and also may enlarge the unlicensed bands as their load become greater. New services (as covered in Chapter 2) will have strong potential impacts on technical neutrality, as the higher data rate services are taken up. They could be run over various carriers, be they mobile, WiFi, or WiMAX, perhaps with a progression to higher data rates and longer range. These new services will be closely linked to EU-level networking and so the constraints will be on assuring compatibilities between services run on top of different protocols. For instance, access to email over a WiFi service in the home should be no different from receiving it over WiMAX while away from the home network.

4.1.3 Benefits for EU consumers and their lifestyles

The benefits of EU-level networking and technical neutrality will bring benefits to both citizens and industry through increased productivity (e.g. see Forge, S. et al, 2007). As many researchers have shown, mobile communications have major externalities on all other sectors of the economy. So from a cost-benefit perspective, driving the EU economy further in terms of GDP growth and employment depends to some extent on the productivity advantage of mobile services.

The social benefit of terrestrial broadcast for news and entertainment is also present. But its importance is diminishing as alternative channels to viewer, notably CATV, satellite broadcast, and in the future, webcasts with IPTV over broadband (including perhaps fixed radio access) take over the entertainment market.

4.2 International dimensions

4.2.1 Consequences of proposed reforms and international ITU and other constraints

The ultimate objectives of the international working are agreements on a set of frequency bands for both commercial and public service/military users to operate without constraining each other. Naturally this must occur in a manner which allows global interworking and where appropriate, volume manufacturing for a global consumer market.

[54] For a detailed analysis of developments, journals such as the IEEE Transactions on Mobile Computing and IEEE Computing's Pervasive Computing journal should be perused.

Moreover this has to be flexible in that the legacy of previous equipment and regulation can be smoothly transformed to the needs of the 21st century.

However it is unlikely that the international dimension for a resource considered as more valuable than water by some can be quickly changed to accommodate new technology and services. Pressures from industry groups anxious to exploit new radio technology are having a gradual impact. But they face the inertia of a system of regulatory spectrum management based on the ITU WRC meetings at four-yearly intervals, a process designed for a different era of public services and incumbent telecommunications operators. Some basic reconsideration of the process may be called for by which spectrum is allocated through negotiations between nearly 200 countries. Simplification of the basic Radio Regulations would be required. This may be possible if far more use of unlicensed bands with suitable technical constraints are made available.

4.2.2 Beyond EU borders without global re-planning – issues, costs and solutions

One alternative to reforming the global procedures would be for the EU to pioneer new directions in spectrum regulation, going ahead without the rest of world at a much faster pace. However, this raises key issues for the EU and its neighbours. Issues are concerned with conflicts technically over interference and in politically sensitive applications – principally military and broadcast services, terrestrial and satellite, where interruption of media services might be construed as a political act.

The coverage question for adjacent countries immediately becomes important. While cellular mobile may only have an overlap coverage of at most a few kilometres, with lower frequencies from the digital dividend, this could be up to 10 km or more, while newer technologies such as WiMAX could be even more – perhaps 20 km. However judicious base station siting and power level setting would presumably be used to limit overlaps to a few kilometres at most. The base station directional antennae can be set up so that the propagation lobes are oriented away from frontier crossings. The reverse issue, of other countries' emissions clashing with the EU in differently utilised bands (e.g. TV broadcasts in digital dividend areas given over to mobile in the EU) is naturally a further effect to be considered, requiring a detailed band by band, geographic border analysis.

A far bigger issue might be interference with a neighbour's terrestrial broadcasting and perhaps even more, unrestrained satellite footprints from EU satellites. Content IPR issues are also relevant, as transmission rights may only have been procured for certain countries and other operators may have the rights outside the EU. Interference with broadcast media might even be seen as a hostile act in some way, if it interrupts, jams or even replaces political and cultural content. A second major issue that might be seen as somewhat aggressive would be overlap with reserved military spectrum in neighbour countries, since effective jamming might be perceived as some form of threat.

Costs would consist of possible damage in monetary terms of disruption of military, political and ordinary services. Damages would have to be assessed case by case or possibly in some form of international arbitration. Impossible to estimate, they potentially could be high.

Potential technical solutions are not straightforward but must be based on first understanding the new spectrum proposals against the major transmissions of neighbouring states and the potential seriousness of any interference, a function of the transmission being affected and its national priority. One technical solution, viable only for certain applications, might be in far wider usage of advanced spread spectrum signals. By their very nature, they may be undetectable in neighbouring countries, as typically they are below the ambient noise level at any frequency in the frontier regions of the neighbour.

Regulatory solutions might lie in reciprocal bilateral agreements with the most affected neighbouring states, for transmissions which are single frequency or frequency dependent. A draft spectrum plan for the EU could be presented, and its impacts examined against the national spectrum plans and agreements drawn up on power levels and reciprocal use on interleaving to give non-interfering strong frequencies.

Overall impacts of going ahead unilaterally may be mitigated by the above approaches but would require a progressive approach to avoid major clashes with neighbouring spectrum regimes. The advantages for the EU would be economic, from early deployment of new radio technologies, without waiting for the far slower worldwide negotiation process.

4.3 Implementation – Big Bang or planned transition?

4.3.1 Options for implementation

Implementation of proposed spectrum reforms and their overall impacts need to be considered in the context of the future EU economy and society. Specifically we consider whether there is a need for an accelerated pace of reform and note that changeover would be principally in the major areas of:

1. Neutrality on technology and services for any band.
2. Harmonized regulation of spectrum allocations and allocation mechanisms across all EU member states.
3. Increased use of unlicensed bands to form a spectrum commons.
4. Introduction of market-based allocation with auctions and secondary trading.
5. A central EU facilitator to co-ordinate spectrum related issues, with a central EU database registry of users and their usages by frequency.
6. Introduction of financial incentives for public sector users to give up spectrum.
7. Rebalancing of existing usages of the spectrum, specifically the digital dividend.

The major options for implementation of spectrum policy include:

- A single major change event or ‘big bang’ for all the EU.
- A progressive implementation of reforms, with a planned transition for the above list one at a time (or several together, if it makes better sense) across the EU. A possible first step would be endorsing the central facilitator and registry to organise the other measures in a programme of reform.
- A staged implementation, either in geographic blocks (e.g. Benelux countries, or Iberian, or Baltic states) or by individual Member State as a series of phases, with a target end date. Member States may reform at their own rate, within limits.

4.3.2 Policy discussion: the practical limits today and tomorrow

The pros and cons of each option are analysed below using a SWOT analysis.

Table 10: Options for implementation of spectrum reform in the EU

A major single change event or 'big bang'	
Strengths Simple, clear.	**Weaknesses** Unlikely to succeed as too much change at once. Requires enormous organization. Requires co-operation of all interested parties and vested interests.
Opportunities May push the EU to the forefront quickly in technical and economic returns.	**Threats** Lack of agreement by vested interests in one MS could derail whole change event across the EU. High risk - could cause the whole reform to be abandoned, as viability of change would be undermined and its failures would be evident. The above might leave EU in a spectrum mess of half-finished measures, different in each MS.
A progressive implementation, by reform, with a planned transition across the EU	
Strengths Allow for differences to be ironed out for each measure. Progressive change gives time needed to persuade interested parties.	**Weaknesses** Lengthy process and may meet further delays as some MS might try to slow process for certain they view as unwelcome measures.
Opportunities Better planning - a far stronger EU spectrum agreement and support plus understanding of reforms.	**Threats** Cannot get agreement in some MS, despite major pressures, due to vested interests. Patchwork of reforms.
A staged implementation, in geographic blocks or by Member State	
Strengths Allows each MS to move at own pace. Should gather consensus of all MS.	**Weaknesses** Longer and may meet delays as each MS or group of MS takes time to agree to reforms
Opportunities Smooth transition as each MS has time to put own house in order. Peer pressure to achieve reforms, if use published scorecards.	**Threats** Failure of some MS to agree at all - patchwork of reforms, with all of the EU at different stages of reform, and moving slowly.

4.3.3 The preferred option with supporting arguments

From the above, it would seem that the second or third options are viable. The second option may be the most pragmatic in getting the EU to move forward on reforms at a set of common stages, led by a central facilitator for coordinating the Member States and a reform programme. The first option appears unrealistic in that doing everything at once may give one chance only – a single point of failure for everything. Thus it is high risk, and also requires enormous preparation and organization with agreement of all interested parties.

The EC commissioned report on secondary trading (Analysys, 2004) noted that 30% of the possible benefits will only be realised if all Member States move together. Thus a European dimension of new allocation mechanisms is important but so much change should be effected as a series of reforms, rather than one.

4.4 Co-existence in the same band - limits and possibilities

4.4.1 Sub-band identification and related issues

Currently there is a different overall allocation pattern by Member State within which are global and regional agreements, e.g. for GSM, UMTS mobile and certain other functions such as TV channels and IMS bands. Introducing a more flexible spectrum use rests on the technologically neutral definition of the spectrum right itself. Such a redefinition must consider the interference environment present and then adduce sufficient controls that existing services, at least, would be able to operate. Part of this might be to identify sub-bands suitable for refarming (suitable politically as well as technically) and particularly identified for a possible common form of allocation.

Today's technology in widespread use does not yet permit sharing the same frequencies to any great extent. That does not mean we should not anticipate such a development, as considered in the next section, but that we have to move to new technology gradually.

The next step therefore, in what is really an iterative process, is to examine whether interference controls can be steadily relaxed as new technology, appears for sharper cut-offs and for full sharing, and what effect that might have on other users. Regulators will have to apply judgement as to the level of risk they are prepared to accept that interference might arise as a result of the proposed relaxation from a command and control situation. Either new divisions for unlicensed bands may be introduced, or in bands with a secondary trading regime, the market might be left to negotiate further changes to interference parameters amongst itself, albeit that the regulator may be required to agree and register any changes proposed. For instance some NRAs where trading is primarily considered (e.g. the UK's Ofcom) have reviewed this model. The NRA then attempts to determine uses (or property rights in the case of trading). For instance, the 900 MHz GSM band has been examined to see what conditions would need to be relaxed or applied to permit W-CDMA to also operate in the band and we can expect examples of this approach to increase.

4.4.2 Constraints and possibilities for frequency co-planning

A model as outlined above considers the specific interference environment present and must be country specific. One might expect to see similar levels of relaxation introduced where environments themselves are similar but a harmonized use or even property right for any particular frequency band across the EU is unlikely today, but should be envisaged for tomorrow. However, this would require far more co-ordinated action at the EU level, hence there is a need for a co-ordinating EU facilitator.

To reach the ultimate goal of maximizing economic use with far more sharing, potential future directions should be led by a regulatory and organizational drive to a technical solution. One way forward would be to agree on bands (e.g. UHF) and within the bands, sub-bands which would be earmarked for re-allocation or refarming, especially below 3 GHz and particularly below 1 GHz.

They would be divided as different allocation regimes:

- Managed command and control allocation, usually for military and public service for services based on sole-use-of-frequency technologies.

- Traded spectrum rights with a licence to hold the spectrum and operate any service over any technology which respected the interference criteria, usually for sole usage applications but with secondary and primary user structure for interleaving, overlays and 'borrowing' when not in use; largely for legacy protocols e.g. GSM.
- Unlicensed bands, increasingly using spectrum sharing.

Agreements required would have to be at an EU level and also pursued at a regional level to encompass neighbouring states. The organizational structure would be of that given in outline in Chapter 2 in looking at pan-European services. A key point to note is that such EU-wide agreements across the three categories could not be set in stone. With the demands from accelerating developments in radio technology over the next two decades, the command and control band could be expected to shrink. Technology directions for the new services will depend far more on unlicensed bands. So progressively unlicensed would tend to expand, as licensed and managed command and control shrink.

4.5 Technical compatibility - problems and consequences

4.5.1 Diverse issues of reception, and down/uplink constraints

The air interface is where reception considerations and constraints with current technologies are manifest and today there seem to be few choices. The above analysis relies on the traditional model with separation for interference reasons. It does not really take into account the advances in technical compatibility as technologies capable of sharing the same reaches of spectrum take hold.

Today's technology needs guard bands for mobile broadband (and for narrowband mobile services) to avoid interference between uplink transmissions and adjacent (downlink) broadcast transmissions. The width of a guard band depends on many factors and could even be more than 10 MHz (Doeven, 2007). Also a guard band is needed between the uplink and the downlink sub-band. The total guard bands and thus the unused spectrum may be quite wide (it might add up to several TV, that is DVB-T, channels of 8 MHz). However this is a moving target. Spectrum efficiency is a factor of digital signal processing technology (and the computing power behind it) which advances every year, so guard bands will tend to narrow in the future until they virtually disappear. Moreover we have to consider the end-to-end network optimization. This could include compression and bit-rate encoding per Hz which significantly cuts the bandwidth required to transport a communication, especially important for video. Moreover, interference of digital signals is also a factor of the signal processing techniques for identification in noise which can only be expected to advance.

4.5.2 The promise of new technologies for sharing spectrum with existing systems

Spectrum management in the future must give more emphasis to sharing, be it in direct forms or with interleaving and overlays based on several forms of sharing technique:

- Time: temporal management of frequencies which are free to use on an ad hoc basis – using CR and frequency hopping.
- Frequency: the standard approach but refined by advanced signal processing including compression and bit-rate encoding to use less bandwidth and narrower guard bands.
- Signal to noise power: the 'interference temperature' and overlay/underlay approach of 'tolerable interference'.
- No detectable power at one frequency: spread spectrum techniques.
- Spatial: directional antenna that focus on communicating transceiver.

The technical and regulatory implications of this are manifold as we should envisage a far more flexible regime covering both unlicensed and licensed bands but possibly not managed command and control regions (for reasons of political and public safety factors) unless prior agreements in restricted bands can be achieved.

More specifically, technical approaches to interference management include concepts of underlay and overlay, vacant slot filling (Shared Spectrum Company, 2004) and sharing. In November 2003, the FCC sought comment on the feasibility of implementing a so-called 'interference temperature' model for quantifying and managing interference. The interference temperature model is intended to provide a more accurate measure of interference by taking into account the cumulative effects of all unreserved RF energy in a given environment. This approach to interference management fundamentally alters spectrum policies by focusing on the actual radio frequency interference environment confronted by receivers, instead of the transmitter operation. Interference temperature is of particular importance to the satellite industry.

In the USA, the FCC proposed to introduce the concept first in frequencies where Fixed Satellite Service (FSS) uplinks are the predominant use, namely, portions of the C- and Ku-band, for a large number of unlicensed devices to operate in the target bands, with appropriate power levels. However, the US satellite industry was concerned about the implications interference temperature concepts have for satellite operations in the C- and Ku- uplink bands. The FCC believed that an interference temperature approach could be superior to its traditional focus on transmitter power and frequency to facilitate increased use of licensed spectrum by *unlicensed* devices and also provide greater protection and certainty for incumbent licensees by more accurately measuring actual interference in a given RF environment. However the whole concept of interference temperature is controversial because it may infringe substantially on existing licensees' operations.

In contrast, is the spectrum commons approach which also envisions use of increasingly intelligent end-user devices – decentralised intelligence – to dramatically increase spectrum sharing. One issue for a spectrum commons approach is the amount of detail or specificity that is contained in the rules and regulations intended to avert the tragedy of the commons, i.e. the over-use of a shared economic resource (Hatfield, 2005). Simple rules such as, listen for other users before you transmit, or, use only the minimum amount of power necessary to communicate, may help to reduce interference and improve utilization of the resource. Likewise, more complex rules limiting the types of signals that are transmitted might possibly make it easier for receivers to reject interference.

At some point, however, detailed restrictions – no matter how well-formulated – may reduce the ability of innovators to progress. The fundamental advantage of the spectrum commons approach is its ability to respond quickly to changes in technology and the marketplace. It must not be lost through detailed restrictions. Thus, over-regulation is the enemy - spectrum managers face a trade-off between increased utilization of the resource in the short term and potential greater innovation in the longer term.

4.5.3 Road map for an eco-system to progress with co-existing differing technologies

To move forward it will be necessary to reach agreement on where best to place unlicensed bands in view of the progression of other users to new frequencies under spectrum reform. Here an economic analysis of where an EU agreement could place unlicensed spectrum is required. Even a relatively small shift could have significant economic consequences. It would then be implemented through performance limits on devices and testing for conformance. Thus the next step is towards defining fixed-boundary frequency bands, which should gradually be converted to either exclusive property rights, or to be part of the commons, with mechanisms for reversibility at some future point.

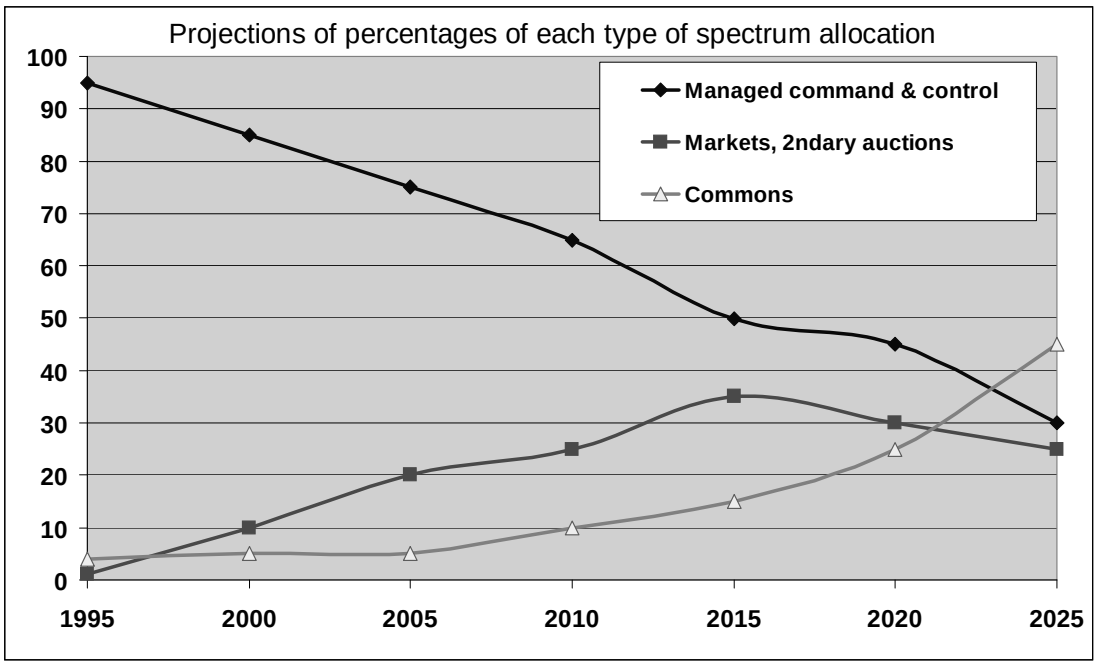
This division would entail establishing some robust measure of spectrum efficiency usage, in terms of optimizing the amount and economic value of communications that occur.

All of this will need a common sense regulatory framework to avoid the chaos that might result in abandoning a national allocation system, and to also avoid opposition to reform based on its poor organization. Questions will have to be asked such as whether today's (public) terrestrial and satellite broadcasting is in some way socially valuable and deserves special privileges, while the priorities are more obvious for public safety services. In the traded bands, attention must be paid to windfall profits from secondary trading against consumer welfare and the price of communications.

The future framework for spectrum management may be founded on some basic measures such as a spectrum registry and an EU facilitator. Key areas to then consider and decide on include: trading standards for market-based allocations; privatization of public services including public safety communications; reserved spectrum for special interest groups; overlay rights, of 'borrowing' licensed spectrum; underlay rights, e.g. use of innovative technologies such as UWB; and the digital dividend allocations. Far more radical management restructuring, such as abolishing an EU facilitator and the NRAs and replacing all with a spectrum court, to deal with questions of allocation and conflicts over interference as has been suggested for the USA, does not seem at this time to be valuable.

Instead we envisage a progressive managed transition to new usages of the spectrum in a gradual manner over the decades, with changing portion so the spectrum allotted to each form of assignment, as shown in the possible road map of Figure 9.

Figure 9: A road map for a shared spectrum eco-system,



5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The radio spectrum is an essential factor for economic progress in the EU – it is a key basis for future productivity, specifically when used for ICTs. But it has more than just commercial objectives – it has a social dimension. The value of the spectrum must be seen in the context of social trends and the public objectives for the well being of the citizen.

As such there are implications for a true single market that are linked to spectrum governance for EU-wide uses. In order to build up all the economies in the EU-27 to be equally prosperous, especially to close the digital divide, spectrum management and assignment needs to be reviewed and revised. In this regard, a mobile Internet with optimal cost efficiency over a broadband bearer will become a prominent demand. However, fragmented regulation will make this more difficult to achieve.

The current disposition of spectrum is inefficient. Older technologies have taken the prime spectrum at lower frequencies and with new technologies being developed there is now a need for spectrum reform. The prime bands at lower frequencies offer better propagation for much lower cost networking and superior building penetration for high bit rate services such as broadband (mobile, or fixed radio local loop) (European Commission (2004).

Thus spectrum management reform will require dialogue involving all Member States to pursue two seemingly contrary goals – a harmonized EU-wide approach with more flexibility and ease of assignment.

EU harmonization of the spectrum has the advantage of organizing a common context for future radio e-communications services. This is increasingly important as the EU progresses in integration commercially and in lifestyles. New radio services can be expected to expand in functions, numbers of users and types of usages. We may expect a far heavier dependence on such services by future EU citizens, in the areas from health to supporting complex lifestyles and a range of new business usages. Opening up of EU-wide service markets should be more competitive and so more cost efficient for users. Harmonization of spectrum usage also means that volume manufacturing can cut the costs of handsets and networking equipment and drive towards common user interfaces.

Harmonization also could reduce the bill to Member States for governance and regulation if some of their responsibilities can be handed over to a central EU coordinator. However, there are arguments against this that should be taken into account, notably:

- The national plans for spectrum uses, especially for broadcast public services, which may be constrained, although they may be seen as having a social role. However even here, the use of common frequency planning across the EU for terrestrial DTV and future developments in its definition may benefit all in the long run, as far as audiences covered, consumer equipment and possibly consumer confusion.
- The problems of negotiating with NRAs, and with Member State governments to reduce their powers, by effectively handing them over in some areas.
- Removal of restrictions on spectrum use in terms of technology and service neutrality in the EC proposals is a key issue. It could substantially increase the benefits that EU industry and society derive from spectrum use.

On the question of 'flexibility', the requirement for co-existence of multiple allocation methods should be considered, the several contenders being:

- a commons for all, with unlicensed bands, becoming the most important.
- trading spectrum with a market mechanism, in co-existence with a free commons.
- collective use in the sense of sustainable interleaving between licensed bands and also overlaps with low interference, perhaps with an arrangement of primary and secondary users.
- managed command and control, the designated assignment by the authorities.

When we examine these various options, the basis for choosing between them is twofold: first, the extent to which the method enables real competition and market freedom stimulating the innovation that will spur the EU economy in terms of jobs, productivity, revenues and overall GDP growth; second, the degree to which the method puts communications at low cost into the hands of the citizen.

This implies ease of entry for the new, for rapid advances in services and their costs as much as pure technology. Thus the main criteria choosing between the different allocation methods turn on measuring how each encourages:

- Fast and easy entry for new radio-based services, service providers and technologies
- Low cost of entry for new service providers and new technology producers
- Efficient (re)use of spectrum
- Innovations in technologies, services and business models
- Neutrality on services or technologies, such that the allocation method does not become a barrier to entry to either
- Minimal regulatory intervention
- Low cost of management (by regulators).

Thus although markets and licence auctions seem to be interesting in the light of the above, their ability to act as a barrier and to choke off new entrants without deep enough pockets, who could introduce more competition and new technology, is less often admitted. The 3G UMTS auctions paint a dismal picture here.

Decisions should driven by economic policy rather than technology or politics, for instance when allocating the digital dividend from the analogue TV switchover. In essence there are two key questions on the proposed EC spectrum policy, first:

How well do the proposed measures fit the needs and potential economic success of Europe in optimally managing, allocating and using spectrum?

The answer from reviewing the EC policy documents is - fairly well. The whole subject is being taken seriously enough and the various proposals are sound as far as they go. But the dialogue is dominated by two considerations:

- The balance between Member States and the EU over governance – is there a need for an EU regulator for harmonized spectrum allocation, and so would policy making and implementation be at an EU level, or national level, or both? The proposal by the European Commission for a European Telecommunications Market Authority obviously prompts the question of whether it could play such a role. Spectrum liberalization is one of the few cases that may well justify a 'necessary centralism'.

This would enable a new spectrum framework to be created, which itself requires a strong degree of harmonization, to eliminate waste through inconsistent use of frequencies across Europe. The European Telecommunications Market Authority, as proposed with its power of veto over national regulators, appears to be the logical platform for liberalization of the spectrum (and the whole industry) – emphasising competition and investments in innovative services and technologies. As such it is the place to position an EU coordinator for spectrum allocation, one who must negotiate change and migration among the Member States, to organize spectrum harmonization across the EU.

- The move to trading as the only alternative to managed command and control with no real consideration of other alternatives. This US-centric view is presumably made for reasons of the tax harvests that Member State treasuries anticipate, and also perhaps the EC for centrally managed EU-wide auctions.

The second question is:

What is missing or needs to be changed?

Our analysis highlights several missing items:

- Identification of where each allocation method fits.
- A scheme for a harmonized approach to releasing spectrum from the military and national public services, in terms of inducements to relinquish spectrum and in the bands of spectrum released and retained by these public service users.
- Legal frameworks for shared spectrum in licensed bands.
- On the technical/regulatory side, the anticipation of more unlicensed bands for a commons and agreement on their source.

Future mobile services and their spectrum requirements are likely to be in two major directions. First is the need for more bandwidth to support major expansion in mobile and fixed-radio broadband. Second is the expansion of new radio technologies which depend on the computer industry model of unfettered communication, of a commons of unlicensed bandwidth, with regulation focused on the terminal devices technical specification, à la WiFi. Unlicensed spectrum will be the basis for the advanced innovation for ICT products and R&D for the next two decades at least.

We conclude with the principle that future operation of e-communications and entertainment radio networks will move more towards Internet access but from a mobile handset. In this model, any terminal device may access any radio network in a completely free manner.

5.2 Recommendations

Suggestions for the way forward should therefore include:

- Harmonization of EU spectrum management reform to be pursued immediately – a framework for carrying out a comprehensive spectrum management for Europe is required. The catalyst would be a central coordinator at EU level, able to facilitate a phased transition in spectrum management across the EU. This facilitator should co-ordinate reforms in concert with NRAs with a registry database of users and uses. The facilitator should have sufficient authority to follow through the reforms below, appropriate to the responsibility for co-ordination.
- Technical neutrality – no specification of any technology or standard. A phased transition to this is recommended, with time limits and milestones.

- Service neutrality – any spectrum band may be used for any application. The notion that function of a specified band is fixed for all time should be abandoned, although there may be agreements to use several or many associated services in one band, e.g. for TV. A phased transition to this is recommended, with time limits and milestones.
- Far more spectrum progressively built up into a commons of unlicensed bands – note that governments may be against this for tax reasons. This move would accompany a change of model of spectrum use – that of unfettered access, similar to the Internet, which is not really yet considered in EC policy.
- Collective spectrum use in the sense of sharing licensed bands, with secondary users, who interleave and overlap without interference.
- Releasing public services and military spectrum to commercial and individual users – the way forward in refarming may be to encourage users with financial incentives to sell their surplus spectrum as a licence to whomsoever they wish, or place it in the unlicensed commons. The former would enable market forces to drive the specific frequencies and amount of spectrum available.
- The digital switchover from analogue to digital TV and the digital dividend as part of harmonization should re-apportion large amounts of the spectrum (of the order of 75%) to non-broadcast TV applications including mobile and fixed-radio broadband access in licensed and unlicensed bands.
- Reform of institutions for standards and research in Europe, so that failures over IPR, standards and technology are not repeated (e.g. UMTS, ERMES, etc). A new R&D initiative with a centre of excellence, a European radio research institute would be ideal. Its goal would be to pursue open, public research for radio technology and for building up global technical standards, establishing an IPR base to avoid the threat of private hoarding of key patents.
- Finally, the European Parliament has a significant role to play in ensuring that the EU develops spectrum policy fit for purpose and in light of technological progress and market development. This of course includes its traditional role in amending or, if necessary, rejecting legislation. Beyond this, the European Parliament is ideally placed to highlight the importance of spectrum policy through raising the profile and level of the debate on this topic through the use of, for instance, non-binding resolutions, committee hearings, written declarations, and so on. The topic is complex but it is crucially important that Europe's citizens understand its importance.

BIBLIOGRAPHY

Airvana (2007) 'Femtocells: overview', presentation at Mobile Broadband, October 2007.

Analysys et al (2004) *Study on Conditions and Options in Introducing Secondary Trading of Radio Spectrum in the European Community*, Final Report for the European Commission, available at http://ec.europa.eu/information_society/policy/radio_spectrum/activities/studies/index_en.htm

Aral, S. et al (2006) 'Which came first, IT or productivity? The virtuous cycle of investment and use in enterprise systems', presentation to the 27th International Conference on Information Systems, Milwaukee, http://ssrn.com/abstract=942291

Benkler, Y. (2002) 'Some economics of wireless communications', *Harvard Journal of Law & Technology*, Vol 16, No 1, Fall, pp. 25-83, available at http://jolt.law.harvard.edu/articles/pdf/v16/16HarvJLTech025.pdf

Benzoni, L. et al (1993) *The Economics of Radio Frequency Allocation*, ICCP #33, OECD, Paris.

Bohlin, E. et al (2006b) Mapping European Wireless Trends and Drivers, Report No 22250 EN, IPTS, Seville, http://www.jrc.es/publications/pub.cfm?prs=1428

Bohlin, E. et al (2006a) 'Telecoms infrastructure to 2030', in *Infrastructure to 2030: Telecom, Land Transport, Water and Electricity*, OECD, Paris.

Coase, R. (1959) 'The Federal Communications Commission', *Journal of Law and Economics*, Vol. 2, October.

Dettmer, R. 2005) 'Up the revolution', *IEE Review*, May 2005.

Doeven, J. (2007) 'Implementation of the digital dividend: technical constraints to be taken into account', *EBU Technical Review*, January.

Europe Economics (2006) Economic Impact of the Use of Radio Spectrum in the UK, study for Ofcom, http://www.ofcom.org.uk/research/radiocomms/reports/economic_spectrum_use/

European Commission (2002) Decision No 676/2002/EC on a regulatory framework for radio spectrum policy in the European Community (Radio Spectrum Decision), adopted 7 March 2002.

European Commission (2004) Communication on A market-based approach to spectrum management in the EU, COM(2005)400 final, 14 September 2005.

European Commission (2007a) Communication on Rapid access to spectrum for wireless electronic communications services through more flexibility (COM/2007)50 final), 8 February 2007.

European Commission (2007b) Decision 2007/344/EC on harmonized availability of information regarding spectrum use within the Community, adopted 16 May 2007.

European Parliament (2007) Resolution, Towards a European policy on the radio spectrum (2006/2212(INI)), P6_TA(2007)0041, 14 February 2007

Forge, S. (2004) 'Is fourth generation mobile Nirvana or… nothing?' *info*, Vol 6, No 1, August

Forge, S. et al (2006) 'Spectrum for the next radio revolution: the economic and technical case for collective use', *info*, Vol 8, No 2.

Forge, S. et al (2005) *The Demand for Future Mobile Communications Markets and Services in Europe*, Report No 21673 EN, IPTS, Seville, http://www.jrc.es/publications/pub.cfm?id=1278

Forge, S. et al (2007) *The Mobile Provide: Economic Impacts of Alternative Uses of the Digital Dividend*, SCF Associates, Princes Risborough, available at http://digitaldividend.eu

Geiss, A. (2004) Issues of Spectrum Policy Relevant to the Civil/ Military Relationship, presentation to CEPT/ FM Civil/Military Meeting, Brest, 23-25 March, http://ec.europa.eu/information_society/policy/radio_spectrum/docs/ref_docs/speeches/civil_military.ppt.

Hatfield, D. (2005) 'Spectrum management reform and the notion of the spectrum commons', *Southern African Journal of Information and Communication*, Vol 4, Spring, available at http://link.wits.ac.za/journal/j0401-hatfield-spectrum.pdf

Hazlett, T. (2001) 'The wireless craze, the unlimited bandwidth myth, the spectrum auction faux pas, and the punchline to Ronald Coase's 'big joke': an essay on airwave allocation policy', *Harvard Journal of Law & Technology*, Vol 14, No 2, Spring, pp. 336-469.

Indepen et al (2004) *An Economic Study to Review Spectrum Pricing*, 2004, study for the UK Radiocommunications Agency, February.

ITU (2005) *The Internet of Things*, ITU, Geneva, http://www.itu.int/osg/spu/publications/internetofthings/

Maliranta, M. et al (2006) 'Informational mobility and productivity: Finnish evidence', *Economics of Innovation and New Technology*, Vol 15, No 6.

McHenry, M. (2005) *NSF Spectrum Occupancy Measurements Project Summary*, Shared Spectrum Company, Vienna, VA.

Mott MacDonald et al (2006) *Study on Legal, Economic & Technical Aspects of 'Collective Use' of Spectrum in the European Community*, report for the Radio Spectrum Policy Unit (RSPU) of DG Information Society & Media, November.

NERA (1995) *The Economic Impact of the Use of Radio in the UK*, Report for the Radiocommunications Agency.

Open Spectrum UK (2007) Comments for Analysys regarding Ofcom's Digital Dividend Review', http://www.ofcom.org.uk/consult/condocs/ddr/responses/nr/open_spectrumuk.pdf

Ovum (2004) *The Economic Contribution of Mobile Services in the European Union Before its 2004 Expansion*, Report to the GSM Association, London.

Minervini, F. et al (2007) *Spectrum Management and Regulation: Towards a Full Fledged Market for Spectrum Bands?*, University of Macerata, DiSSE, working paper No 7.

Richards, E. (2007) 'A central telecoms regulator would hurt Europe', *Financial Times*, 30 October, http://www.ft.com/cms/s/0/3cf4f256-8702-11dc-a3ff-0000779fd2ac.html?nclick_check=1

RSPG (2005) Opinion on Wireless Access Policy for Electronic Communications Services (WAPECS): A more flexible spectrum management approach, Radio Spectrum Policy Group, RSPG Opinion #3, RSPG05-102final, 21 November, http://rspg.groups.eu.int/doc/documents/meeting/rspg8/rspg_05_102.pdf

SCF Associates (2006) *Benchmarking Impacts of EU Policy: Options for Economically Efficient Management of Radio Spectrum*, Report for DG Information Society & Media, Brussels, December

Smura, T. et al (2006) 'Radio spectrum policy in Europe', in Sakari, L. (ed), *Innovation in Telecommunications: Proceedings of the Research Seminar on Telecommunications Business*, http://www.tml.tkk.fi/Opinnot/T-109.7510/2006/Proceedings_2006.pdf

Srivastava, L. (2006) 'Radio frequency identification: ubiquity for humanity', *info*, Vol 9, No 1.

Starks, M. (2007) *Switching to Digital Television: UK Public Policy and the Market*, Intellect Books, Bristol, UK

Sterling, C. (2007) *Military Communications*, ABC Clio, Santa Barbara, CA.

Tramont, B. (2005) 'Remarks of Bryan Tramont' Spectrum Policy Conference, Guatemala City, Guatemala, available from http://cadep.ufm.edu.gt/telecom/ingles/interior.asp?menu=lecturas

Turton, S. (2007) 'EU spokesman savages self-serving Ofcom', *PCPRO*, 31 October, available at http://www.pcpro.co.uk/news/134442/eu-spokesman-savages-selfserving-ofcom.html

Werbach, K. (2004) 'Supercommons: toward a unified theory of wireless communication', *Texas Law Review*, Vol 82, pp. 863-973, http://werbach.com/research/supercommons.pdf

ZetaCast (2007) *Review of DTT HD Capacity Issues*, An Independent Report Commissioned by Ofcom, http://www.ofcom.org.uk/consult/condocs/dttfuture/report.pdf

LIST OF ACRONYMS

3G	Third Generation Mobile
AWT	Alternative Wireless Technology
BAN	Body Area Network
CATV	Cable television
CDMA	Code Division Multiple Access
CEPT	Conference Européenne des administrations des Postes et des Télécommunications
CR	Cognitive Radio
DSL	Digital Subscriber Line
EBU	European Broadcasting Union
ERT	Emerging Wireless Technology
Flash OFDM	Flash Orthogonal Frequency Division Multiplexing
GDP	Gross Domestic Product
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications (originally Groupe Spécial Mobile)
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
IPR	Intellectual Property Rights
IPv6	Internet Protocol Version 6
ISDN	Integrated Services Digital Network
ISV	Independent Software Vendor
ITU	International Telecommunication Union
MAN	Metropolitan Area Network
MMS	Multimedia Messaging Services
MIMO	Multiple In Multiple Out
MNO	Mobile Network Operator
MS	Member State
NFC	Near Field Communication
NICs	Newly Industrialised Countries
NRA	National Regulatory Authority
PSTN	Public Switched Telephone Network
RFID	Radio Frequency Identification
RSPG	Radio Spectrum Policy Group
SMS	Short Message Service
SDR	Software Defined Radio
UMTS	Universal Mobile Telecommunications System
UWB	Ultra Wide Band
VAR	Value Added Reseller
VoIP	Voice over Internet Protocol
W-CDMA	Wideband Code-Division Multiple-Access
WiBro	Wireless Broadband
WiFi	Wireless Fidelity
WISP	Wireless Internet Service Provider
WLAN	Wireless Local Area Network
WiMAX	Worldwide Interoperability for Microwave Access
xDSL	Refers collectively to all types of digital subscriber lines