



INTERNATIONAL TELECOMMUNICATION UNION

**WORKSHOP ON RADIO SPECTRUM MANAGEMENT
FOR A CONVERGING WORLD**

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BACKGROUND PAPER:

**RADIO SPECTRUM MANAGEMENT FOR A
CONVERGING WORLD**



International Telecommunication Union

This paper has been prepared by Eric Lie <eric.lie@itu.int>, Strategy and Policy Unit, ITU as part of a [Workshop on Radio Spectrum Management for a Converging World](#) jointly produced under the New Initiatives programme of the Office of the Secretary General and the Radiocommunication Bureau. The workshop manager is Eric Lie <eric.lie@itu.int>, and the series is organized under the overall responsibility of Tim Kelly <tim.kelly@itu.int>, Head, ITU Strategy and Policy Unit (SPU). This paper was edited and formatted by Joanna Goodrick <Joanna.goodrick@itu.int>. A complementary paper on the topic of Spectrum Management and Advanced Wireless Technologies as well as case studies on spectrum management in Australia, Guatemala and the United Kingdom can be found at: <http://www.itu.int/osg/sec/spu/ni/spectrum/>.

The views expressed in this paper are those of the author and do not necessarily reflect the opinions of ITU or its membership.

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1 Introduction

From its humble beginnings as an abstract mathematical idea propounded by Jean Baptist Fourier (1768-1830), radio spectrum (or spectrum for short) has now become an indispensable element in a diverse range of applications including broadcasting, mobile and satellite communications and radar. Vital services such as national defence, public safety, disaster warning, weather forecasts and air-traffic control all depend on access to spectrum.

1.1 Trends in spectrum demand

The range of services for which spectrum is used continues to grow, while the demand for such services has seen a phenomenal increase in recent years. In the past decade, ITU has recorded more frequency assignments than during the entire previous history of radio.

A particularly striking example of this growth in demand for wireless services can be seen in the growth of mobile telephony worldwide over the past decade (see Figure 1). In 2002, the worldwide number of mobile phone subscribers surpassed the total of fixed-line customers and this trend is predicted to continue.

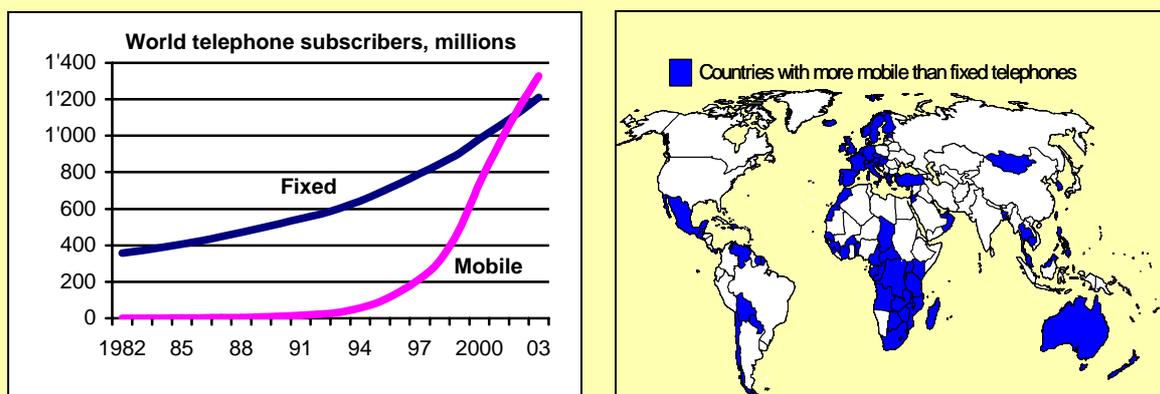
To a large extent, the recent trend of liberalization, deregulation and privatization in telecommunication services, particularly in the mobile and ISP sectors, have increased competition, in turn causing mobile telephony prices to fall and demand to rise (see Figure 2). Correspondingly, new technologies and services, such as mobile data, have been developed alongside to tap this increased demand for ubiquitous access to communication.

With its cost advantages and its ability for rapid deployment, wireless access for telephony and data services has also conquered new markets. Wireless networks are fast becoming the preferred infrastructure solution for developing countries and rural areas where fixed-line communications have been found to be too costly to deploy.

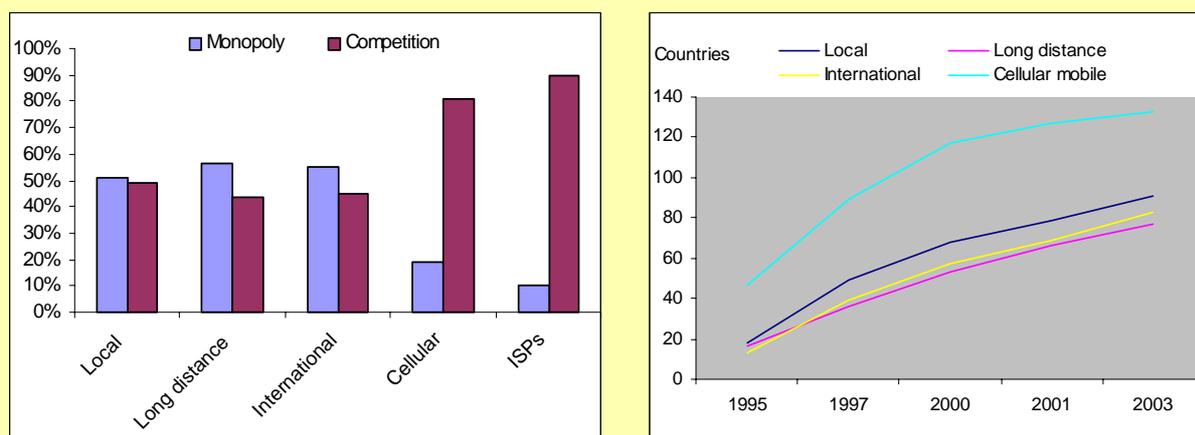
Meanwhile, while the recent growth in demand for mobile telecommunication services has driven a large portion of spectrum demand, the growing popularity of entirely new applications such as the Global Positioning System (GPS), which was originally developed for defense purposes, as well as radio tracking applications such as the use of Radio Frequency Identification (RFID) tags have also placed a greater burden on spectrum resources.¹

Figure 1: Mobile overtakes fixed

Number of worldwide fixed and mobile telephone subscribers, 1982-2003 and countries having more mobile than fixed telephone subscribers, 2002



Source: ITU World Telecommunication Indicators database.

Figure 2: Countries allowing competition in telecommunication services

Source: ITU World Telecommunication Regulatory Database.

1.2 Implications for spectrum management

While governments have kept pace with spectrum demand over the better part of the last century by gradually increasing spectrum supply, technological advances and economic liberalization over the last few years have dramatically increased the pace of spectrum consumption, causing demand to increasingly outstrip supply. This spectrum crunch has placed greater pressure on regulators to correctly ration and balance spectrum demand between various competing uses. With this growing strain on regulatory resources, the shortcomings of the traditional, centralized approach to spectrum management have been made more apparent, causing governments to seek new approaches to spectrum management.

This paper is intended to serve as a primer for some of the new spectrum management approaches that have been proposed or are being practiced by a growing number of countries. Section 2 provides a description of the traditional regulatory framework for spectrum management while section 3 examines the role of spectrum management today. Section 4 goes on to describe some of the new market-based approaches to spectrum management that are currently being implemented or considered by a growing number of countries. Finally, section 5 discusses some of the crosscutting issues that the adoption of these new approaches may raise.

2 Regulatory frameworks for spectrum management

Because two or more radio signals occurring simultaneously and over the same frequency can interfere with each other and nullify their benefits, spectrum must be managed to prevent interference. When Guglielmo Marconi invented communication over radio waves in the late nineteenth century, there was no system of management of the electromagnetic spectrum to ensure its orderly use. As a result, users of radio communication devices then simply transmitted over any spectrum band that was suitable for their purposes. However, as applications and services for radio communications grew, interference became an increasing problem.

Faced with the growing problem of interference, it was soon recognized that national and international regulation of the spectrum would be necessary for the effective use of radio communications, prompting governments to introduce a framework for radio licensing on a national level and a framework for spectrum coordination at an international level. In 1903, two years after the first successful transatlantic transmission and reception of radio signals, Germany sponsored a "preliminary conference concerning wireless telegraphy" which eventually led to the signing in 1906 of the first International Radio Convention that coordinated the use of spectrum at an international level. Concurrently, national governments were also taking similar measures to manage their spectrum. The New Zealand Government was reputedly the first in the world to take control of spectrum management by way of the New Zealand Wireless Telegraphy Act 1903. This pioneering piece of legislation granted the New Zealand Government the sole right to receive, transmit and administer wireless communications.²

The basic design of spectrum regulation and management that emerged was rooted in the radio technology that Marconi developed, which required high signal to noise ratios. To avoid interference, a multi-layered system of spectrum management was developed. This consisted essentially of two steps: the international allocation of spectrum bands according to broadly defined services and the national assignment of licences by national regulators to users who would be given exclusive privileges to operate over certain frequencies within these allocations.

2.1 International Telecommunication Union (ITU)

Today, spectrum at the international level is managed within the framework of the International Telecommunication Union (ITU). This specialized agency of the United Nations has among its major purposes the avoidance of radio interference and the equitable and efficient use of spectrum and orbital resources. This mission is conferred mainly to its Radiocommunication Sector (ITU-R).³

ITU-R develops and adopts the Radio Regulations, a voluminous set of rules that serve as a binding international treaty. It essentially governs the use of spectrum by allocating spectrum to some 40 different services around the world. ITU-R also acts as a central registrar of international frequency use, recording and maintaining the Master International Frequency Register which currently includes around 1 265 000 terrestrial frequency assignments, 325 000 assignments servicing 1 400 satellite networks, and another 4 265 assignments related to satellite earth stations. With these resources, ITU-R coordinates efforts to eliminate harmful interference between radio stations of different countries and promulgates recommendations on technical and operation matters to improve the use of spectrum and of geo-stationary orbits for radiocommunication services. The ITU-R also sponsors World Radiocommunication Conferences (WRC) once every three years, which update the Radio Regulations in response to changes in the needs and demands for spectrum.

2.2 Regional organizations

The management of spectrum on an international level, however, is not restricted to ITU. As a critical resource, regional organizations have also begun to play a greater role in spectrum management policies. As a notable example, member states of the European Union (EU) are subject to mandatory EC legislation and to the optional regulation of the European Conference of Post and Telecommunications Administrations (CEPT), which provides detailed guidance to National Regulatory Authorities (NRA) on frequency allocations, harmonization and technical criteria.

It is interesting to note that in the case of the EU, the role of regional institutions in determining spectrum use on a national level may be expanding. Citing the need for greater certainty, the recently adopted “Decision on a Regulatory Framework for Radio Spectrum Policy in the European Community” proposes to make CEPT decisions mandatory among member states in cases where policy agreement is reached on harmonising the use of radio spectrum to implement EU policies.⁴

2.3 National institutions

After a set of spectrum bands have been allocated for a service by ITU, each nation adopts some or all of those bands for the service within its jurisdiction. Based on these allocations, a national table of frequency allocations or “band plan” is developed by a national regulatory administration that has been tasked with the function of spectrum management.⁵ Accompanying rules are also sometimes developed alongside each band in order to define the particular band’s licensing, operating and technical rules (see Table 1). The national regulatory administration then assigns licences to users giving them the exclusive right to operate on a specific frequency in a specific location or geographic area and under specified technical conditions (power, antenna height, etc).

Spectrum is usually assigned using to one of several approaches.⁶ Traditionally, where demand for spectrum within a particular band is considerably less than supply, most regulators have adopted a “first-come, first-served” approach. However, where spectrum demand exceeds supply, regulators are required to choose between competing applicants. Comparative hearings or “beauty contests” are occasionally used to allow regulators to make a licensing decision based on an established set of criteria, which may include the financial stability of the applicant and its technical competence – among other factors. In some cases, lotteries may be used to award licences through random selection. Increasingly, however, regulators have turned towards spectrum auctions to awarded licences (see Box 1).

Box 1: Putting spectrum on the auction block

Spectrum auctions can be considered to be one of the biggest spectrum policy innovations in recent times. As part of its Radio Communications Act of 1989, New Zealand was the first country to authorize auctions of both “apparatus licences” and “spectrum rights”. Since then, a growing number of countries have used auctions to assign commercial spectrum licences where there have been competing licensees. For example, 13 out of the 33 countries that had assigned spectrum for UMTS services by 2002 had used auctions.⁷

Spectrum auctions have been lauded as an efficient mechanism of assigning commercial spectrum licences for which there is a high demand. Auctions have been seen as a faster way of distributing licences than administrative hearings or “beauty contests”, while at the same time ensuring that licences will be put to their most productive use as they are competitively assigned to users who value these licences the most. Licence proceeds have also become a lucrative source of income for government treasuries.

Nevertheless, auctions have introduced their own set of difficulties.⁸ Despite the large body of work dedicated to the study and application of good auction design, the number of variables that need to be considered, such as future demand and technological development, render the effects of auctions unpredictable. Furthermore, auctions still operate in the rigid framework of administrative spectrum allocations where if too little spectrum is allocated for a particular use or for auction, the auction results will result in an artificial scarcity premium for the government. Although successful in terms of revenue generation for governments, examples of unintended auction results include a few 3G auctions in Europe that have resulted in financial difficulties for several carriers and the return of auctioned licences. Such consequences can lead to pressure towards industry consolidation and a reduction in competition in the marketplace.

Source: ITU research.

3 The role of spectrum management

3.1 Objectives

In managing spectrum, regulators are concerned with two forms of efficiency: technical and economic, which are pursued within the overall context of public policy.

The objective of technical efficiency principally relates to achieving the most intensive use possible of available spectrum within acceptable interference limits. It also seeks to promote the development and introduction of spectrum-saving technologies. Economic efficiency, on the other hand, involves ensuring that spectrum is allocated and assigned to uses that derive the highest economic value from it. Overall, the regulatory process of ensuring both technical and economic efficiency has to be sufficiently flexible and responsive to adapt to changes in market valuations and technologies.

Public policy goals also play an overriding role in determining spectrum management policies. Efficiencies may have to be sacrificed in order to safeguard the provision of certain public services such as defence, safety and public broadcasting services. In addition, the pursuit of technical and economic efficiencies are also constrained by international obligations related to spectrum use.

3.2 Changing paradigms and convergence

Under static conditions, the administrative management of spectrum can be expected to yield technical and economic efficiencies. However, in the current environment of fast paced technological and market change, centralized administrations have been seen as slow to react, inefficient and biased towards the status quo and incumbent interests.⁹

Further taxing this inherent rigidity of the regulatory system, the increasing “digitization” of information and communications and the resulting convergence of technology also have resulted in the “blurring” of the boundaries between traditional service definitions along which regulators allocated spectrum. Where traditionally different radiocommunication services were regarded as separate, involving different spectrum allocations, a single platform can now be used to deliver a wide variety of services to customers. For example, broadcasting, is moving towards more interactive applications with the introduction of IP datacasting, where digital content formats, software applications, programming interfaces and multimedia services are combined through Internet Protocol (IP) with digital broadcasting. Similarly, mobile systems are now capable of delivering access to live broadcasting content.¹⁰ In addition, third-generation (3G) mobile networks are potentially capable of transmitting data rates of up to 2Mbit/s, overlapping with the present performance of broadband fixed wireless access.

Beyond the inherent weaknesses of a centralized spectrum management approach, it is also increasingly acknowledged that market players such as operators and equipment manufacturers possess more knowledge about the spectrum they require as well as more information regarding the appropriate technologies to deploy and consumer preferences, than an administrative body would. As such, there exists considerable merit in allowing more spectrum management decisions to be made by those who would eventually use the spectrum.

Faced with increasing pressures from unpredictable markets and rapid technological change, a growing number of countries have started de-regulating, or are considering deregulating, portions of their spectrum management regimes; replacing the traditional centralized command and control regulatory approach with more market-based approaches.

4 New approaches to spectrum management

There is a growing trend towards deregulation and a greater reliance on market forces in spectrum management. Many countries have now started to introduce some form of market-based mechanism in managing spectrum. At one end of the scale, many countries have retained centralized control over functions such as spectrum allocation while introducing market-based mechanisms, such as auctions, to assign spectrum. At the other end of the scale, a few countries, like Australia, Guatemala and New Zealand, have gone further in deregulating spectrum management by allowing the market-based allocation of spectrum use.

While these market-based measures have been introduced within a system of exclusive rights, where spectrum frequencies are assigned for the exclusive use of a licensee, many countries have also allocated spectrum bands for licence-exempt use, effectively allowing more freedom for market players to manage spectrum among themselves.

This section will describe two significant approaches to spectrum management that are being widely considered for implementation or expansion: spectrum trading and license-exempt spectrum.

4.1 Spectrum trading

Moving beyond the initial phase of spectrum rights assignment, there exists a much wider scale of policy options that allow for the market-based determination of spectrum allocation and assignment. At this secondary phase of spectrum management, market players can be entrusted with a wide variety of rights that can be exercised through trading, these range from spectrum leasing to changing spectrum use.

In their consultation document on the implementation of spectrum trading, the former Radiocommunications Agency (RA) in the United Kingdom identified four major modes of spectrum trading, reflecting a wide range of ownership rights available¹¹:

- mode 1: change of ownership;
- mode 2: change of ownership and reconfiguration (which covers partition and aggregation);
- mode 3: change of ownership, reconfiguration and change of use, and
- mode 4 : change of ownership and change of use.

Spectrum trading variants also include spectrum leasing and spectrum sharing arrangements.¹² Different modes and trading variants have been applied among the different countries that have allowed secondary trading.

4.1.1 Modes of spectrum trading

4.1.1.1 *Spectrum leasing and spectrum sharing*

Spectrum leasing or sharing typically involves a partial transfer of a licensee's rights to spectrum either for a limited period of time and/or for a portion of the spectrum encompassed in the licence. This includes, for example, the transfer of the right to transmit from one site under a multi-site licence for a temporary period. The flexibility afforded by such an arrangement is particularly ideal for situations where a lessee's requirements are minor or temporary. It also allows licensees to benefit by allowing them to receive returns on portions of their assignment for which they have no present need. This allows unused spectrum to be released into the market and creates a financial incentive for licensees to adopt more efficient ways of utilizing their existing spectrum.

Box 2: Spectrum leasing in the United States

In May 2003, the Federal Communications Commission (FCC) adopted a “landmark” order on spectrum leasing that authorised most wireless radio licensees with exclusive rights to their assigned spectrum to enter into spectrum leasing arrangements.

Under the leasing rules adopted, licensees in certain services are allowed to lease some or all of their spectrum usage rights to third parties for any amount of spectrum and in any geographic area encompassed by the licence, and for any time within the term of the licence.

The order also creates two different mechanisms for spectrum leasing depending on the scope and responsibilities to be assumed by the lessee:

The first leasing option – “spectrum manager” leasing – enables parties to enter into spectrum leasing arrangements without obtaining prior FCC approval so long as the licensee retains both *de jure* control of the license and *de facto* control over the leased spectrum. The licensee must maintain an oversight role to ensure lessee compliance with the Communications Act and all spectrum related FCC rules. In enforcing the rules, the FCC will look primarily at the licensee on compliance issues but lessees are potentially accountable as well.

The second option – *de facto* transfer leasing – permits parties to enter into leasing arrangements, with prior approval of the FCC, whereby the licensee retains *de jure* control of the license while *de facto* control is transferred to the lessee for the term of the lease. Lessees are directly and primarily responsible for ensuring compliance with all FCC rules. For enforcement purposes the FCC will look primarily to the lessee for compliance, and lessees will be subject to enforcement action as appropriate. Licensees will be responsible for lessee compliance in so far as they have constructive knowledge of the lessee’s failure to comply or violation.

Source: Report and Order and Further Notice of Proposed Rulemaking (FCC 03-113), Federal Communications Commission.

In leasing and sharing arrangements, however, it would be important for licensees and lessees to be clear on how rights and obligations are apportioned, especially in cases where enforcement action may have to be taken by the regulator (see Box 2).

4.1.1.2 Changes in ownership

In the 1950s, a few economists initially mooted the idea of the establishment of private ownership rights over spectrum, the most prominent being the Nobel Prize-winning economist Ronald H. Coase in 1959.¹³ Although dismissed at the time, the idea of awarding greater rights of ownership over spectrum and the concurrent ability to trade those rights is currently being re-examined by a number of countries.

Presently however, in most countries, the transfer of ownership of a spectrum licence to another party after the initial assignment can only be effected in very limited and difficult circumstances. For example, in the United States, the Communications Act of 1934 limits the ability of licensees to transfer their spectrum rights without a laborious and costly application and public review process.

Proponents of greater ownership rights over spectrum highlight a number of gains that can be realised just from allowing the transfer of licence rights in a secondary market, even without any accompanying rights to change spectrum configuration or usage. Primarily, economic efficiency could be more easily achieved by exposing licensees to the opportunity cost of their spectrum. If the value a licensee places on the spectrum is lower than that placed on it by another party, the reassignment of the spectrum to the other party would result in a gain in economic efficiency. To a lesser extent, allowing reassignment would also lower barriers to entry into the market, firstly, by reducing risk through the possibility of spectrum resale and secondly, by allowing prospective market entrants to access spectrum on the market instead of lobbying or applying for spectrum to be administratively allocated and assigned to them.¹⁴

Changes in spectrum ownership or licensee through secondary trading have been permitted in some bands by Australia, Canada, Guatemala, New Zealand and the United States. The FCC in the United States has allowed trading in licences in secondary markets. Prior approval from the FCC is necessary, however, before a trade can take place and as a result trading has been limited because of the added risks involved. Nevertheless, the FCC is currently reviewing its rules and procedures to lower barriers in the secondary market and to promote more flexibility.¹⁵

4.1.1.3 Spectrum reconfiguration

The ability to partition and aggregate spectrum to a user’s needs has been identified as an important element in achieving greater flexibility and efficiency in spectrum use. Users would have the incentive to only

purchase or retain what they require while also allowing them to respond to changing spectrum needs over time. Allowing spectrum partitioning would also provide incentives for licensee's to use spectrum more efficiently as they could partition and sell off unused spectrum while allowing spectrum aggregation could facilitate the introduction of wider networks that may be of greater value than independent and isolated systems.

Nevertheless, where partitioning and disaggregation during secondary trading is allowed, there has been some concern over the danger of fragmenting spectrum into parts too numerous and too small for use or for practical aggregation in the future. This, however, has not been a major concern in most countries where it is allowed. In the United States, partitioning and disaggregation rules allow licensees operating certain services the option to divide their licences by geography and frequency. However, the level of activity promoted by this measure has not been significant with only less than 0.1 per cent of licences auctioned by the FCC having been through the partitioning or disaggregation process.¹⁶ This has largely been attributed to a number of factors. Firstly, partitioning the spectrum is seen as devaluing the asset. Secondly, licensees may seek to roll-out networks in their unused portion of spectrum in the future and thirdly, spectrum trading costs in the United States are seen as too high. In general, spectrum leasing is seen to be a better alternative to partitioning and sale.

4.1.1.4 Changes in use

It is generally acknowledged that allowing changes in spectrum use would provide the greatest flexibility in terms of subjecting spectrum management to market forces. Lifting restrictions on usage has been highlighted by some economists as fundamental for the benefits of spectrum trading to be realised. Given the unpredictable nature of spectrum demand and technological progress, it would appear that the best approach would be to devolve as many spectrum management decisions to market players. They are most likely to have the necessary information and agility to respond fastest to changes in consumer interests.

If spectrum allocation continues to be restricted according to predefined service definitions, equipment manufacturers and operators will necessarily concentrate on developing and deploying systems for the specific bands in which their services are allowed to operate, regardless of whether it represents an efficient use of spectrum.¹⁷ In turn, this in-built equipment rigidity also prevents the use of such equipment over other suitable bands that may be under utilized. Allowing changes in spectrum use, however, would allow spectrum and equipment to be redistributed according to market demand. In New Zealand, for example, spectrum sold originally for multipoint distribution service is being used flexibly as multipoint broadband wireless local loop.

In countries where spectrum trading has been introduced, the trend is to provide flexibility in services and use of technologies. For example, in Australia no service or technology constraints are specified in spectrum licences. Australian "standard trading units" (STUs) of spectrum have been designed to accommodate all likely uses.

However, both in Australia and New Zealand, potential flexibility is constrained by the way spectrum is packaged for initial auction. This is done so as to facilitate the most likely use of the band under consideration. As such it does not result in a completely service neutral outcome. Here, likely use is determined by the availability of equipment and typical international use of the band.

The permitted extent of change of use can also vary widely, depending on the particular concerns of the regulator. For example, it could be very limited, allowing a private mobile radio license originally issued for taxi use to be used by taxi or courier services, or it could be very flexible, allowing mobile spectrum to be used for broadcasting. Depending on the geographic isolation of the country, changes in spectrum use can be constrained by international obligations, such as the ITU Radio Regulations, spectrum harmonization requirements and bilateral agreements. Governments may also seek to restrict changes in use in order to maintain diversity in the provision of radio services. For example, mobile communication services could be offered through a range of alternatives from self-provided trunked mobile systems to cellular telephony. Some of these obstacles to changes in spectrum use are discussed later in this paper.

4.1.2 Implementing spectrum trading

The implementation of spectrum trading, in its different modes, involves the consideration of a number of issues. These include how to make the transition from more traditional approaches to spectrum management,

how spectrum should be packaged, how long licence or ownership rights should be granted for and what institutional arrangements should be established to ensure the smooth operation of the market.

4.1.2.1 *The transition to spectrum trading*

Despite some of the extreme proposals for regime change that have been advanced (see Box 3), countries that have implemented spectrum trading have tended to adopt a progressive approach to its introduction. A step-by-step approach to trading gives regulators the time to facilitate spectrum reorganization and markets the opportunity to gain familiarity with the new regime.

Limiting spectrum trading to only new assignments of licences, including overlay licences, is a convenient approach in making the transition to spectrum trading while accommodating the interests of incumbents.¹⁸ In addition to this, however, more radical approaches have also been successful (see Box 4).

In most countries where spectrum trading has been introduced, trading is permitted first in certain bands or in classes of licences that have been identified as appropriate. This list is then gradually expanded. Some of the factors that are considered in determining whether a category of licence is suitable for trading and through what mode (change of ownership, repartition, change of use, etc.) include:

- demand for re-allocation of spectrum in the particular band or class of licensees;
- degree of scarcity for frequencies in the particular band and the estimated trading volumes in the future as the introduction of spectrum trading may not be worthwhile if low trading volumes are expected;
- stability of the band, which can be influenced by either imminent changes international spectrum allocation or the introduction of new technology in networks with uncertain market and technical factors;
- spectrum allocation within the Radio Regulations and other international coordination requirements, and
- arrangements for harmonized use.¹⁹

The introduction of more complex forms of trading that allow for reconfiguration or changes of use or both are more likely to involve an increase in the risk of interference and would require much more detailed licensing conditions.

Box 3: The “big-bang” theory

According to this concept first raised by American economists Kwerel and Williams (2001), a big bang approach would put all spectrum into the trading market in a single process. It would effectively be the equivalent of a completely new assignment of all the rights to use spectrum.

Under this approach, the FCC and the NTIA would announce one year in advance that an auction will be held at a specified time for all spectrum, including spectrum used for broadcasting, public safety, the military and spectrum set aside for guard band usage.

Any current licensee owning user rights for spectrum will have the right to offer its currently used spectrum in the auction, but will not be obliged to do so. However, users that do not participate in the process may be constrained in its market activities for the following five years.

During the auction, every qualified participant is free in making their bids, only restricted by the auction design and the acquired eligibility rights. Each qualified bidder is also allowed to make bids for their own spectrum band which they have put up for auction. Users who put up their spectrum for auction may chose to reject any bid and retain their spectrum.

If the current user makes the highest bid in the auction, they will keep the particular right to use that spectrum. If another participant makes the highest bid, ownership of the user right will be transferred to them. The former user receives a compensation equal to the bid made by the winner of the auction.

Concerns about such a big bang auction include the administrative costs related to such an auction, the difficulty in designing an auction of this scale and how to package spectrum rights for sale and eventual trade especially where there is an existing mix of different license regimes for different spectrum bands.

Source: Faulhaber and Farber, Spectrum Management: property rights, markets and the commons. (2002) Paper presented at the 14th Biennial Conference of the International Telecommunications Society, August 18-21, Seoul, Korea.

Box 4: Spectrum management in New Zealand

New Zealand has shown that it is feasible to create tradable spectrum rights and to auction these rights despite the presence of incumbents in the bands. This was largely accomplished through a three-tier system of rights:

Management rights bestow the exclusive right to the management of a nationwide band of frequencies for a period of up to 20 years. Within this band, the manager can issue licences. They are not constrained as to the uses for which licences are issued.

Licence rights are derived from spectrum licences that are issued by the management rights holder which allow licensees the right to use frequencies within their bands. Licences are use specific and defined in terms of transmitter sites. The management rights holder can issue licences to itself.

In blocks of spectrum where management rights have not been created, the legacy regime of non-tradable **apparatus licences** continues.

The Government favoured a progressive conversion of licences to a spectrum rights regime. As the initial owner of all management rights, the Government has used auctions to make primary assignments of tradable management rights. There were 91 management rights as at February 2004, with the New Zealand Government retaining ownership of 15 of these rights, predominantly over spectrum used to provide public services.

It is left to the ensuing management rights holders whether or not to trade their rights. There are no restrictions on the activities of the operators, the number of entrants into the markets or specialised licensing requirements.

Source: Ministry of Economic Development at <http://www.med.govt.nz/rsm/> and <http://spectrumonline.med.govt.nz/>.

In general, countries that have introduced or are planning to introduce spectrum trading have earmarked spectrum bands or licence classes covering services such as mobile networks, mobile data networks, paging networks, private business networks and certain categories of terrestrial fixed links as most suitable for trading under one of the various modes. Later phases may subsequently include spectrum bands of licence classes covering services such as sound broadcasting and television broadcasting, as such services commonly involve an element of public broadcasting policy considerations to be taken into account. Nevertheless, it is worth noting that in New Zealand, the spectrum-trading regime was first implemented in the area of commercial radio broadcasting, where the perceived need for reform was the greatest.

4.1.2.2 *Dividing and packaging spectrum for trading*

The way spectrum is divided and eventually packaged in terms of geography or bandwidth for initial assignment has a considerable influence on the ease of trading implementation and the eventual development of the spectrum trading market.

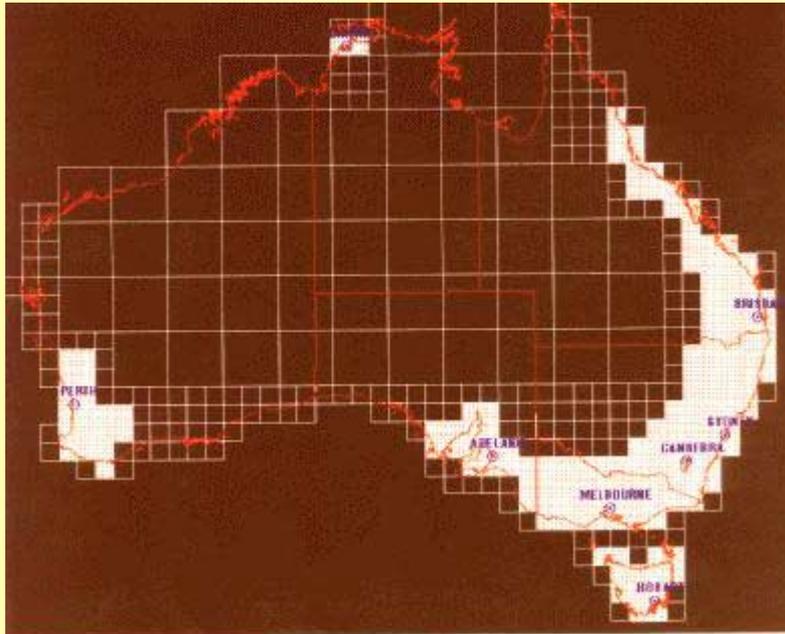
While assigning licences encompassing variable amounts of spectrum on a case-by-case basis is practised by most spectrum trading countries, Australia has adopted a more structured basis as a point of departure by first dividing spectrum into standard units of geographical coverage and bandwidth (see Box 5). Such an approach provides some advantages in terms of flexibility of use and ease of reconfiguration, which in turn facilitates the easier introduction of spectrum trading, but is notoriously difficult to implement given the amount of variables that have to be rationalized in creating uniform spectrum blocks.

Regardless of whether spectrum is divided into trading units or not, regulators will still have to weigh a number of considerations in deciding on the optimum spectrum package sizes for initial assignment. If spectrum packages are too small, users will have to incur increased transaction costs through the process of aggregating the necessary amount of spectrum. It also raises a concern regarding the possibility of holdouts. Not only would the creator of a State or national network have to negotiate with multiple spectrum owners, but if any refused to sell, the network could not exist as planned. On the other hand, if spectrum packets are too large, additional costs will be incurred in disaggregating and reselling the spectrum. Furthermore, the assignment of spectrum in large packages can also act as a barrier to entry into the market as higher prices would have to be paid.²⁰ In thin markets where demand for spectrum is lower, the packaging and assignment of spectrum in smaller lots may increase market interest and the likelihood of additional competition (see Box 6).

Box 5: Spectrum as commodity*Australia and the standard trading unit (STU)*

In Australia spectrum blocks owned by licensees are represented in units called standard trading units (STUs). An STU covers a predetermined geographic area and frequency band. STUs can be combined vertically to provide increased bandwidth or horizontally to cover a larger area. An STU is the smallest spectrum unit recognized by the ACA and its bandwidth and geographic dimensions cannot be further divided.

The minimum frequency band for any spectrum licence would have a width of one STU bandwidth. In some bands this bandwidth is as small as 0.0125 MHz. The minimum geographic area for an STU is a single cell of a Spectrum Map Grid. The Spectrum Map Grid covering Australia is shown below, and consists of cells of various sizes depending on their location.



Different cell sizes are used depending on the levels of population. Larger cells are defined in rural areas. Small cells are defined in population density areas, such as cities, towns and their suburban areas

Auction lots of spectrum space are then defined for sale. An auction-lot area is defined by reference to the spectrum map grid. The auction-lot areas are defined to cover the total area available from each band release and with no overlap of areas. Auction-lot areas are created by a process that aggregates map grid cells. The process takes account of the value of populated areas, the incumbent services and the requirements of technical framework itself, for example, the size of the emission buffer zone.

Source: Australian Communications Authority.

Auction theorists have considered this question and some have proposed package bidding as a possible solution. Regulators could let interested parties bid on smaller individual parcels or on a package of individual parcels. If the total bid for the package were greater than the total for the individual parcels, then the spectrum would go to the single bidder for the package. In the United States, the FCC has introduced package bidding into its spectrum auctions.²¹

4.1.2.3 License duration and security of tenure²²

The length of time a licence or ownership title for spectrum is issued for, and the certainty that it will run for its stated period of time are major considerations in the trade of spectrum. Short-term licences and uncertainty as to its eventual duration serve to dissuade purchasers from making the necessary long-term investments in research and development as well as in building infrastructure for the delivery of services over that spectrum. On the other hand, long-term licences and significant barriers against government re-appropriation or restructuring of spectrum would overlook the need for periodic reorganization of spectrum bands at the national or international level as a result of changes in technology, public policy or otherwise.

Box 6: Fragmenting spectrum in Guatemala

Spectrum rights in Guatemala are granted in fully transferable and fragmentable frequency usage titles (*Titulos de Uso de Frecuencias* or “TUF”s), which have technical limitations to protect against interference but which have no service limitations. Under the system, all spectrum that is not assigned can be requested. Following a request, the regulatory administration determines whether the request would infringe upon any other person’s rights and if it does not, it opens up a period where other parties may object to the granting of the right, which must be based on a violation of the protesting party’s existing right, and where other parties may seek a portion of that requested spectrum. In the latter case, the administration is obliged to start an auction. In cases where fragmentation would promote competition, the law requests from the administration that it auctions the requested spectrum in a fragmented fashion.

The first TUF auction in Guatemala was launched on 4 June 1997. It comprised 20.8MHz of nationwide spectrum in the 800MHz range, which was used for trunking or specialized mobile radio (SMR). There were initially 11 bidders, including the incumbent GUATEL. It was decided to fragment the 20.8MHz of spectrum was into 19 pairs of outbound and inbound bands: seven band pairs of 1 MHz each, and 12 bands of 200kHz each. The auction ended after two weeks of intense bidding, with total payments of about USD 3 million. Out of the initial seven bidders, 11 bidders won at least one lot.

Source: Pablo T. Spiller and Carlo Cardilli, Towards a Property Rights Approach to Communications Spectrum (1999), Yale Journal of Regulation, Vol. 16, No.1.

There are a number of licensing options are available which allow differing levels of flexibility and balance:

- Fixed-term licences, which would allow for periodic review;
- Revolving licences, which would allow for the opportunity for periodic review and decrease the need for regulatory intervention to re-issue new licenses, and
- Perpetual licences with provisions for recovery.

Depending on how narrow the provisions for recovery are and how much minimum notice is necessary for recovery, the last option would give the greatest play to market forces but may limit the strategic flexibility of the regulator.

In practice, the characteristics of the spectrum to be licensed play a large role in determining its licence duration and security of tenure. For example, the most likely services the spectrum would be used to provide and the scale over which the services would be provided are factors that would determine the sunk costs that are required for its rollout. In the United States, licensees providing service to the public have, in effect, their licences in perpetuity. Ten-year licences are initially auctioned but then can be renewed repeatedly for ten-year periods. Licensees would only be displaced when their service was discontinued (e.g. analogue mobile) or when a reorganization of spectrum allocations takes place.

4.1.2.4 *Institutional arrangements*

4.1.2.4.1 *Competition safeguards*

Competition safeguards are central in planning for the introduction of spectrum trading as the possibility of spectrum consolidation may potentially lead to a decrease in the number of competitors. Spectrum hoarding, in particular, has been highlighted as a key concern.

In Australia and New Zealand competition concerns regarding spectrum trading are largely resolved by *ex post* enforcement of competition law.²³ In other countries, regulators have resorted to more *ex ante* competition policy measures, usually in the form of requirements for regulatory clearance of spectrum trades. For example, in the United States, FCC approval is required before a licence transfer can be made.

Other *ex ante* safeguards include spectrum ownership caps that limit the maximum amount of spectrum a single entity is allowed to own. Spectrum ownership caps are applied in a number of countries, for example, in the United States. Such an *ex ante* approach may avoid a lengthy *ex post* resolution of market dominance issues. For example, in New Zealand, national courts did not uphold the decision of the Commerce Commission, the national competition authority, concerning the dominant position New Zealand Telecom (NZT) would acquire if it was permitted to purchase all the AMPS spectrum. The New Zealand Government is now reviewing the need for spectrum caps on a case-by-case basis.²⁴

Box 7: Information requirements

For a transaction to take place, a potential spectrum buyer requires information as to the spectrum that is available for sale. In other more mature markets information gaps have typically been addressed through private intermediaries, such as through brokers or market analysts that rely on voluntary disclosure. Nevertheless, in the absence of such intermediaries and to facilitate a fledgling spectrum trading market, some administrations that have introduced spectrum trading have required buyers and sellers to provide a certain level of information regarding their trades. At the very least, registries containing basic information such as a list of assigned spectrum and their users have been maintained. For example, Australia provides an online register of spectrum licences that allows buyers of spectrum to search for potential sellers. However, information on confidential users for reasons of national security is withheld and pricing information is not collected or recorded by the ACA. In general, information on transactions can be mandated through regulatory compulsion and disseminated by publication directly or in aggregated form, periodically or in real time, and through a number of means, for example on a publicly accessible website.

To a large extent, the differing levels of mandatory disclosure reflect a balance between the desire to maintain open and competitive markets against commercial prerogatives to privacy and security. On the one hand availability of information on prices and transactions provide valuable information regarding supply and demand and allows the market to allocate resources efficiently, furthermore, increasing the level of information available to all parties levels the playing field and reduces the scope of informational advantages. On the other hand, market participants may worry that purchase and sale information may reveal sensitive information regarding their business plans.

Source: Implementing Spectrum Trading, A Consultation Document, July 2002, Radiocommunications Agency, United Kingdom available at www.ofcom.org.uk/static/archive/ra/topics/spectrum-strat/consult/implementingspectrumtrading.pdf.

4.1.2.4.2 Trading mechanisms and market intermediaries

Once a spectrum trading framework is in place, markets can be left to develop of their own accord with the trading process carried out by appropriate private sector intermediaries. These could include brokers, private spectrum exchanges or dealers that purchase spectrum and repackage them for resale. To a certain extent, such services have developed in a few countries where spectrum trading has been introduced. In Australia, for example, specialised consultancies have assumed some of the role of facilitating spectrum trades. However, the emergence of a full range of intermediaries similar to those in other industries has yet to be seen. Nevertheless, as spectrum markets develop in size and sophistication, it is expected that different sorts of services and derivatives will evolve, depending on the needs of the market.

In the alternative, administrations have the option of taking steps to shape the development of a spectrum trading mechanism. Specific trading mechanisms could be mandated by administrations, standardizing the means by which spectrum rights can be transferred or a central trading institution could be established in order to establish greater oversight over the trading process.

There is a danger, however, that in such an approach, administrative costs will be high, increasing the costs of trading and decreasing the incentive to trade. There are, however, less interventionist approaches that can be taken to facilitate the development of spectrum trading markets, through means such as the dissemination of various amounts of trading information for example (see Box 7), or through the establishment of a common resource to bring together buyers and sellers, like for example, a public database of spectrum for sale or spectrum sought or the organization of periodic auctions at which spectrum owners could offer spectrum lots.

4.1.2.4.3 Windfall gains and taxation

The conversion of licences to tradable licences may result in incumbent licensees receiving capital gains, especially when the original licence was not obtained through an auction process. Although there are no strict economic reasons to prevent windfall gains, concerns are likely to be raised among the general public if the gains are substantial in relation to the original assignment price. The question of government levies for net gains in spectrum trades has been considered as a possible remedy. Nevertheless, the imposition of taxes or transfer fees on profits may have a negative effect if it reduces the incentive to trade. In Australia, taxation law was one of a number of “unforeseen consequences” by the Australian spectrum regulator that impacted spectrum trading. In particular, State Governments also sought to apply high levels of stamp duty on trading transactions.²⁵

4.1.3 Spectrum trading in review

Spectrum trading has been welcomed to different degrees by different markets. The United States registers an annual trading volume in the thousands while the New Zealand market is characterized by thin trading volumes. Beyond the fundamental issue of market size, some analysts have attributed this low volume of spectrum trading in New Zealand to a number of factors that can be instructional.²⁶ Firstly, there remains some confusion regarding old and new licences, as well as nervousness in the industry about the expiry date of current licences. There has also been uncertainty about the way spectrum will be treated for international standardization purposes, as the availability of equipment often constrains spectrum utility. As New Zealand uses auctions for initial spectrum assignments, introducing a secondary market will have less of an impact when the primary mode of assignment is already market based. The most important factors, however, are tied to the nature of market demand for spectrum. Spectrum purchases are typically made by operators who intend to build out networks. As such, they have little intention to sell the spectrum in the short term. It also appears that there are few operators vying for spectrum in New Zealand. In the recent 3G-spectrum auction, six blocks of spectrum were offered and only four bids were received.

Admittedly, compared to the long history of centrally regulated spectrum management, practical experience with regard to spectrum trading has been limited to a handful of countries. However, a number of positive developments have nevertheless been attributed to the introduction of spectrum trading in these countries. In New Zealand, for example, the introduction of spectrum trading facilitated the creation of a fourth broadcast network covering 70 per cent of the population while in Guatemala, the introduction of spectrum trading has been credited with an increase in the telephone subscriber rates (see Box 8).

Despite these successes, a number of significant misgivings still remain with regard to the introduction of spectrum trading. Some of the most worrying include an increased risk of interference and heightened competition concerns, especially with regard to spectrum hoarding where market participants may seek to accumulate access spectrum to deny the emergence of competition. Furthermore, spectrum trading may also introduce its own set of inefficiencies that may include increased difficulties and higher transaction costs in assembling spectrum bands in contiguous areas and in realizing economies of scale or other welfare benefits resulting from international harmonization and standardization. There will also be some conceptual difficulty in deciding how to deal with the large portions of spectrum that are now used by public services or for other purposes that defy market pricing. Some of these issues are discussed in the following sections.

4.2 License-exempt spectrum

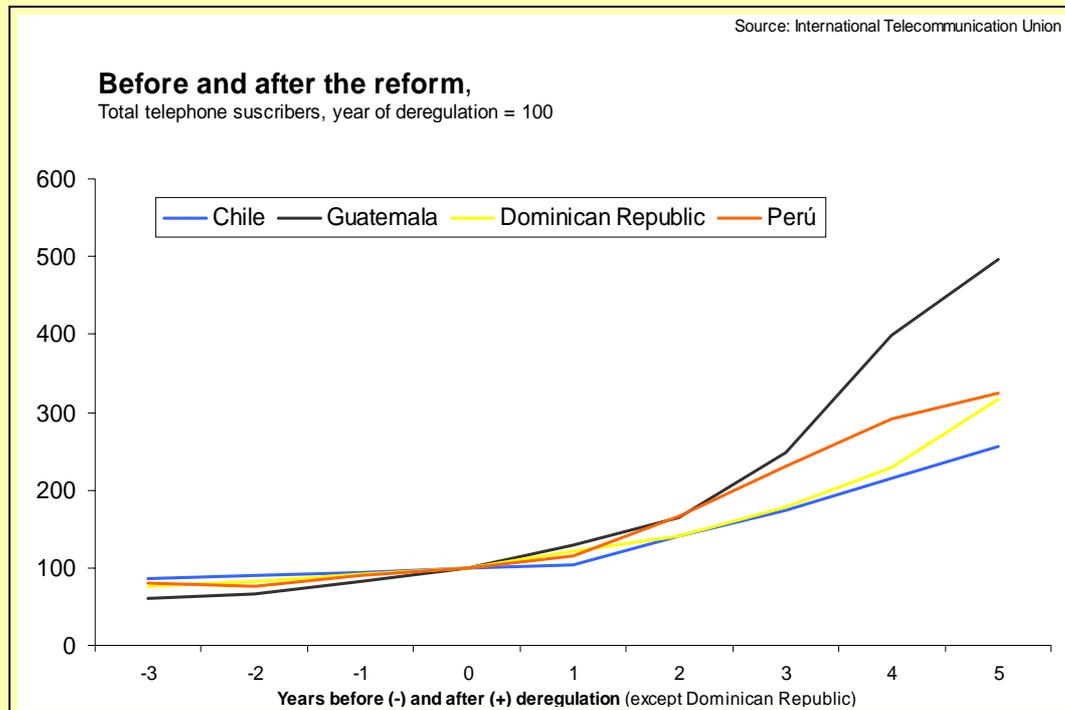
In contrast with spectrum management regimes based on exclusive rights, a licence-exempt model does not assign users exclusive use privileges over spectrum. Instead, access to spectrum is either open to all users (open access spectrum) or to a group of users who hold the rights to that spectrum in common (spectrum commons). In this way, multiple users are encouraged to reuse the same spectrum space.

4.2.1 Open access spectrum

Licence-exempt spectrum use is usually permitted in two forms. The first involves low power transmissions, where interference is limited by strict power limits and regulatory equipment approval. This allows low-power users to co-exist in bands simultaneously used for higher power emissions. The second involves spectrum use in bands allocated for licence-exempt use. Bands like the 2.4 GHz “industrial, scientific and medical” (ISM) band, where 802.11b standard operates, as well as the 5 GHz band, where the 802.11a standard and the emerging 802.16 standard operate, have generated considerable attention in recent times. Most regulators require users of these bands to be subject to certain restrictions, such as output power limits or communication protocols, and other “etiquette rules” aimed at minimizing interference. While users of these bands are permitted higher power outputs due to the protection offered by the dedicated bandwidth given to licence-exempt use, the use of the spectrum itself is typically granted on a non-interference, non-protected basis. Users in these bands are liable for interfering emissions they cause but are not protected from interference from others. Significant incentives are therefore created for users to deploy innovative systems that offer dynamic traffic-channel monitoring and selection and fast frequency hopping spread spectrum waveforms.

Box 8: Telephone subscriber rates in Guatemala*Before and after the Reform*

In Guatemala, the initial effects of the introduction liberalization have been visible in the telephony sector. From 1996 to 2001 the total number telephone of lines (fixed and mobile) increased at an annual compounded rate of 38 per cent. Under State monopoly, the annually compounded rate from 1985 to 1995 was nine per cent. Although the sudden increase in penetration rates can be attributed to privatization and liberalization of the entire telecommunication sector, a comparison in performance with other countries implementing the same reforms, except for spectrum trading, have shown more modest growth.



The graph uses as a baseline the year of the reforms: 1988 for Chile, 1993 for Peru, and 1996 for Guatemala. The growth rate in Guatemala far surpasses that for either country. Five years after the reform the annually compounded growth rate for Chile and Peru was 21 per cent and 27 per cent respectively, compared to Guatemala's 38 per cent.

Source: ITU Country Case Study, Radio Spectrum Management for a Converging World in Guatemala.

In addition to the technological and service innovation brought about by licence-exempt spectrum use, eliminating the requirement for administrative licensing also lowers barriers to market entry and spurs competition. The increasing popularity of services delivered over licence-exempt bands in many parts of the world serves as a strong testimony to benefits that can be reaped from an open spectrum approach (see Box 9).

Despite the rapid success enjoyed by some services provided over licence-exempt spectrum, significant concerns remain regarding the long-term viability of an open access regime. Over time, logic dictates that the increasingly diverse and intense use of such bands would gradually increase the potential for congestion and interference causing an eventual degradation in service quality. The experience of the citizen band (CB) radio in the United States is often highlighted as an example of a tragedy of the spectrum commons, even though it is uncertain as to how large a role service degradation played in its drastic fall in popularity in the mid-1970s.²⁷

Despite this concern, licence-exempt bands have nevertheless served as a valuable catalyst for the emergence of successful technologies that serve to increase technical spectrum efficiency and minimize interference. If technological progress continues at its current pace, a tragedy of the commons may be avoided or, at least, indefinitely postponed.

Box 9: The growth of “Wi-Fi”

The term “Wi-Fi” commonly refers to the array of technical standards that can be used to create “wireless local area networks”, or WLANs (known also as “radio local area networks” or RLANs). Strictly speaking, Wi-Fi is a certification that manufacturers can apply to their products once they satisfy certain interoperability criteria. Meanwhile, WLAN denotes a radio networking technology used to connect personal computers or other appliances to a local network. WLANs can be operated for private use, such as in the home, or to create short-range, public networks. Known as “hotspots,” these networks can be found in airport lounges, coffee shops or even neighbourhoods.

There are many technical standards used to create WLANs. Those that have received the most attention are the 802.11 family of wireless technical specifications developed by working groups of the United States’ Institute of Electrical and Electronics Engineers (IEEE). The most popular specification is currently 802.11b, which uses the 2.4 GHz “industrial, scientific and medical” (ISM) bands. Many people employ the term “Wi-Fi” to refer strictly to 802.11b equipment, although the term has come to be used by the general public as synonymous with all WLAN networks and devices. That would include the 802.11a standard, which operates in the 5 GHz bands. More recently, the 802.16 standard that has been approved by IEEE which enables wireless metropolitan area networks, or WMANs (these are also referred to as “Wi-Max” networks). For the purposes of this paper, Wi-Fi is used generically to refer to all WLAN products, reflecting its popular usage.

A number of countries have dramatically increased the rate of use of wireless networks. In the United States, for example, it has been reported that the number of Wi-Fi implementations doubled between 2001 and 2002. More than one million Wi-Fi access points are estimated to be in use by more than 700 000 US enterprises.²⁸ Internet service providers (ISP) have even begun using Wi-Fi technology to cover entire cities.²⁹

There are a large number of optimistic estimates about the future growth of the Wi-Fi market. For example, analysts predict that by 2006, there will be 800 000 European Wi-Fi hotspots, 530 000 in the United States and 1 million in Asia. Wi-Fi revenue in Western Europe and in the United States is expected to rise to USD 5.4 billion this year, up from USD 33 million in 2002.³⁰ In the United States, estimates indicate that more than 5 million American households will migrate to mobile and high-speed wireless broadband networks for their primary connection by 2006.³¹ There is another prediction that replacement of wired services by wireless access is expected to accelerate dramatically and will reach an additional 10 million wireless access users by 2005.³²

Source: SPU Global Market Trends, “Wi-fi takes the sector by storm” available at: <http://www.itu.int/osg/spu/spunews/2003/oct-dec/wi-fi.html> and “Report on the Development Of Wireless Local Area Networks In OECD Countries” available at: <http://www.oecd.org/dataoecd/44/42/2506976.pdf>.

4.2.2 Spectrum commons

Similar to the approach taken in an open access regime, a spectrum commons does not assign exclusive rights to individual users. However, rather than opening access to all users, access rights to spectrum are limited to a group of users who assume the management of that band. As it is generally assumed that open access resources tend to get overused rapidly, resources for which clear common ownership rights are established are likely to be utilized more efficiently.

This commons approach to spectrum is essentially modeled on common property management regimes that are practiced in other industries, such as fisheries. While the administrative allocation of spectrum for the purposes of establishing spectrum commons have been relatively rare, the management of some license-exempt frequency bands have nevertheless taken on the characteristics of spectrum commons in some cases (see Box 10).

4.2.3 Spectrum scarcity and technology

Proponents of non-exclusive rights to spectrum in general place great faith in the fact that spectrum scarcity is less of an issue than the proponents of exclusive use believe. Given the current rapid pace of radio technology development, open access and spectrum commons regimes are envisioned as the ideal framework for the development and deployment of wireless networks that may eventually remove the threat of spectrum scarcity (see Box 11).

Box 10: Unlicensed PCS in the United States

Starting in the late 1980s, cellular companies and computer makers began to petition the FCC to allocate new spectrum for experiments with a new generation of personal communication services. The FCC consolidated the proposed new services (isochronous applications, such as wireless PBX, and asynchronous applications, such as nomadic data devices) in a proceeding for unlicensed PCS services (UPCS). The unlicensed status reflected a general agreement among interested parties that a licence-exempt regime with a minimum of regulatory restraints would foster innovation. Two self-governing industry organizations, the Unlicensed PCS Ad Hoc Committee for 2GHz Microwave Transition and Management (UTAM) and the Wireless Information Networks Forum (WINForum) were formed by manufacturers to deal with critical administrative and technical issues. UTAM proposed a plan for band clearing and frequency coordination while WINForum addressed technical issues related to coordination among users. All manufacturers of devices utilizing the UPCS band were required to become UTAM members.

In 1994, the FCC finalized its rules governing the UPCS band. The 1 910-1 920 Mhz band was assigned to asynchronous devices while 1 920-1 230MHz was assigned to isochronous devices. Wireless PBX is the dominant application in the isochronous band, being deployed mainly in large worksites with highly mobile workers. Although there are claims that the band is congested in some areas, spectrum demand is generally accommodated by the rules that promote coordination among users. The asynchronous band, however, lies fallow with no products developed for its use, largely because of problems associated with band clearance and the success of competing technologies using the 2.4 GHz ISM band.

While technological and service innovation has not flourished in the band as envisioned, the market remains healthy and the system of industry governance appears to have worked effectively. The band clearing process has been successful and UTAM has reported a sound financial situation. According to UTAM, no disputes between UPCS users have been reported. UTAM has also been successful in its role as a monitor in preventing the unauthorised use of the band.

Source: Carol Ting, Johannes M. Bauer, Steven S. Wildman, The U.S. experience with non-traditional approaches to spectrum management, Prepared for presentation at the 31st Research Conference on Communication, Information and Internet Policy, Arlington VA, USA, September 19-21, 2003 available at <http://quello.msu.edu/wp/wp-05-03.pdf>.

4.3 Towards a more flexible framework

There are a large number of policy options for a country to select from when migrating to a more market-based approach to spectrum management. Although the stronger trend is towards establishing market-based exclusive rights regimes, particularly through spectrum trading, spectrum management policy can pick from a broader range of options. Spectrum trading, spectrum commons and open access spectrum management regimes have unique advantages and disadvantages. Unfortunately, experience in new spectrum management regimes has been relatively limited for their advantages and disadvantages to be accurately established. Nevertheless, prudence suggests that introducing a mix of regimes would be the best overall approach.³³

Box 11: Open wireless networks

A number of academics have advocated the establishment of licence-exempt environments that foster the development of open wireless networks which would be predicated not on the classical assumptions of spectrum management but on network and equipment design to enable the optimisation of user capacity.

Classical spectrum management techniques are based on the assumption that radio transmissions are made to “dumb” receivers that are unable to distinguish between different signals transmitting on the same frequency. As such, separate and isolated frequencies have to be dedicated to different transmissions in order to minimize interference. Instead of being constrained by these assumptions, an ideal open wireless network is predicated instead on the use of advanced wireless technologies that achieve processing and collaborative gain to overcome these constraints.

For example, using intelligent devices employing advanced spread spectrum technologies such as ultra wide band would allow the transmission and reception of more signal information at lower power levels on a given set of frequencies (processing gain). These devices, which would also act as repeaters, could then be weaved together to allow the creation of an expansive network where each added user also adds capacity at least proportionately to his or her demand (collaborative gain).

Source: ITU research based on Yonchai Benkler, Some Economics of Wireless Communications, Harvard Journal of Law and Technology, Vol 16, No. 1 Fall 2002 and Lawrence Lessig, “The Future of Ideas: The Fate of the Commons in a Connected World”, 2001, Random House, New York.

Economists have suggested several frameworks for accommodating such an approach. For example, different regimes could be created in different bands in much the same way designated bands are now allocated for licence-exempt spectrum. However, these allocations would continue to take place within the framework of a traditional centralized administrative framework, a situation that is not seen as ideal.

Alternatively, a market framework based on spectrum trading could leave the decision to create a spectrum commons entirely up to spectrum owners. This could be a viable option provided that there exists sufficient economic incentives for spectrum owners to surrender their exclusive rights for the creation of a spectrum commons. For example, if the creation of an open wireless network (as described in Box 11) was feasible, individual owners may be persuaded to pool their resources into creating the bandwidth necessary to establish such a network.³⁴

Another option would be to mandate the co-existence of exclusive rights with underlying open access rights.³⁵ As most proponents of open spectrum access believe that ubiquitous underlay rights would be sufficient to unleash the potential of emerging wireless technology such an approach may strike a balance. Nevertheless, as recent industry consultations in the United States have demonstrated, incumbent users have strong incentives to keep underlay users at a minimum, either to prevent them from becoming a viable competitive alternative or to protect their own exclusive use.

In the absence of empirical data clearly indicating the superiority of one framework over another, the success of such spectrum management approaches will have to be assessed through trial and error.

4.4 Future trends

The introduction of spectrum trading or other deregulatory approaches is unlikely to act as a further stimulus to spectrum demand in the current market climate of increasing consolidation. Unlike the wave of telecommunications liberalizations in the 1990s, the communications industry, manufacturers and operators alike, appear to have entered a period of maintenance where they are looking towards minimizing investments and maximize returns. Nevertheless, the introduction of new technology that can increase network flexibility and communications capacity is likely to attract industry attention as they will eventually allow operators to maximize the use of their existing spectrum. Spectrum management approaches that facilitate this process could eventually reap the most gains.³⁶

5 Cross-cutting issues

5.1 Interference

National administrations have traditionally regarded interference management as one of their central responsibilities under their overall objective of maximizing the technically efficient use of spectrum. This has largely resulted in the majority of countries adopting the classical approach to spectrum management that demands tight regulatory control over how spectrum can be used.

In the absence of exhaustive and precise technical details of all services and systems over different topographical and meteorological conditions, a spectrum management approach that allocates spectrum along the lines of services or systems with homogeneous characteristics (in terms of compatible RF power level, similar bandwidths, similar protection environments, similar potential for interference and similar performance requirements) reflects the most practical way of attaining spectrum efficiency. Within this service-based allocation framework, regulatory administrations then co-ordinate the co-existence of different systems within the same frequency band as well as between systems in adjacent frequency bands through license assignments.

While this approach to interference management brings about a certain measure of technical efficiency by removing some usage variables, it suffers from a certain amount of inflexibility and unresponsiveness. With the introduction of more market-based approaches to spectrum management, a more flexible and transparent framework would be required. Although changes in the way spectrum assignments are managed may not require significant changes in the current regime, changes in spectrum allocation practices that allow for changes in spectrum use will impact the interference environment considerably.

5.1.1 Boundary conditions and increasing user responsibilities

Using more broadly defined services may be considered as a means to increase the flexibility of the current interference management approach that relies on service-based allocations. However, such an approach would continue to act as a barrier to the full realization of the benefits that could be afforded by liberalizing spectrum use.

Alternatively, clear boundary conditions could be set around spectrum assignments. Some critics have argued that usage restrictions on spectrum should be replaced with interference limits designed to achieve the same ends.³⁷ In some countries where spectrum trading has been introduced, the administration may set the initial limit for interference parameters (e.g. New Zealand, Australia and the United States) or they may be set by industry with oversight from the regulator. For example, in Australia, interference levels are administratively set at the geographic boundaries of each standard trading unit (STU) while in New Zealand, area and frequency parameters are administratively defined on a case-by-case basis for initial licence assignments.

While the approach of setting absolute boundary conditions offers clarity and simplicity in its application, it risks technical inefficiency, as it does not reflect the characteristics of the actual systems that are deployed when spectrum use changes. As such, provided that sufficient technical data and calculation tools are available, the eventual setting of boundary conditions should be delegated in some measure to users. In countries employing such a framework, users are typically given the option of varying initial boundary conditions either through bilateral negotiations or through administrative appeal. For example, in Canada, initial boundary conditions are trigger values for negotiation that are set conservatively to minimize the potential for interference.

In most cases, if an agreement between the affected parties is not possible, then some form of dispute resolution procedure typically applies, for example in Australia, an independent conciliator may be appointed by the ACA if parties are unable to arrive at an agreement. However, resolution of disputes through the courts was tried but was found to be impractical and lengthy in New Zealand. The monitoring of interference conditions in these countries is largely left up to users.

New Zealand provides an interesting example where the devolution of interference management has been taken one step further. Under its framework of tradable “management rights”, a “management right” owner would essentially assume the role of the regulatory administration in setting boundary conditions for its “licensees” within the band it holds “management rights” for. This approach effectively reduces the interference management burden on the administrative regulator. Nevertheless, it has been noted that in one case, the regulator had to intervene significantly. Management rights for cellular bands around 900 MHz allowed the operation of AMPS and GSM systems in adjacent bands. Interference problems resulted and the regulator intervened by releasing spare spectrum to act as a guard band.

While initial boundary conditions set by regulators serve as a useful reference point for users, it would nevertheless be possible to require coordination between users in their absence. New users, or uses, of the spectrum could be required to undertake interference coordination with existing users as a prerequisite for the deployment of their system. Although it may offer slightly more technical efficiency than the generic approach taken above, the approach would entail less certainty in the absence of an initial reference point.

5.1.2 Emerging technologies

Interference management techniques, however, will eventually have to evolve to accommodate and exploit emerging technologies that have the potential to reduce the impact of the interference environment. To some extent, these technologies have been deployed in frequency sharing arrangements that allow new allocations in frequency bands have already been occupied by other services. While low-density power technologies like spread spectrum and ultra wide band systems hold great promise in allowing spectrum underlay to be exploited, frequency agility technologies and smart antenna technology offer great potential in mitigating interference concerns (see Box 12).

Box 12: Frequency agility

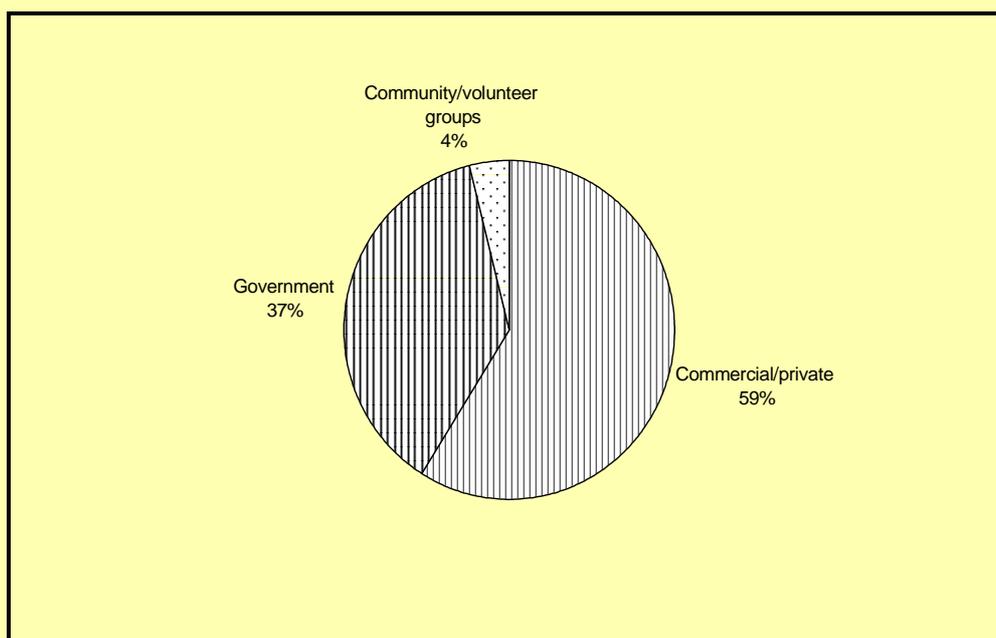
Avoiding interference on a dynamic basis can be undertaken at a macro and micro level. At a macro level, an interference free channel is used for an extended period of time while at the micro level, frequency agility involves the rapid hopping between frequency channel in a sequence. The use of “polite technologies”, such as dynamic frequency selection (DFS) and transmitter power control (TPC), is a good example of the macro approach. In DFS, a transmitter listens for other users before selecting a channel to use while TPC ensures that the transmitter uses the lowest power level commensurate with the quality desired, thus keeping the level of interference down. In the United Kingdom, the use of DFS and TPC was a mandatory condition for the deployment of high-performance radio local area networks (HIPERLANs) in the 5GHz band which was occupied by satellite services. At a micro level, spread spectrum technology using frequency hopping also has interference mitigation characteristics. Rapid variation of the signal reduces the chance for same signal interference in hostile environments such as licence-exempt bands. Radio local area network (RLAN) devices operating in the licence-exempt 2.4 GHz band typically use this technique.

Source: AEGIS Spectrum Engineering, Implications of international regulation and technical considerations on market mechanisms in spectrum management, 2001, available at <http://www.aegis-systems.co.uk/download/spreview.pdf>.

5.2 Non-commercial uses of spectrum

In most countries, public services consume a significant portion of valuable spectrum (see Figure 3). Important services such as defence, law enforcement, public safety, public service broadcasting and air traffic control rely on spectrum for much of their communications needs. Under a classical spectrum management approach, spectrum bands would be reserved for the delivery of such services by the government.

Over the past decade, however, increased pressure has been placed on governments to transfer more spectrum from public service use to commercial use. Commercially interested parties argue that commercial demand for spectrum has grown at a greater rate than public spectrum demands, while improvements in technology have enabled public services to utilize more spectrum-efficient systems. On the other hand, public service players have counter-argued that operations have become more complex and sophisticated requiring greater amounts of spectrum for enhanced communications and navigation needs. In order to arrive at an efficient and equitable balance, there has been an increasing recognition for the need to expose public service spectrum use to market-based incentives to economize on spectrum use.

Figure 3: Frequency assignments by type of user in Australia (March 2001)

Source: Australian Communications Authority.

At one extreme, a number of experts have advocated the equal treatment of public services and commercial services, requiring public bodies to obtain spectrum on the market like any other commercial service provider.³⁸ However, there appears to be broad agreement that at the present time it is inappropriate for spectrum reserved for public services, in particular defence and public safety, to be allocated and assigned exclusively through market forces. Countries that have introduced spectrum trading have continued to reserve spectrum for public services and for global frequencies dedicated to aviation and maritime communications and navigation. Nevertheless, this has not prevented a number of countries from exposing public services to economic incentives that could promote efficient spectrum use.

5.2.1 Administrative incentive pricing

In addition to initial one-off assignment fees, owners of rights to use frequencies in many countries pay recurring user fees. These fees are typically based on administrative costs or the opportunity costs of spectrum usage. In the latter case, user fees are usually known as administrative incentive pricing (Box 13).

Box 13: Spectrum pricing in Australia

The Australian spectrum pricing system is conceived on the assumption that charges to the users of spectrum should serve two objectives:

- act as a rationing device and set in a manner that encourages efficient use of spectrum, and
- deliver a fair return to the community for the private use of a community resource.

The radiocommunication licence taxes (for transmitters and receivers) are based on a formula that takes into account:

- the spectrum location authorised by a licence (some spectrum bands are in higher demand and are therefore more congested than other bands);
- the amount of spectrum (bandwidth) used by a licensee;
- the geographic coverage authorised by the licence; and
- the power of the transmitter (transmitters operating a low power will attract a discount).

ACA acknowledges that, in the interests of simplicity and accessibility to spectrum users, the fee formula incorporates some compromises and a degree of crudeness in the manner in which different factors are measured and charged. Since introducing the fee formula in 1995, the ACA has continued to monitor and adjust the fees. The ACA has a programme to review fee levels, in particular in bands, which are experiencing congestion and in which there is arguably a case for increasing fees. Ideally, in spectrum bands and geographic locations where there is scarcity and congestion, fees should be set at "market" levels. However, the task of establishing those market levels is very difficult. Methods by which values might be established that would match supply with demand include:

- shadow pricing against auction outcomes;
- shadow pricing against alternative (non-wireless) service delivery mechanisms;
- gathering evidence of market values from observing trading in the secondary market, and
- where there is evidence of congestion (excess demand) in a band or location, gradually increasing annual spectrum charges to the level which causes an easing of that congestion.

In addition to commercial services, the ACA levies spectrum pricing on a number of public users of spectrum. For example, the Department of Defence pays around A\$ 8.4 million each year for spectrum reserved in the defence bands. It pays a further A\$ 979 000 for spectrum it uses outside the defence bands and A\$ 245 000 for classified assignments. Although it may be difficult to make judgements about opportunity costs in the defence environment, for example security reasons may prevent full disclosure of the purpose for which spectrum is used, the ACA nevertheless believes that charges for defence spectrum should continue to be made on the same basis as for other users. This provides the best assurance that there will be an incentive for the Department of Defence to make efficient use of spectrum, including surrendering spectrum that it no longer requires. It should be noted that there have been several examples where the Department of Defence has been willing to give up or share spectrum.

Source: ITU Country Case Study, Radiospectrum Management for a Converging World: Australia.

Administrative incentive pricing can be a means of bringing market forces to bear on spectrum use by public services. Opportunity costs of the current use of spectrum would reflect the economic value of the spectrum in the best alternative use. In theory, current users would therefore be willing to hand back rights to use spectrum if the opportunity costs of using spectrum, reflected through administrative incentive pricing, are higher than the economic value to the user.

Administrative incentive pricing, however, is an imperfect substitution for market-forces. Information deficiencies as well as methodological problems in determining fees equivalent to the opportunity costs of current spectrum use, renders it an imperfect tool. Nevertheless, in the absence of other alternatives, there still remains considerable scope for the use of administrative incentive pricing in the case of public-safety services and other services deemed unsuitable for the application of more significant market based approaches, such as spectrum trading, especially when it can be used in conjunction with other market-based incentives such as the permitting of spectrum sharing and leasing.

5.2.2 Spectrum sharing and leasing

As an alternative or a complement to administrative incentive pricing public service use of spectrum may also be exposed to economic incentives to some degree by allowing them to enter into leasing or some other form of spectrum sharing arrangement, provided that such arrangements would not endanger operational effectiveness. In such cases, trading may introduce an economic incentive for public sector services to release some amount of spectrum for commercial use and to adopt practices and technologies that increase spectrum efficiency.

The FCC, for example, is currently considering expanding the leasing regime to allow public-safety entities to lease out their spectrum.³⁹ Doing so would allow wireless entrepreneurs to access larger amounts of spectrum, particularly in rural areas where wireless services would be appreciated the most. In addition to providing wider access to spectrum, leasing would also enable small communities to generate revenues from a largely under utilized asset that the general public will not miss.

However, there are potential problems of which interference and the resulting risks to safety are the biggest as future spectrum usage is difficult to predict. For example, in the United States, mobile service operator Nextel's system co-existed with public safety systems in the 800 MHz band for a number of years before becoming a notable source of interference.⁴⁰

Apart from spectrum sharing alternatives that have been described in section 4 above, two economists at the FCC have proposed an interesting alternative in involving "call options", which may be of particular applicability to public services.⁴¹ In such a framework, a public service would be able to lease out or transfer its radio spectrum to commercial users subject to the condition that the lessee or purchaser surrenders its right to that spectrum if a predetermined event occurs. In the hypothetical example they provide, the US Forestry Service uses spectrum, which is assigned mainly to fight fires that occur during the dry season. During the wet season, it may be willing to transfer or lease its rights to that spectrum but is unable to given the risk that a fire might occur during that season. However, that risk may be eliminated if the Forestry Service could transfer its rights subject a "call option" that would require the lessee or purchaser to surrender its spectrum in the event of a fire during the wet season. Such an arrangement would be made possible with the use of emerging technologies, such as software radio technology and radio beacons, which guarantee the public service user instantaneous recovery of the spectrum.

5.3 International considerations

To a significant extent, spectrum management at the national level is constrained by international obligations resulting from agreements that countries have been entered into for mutual benefit, primarily for purposes of interference management and spectrum harmonization.⁴²

5.3.1 Spectrum harmonization

International spectrum harmonization offers both benefits and constraints to countries that adhere to these norms. Internationally harmonized channels are required for the cross-border movement of certain wireless services such as radio communications on ships and aircraft as well as global roaming on mobile phones. In addition, services that transmit signals across borders, such as satellite services, also require some degree of international harmonization. Finally, the harmonization of spectrum usage across countries allows wireless

equipment manufacturers in achieving larger economies of scale and operators in achieving a more rapid rollout of new services.

Along with the benefits offered, international harmonization requirements, both global and regional, also impose constraints on changes in spectrum use, which can result in inefficiencies in the form of regulatory delay and which can act as a barrier to the development of new and alternative services for that frequency (see Box 14). Countries can also be restrained from adopting new approaches to national spectrum management, like spectrum trading or open spectrum, which allow spectrum users full freedom to determine spectrum use. Strict harmonization requirements can also inhibit the emergence of competing technologies and services over other frequencies. There are benefits that can be reaped from allowing multiple or competing standards to develop as the type and quality of services offered tend to differ across technologies. For example, CDMA networks introduced more and better data services earlier than those available on GSM networks.⁴³

Nevertheless, despite the apparent constraints of in aiming for international spectrum harmonization, there still remains some scope for flexibility. The evolution of harmonization and standardization in mobile communications provides a good illustration of how flexibility and competition between standards and technology may be preserved while allowing the benefits of harmonization and standardization, like global roaming for mobile phones and economies of scale, to emerge (see Box 15).

The example of the evolution of harmonization and standardization in mobile technology illustrates a few important factors to consider in the pursuit of harmonization. Firstly, where harmonization is seen as advantageous, it should nevertheless not set more limits than necessary to achieve its goals. For example, it should be aimed at broad categories, such as the entire family of IMT-2000 standards, within defined bands rather than at a specific technology description, such as UMTS. This would allow for competition between technologies and standards to continue. Secondly, after harmonization has delivered its benefits, competing services and technologies should be allowed to access the spectrum. Finally, the creation of standards for harmonized bands should be left open and led by industry in order to facilitate market based competition between manufacturers and operators.

In this respect, at the international level, ITU Radio Regulations and recommendations impose relatively few constraints in terms of mandatory harmonization requirements. Spectrum allocations for the purposes of harmonization are typically confined to that necessary for the efficient provision of cross-border services, such as satellite services, and the facilitation of cross-border movement of radio transmissions, such as in aviation and maritime uses. These are typically phrased in terms of broad service categories and are largely technology neutral. In addition, spectrum harmonization activity under the auspices of ITU for the provision of commercial services has also becoming increasingly industry initiated at the core, as the case of the development of the IMT-2000 recommendations has illustrated. Nevertheless, there still remains significant scope for increasing flexibility and for giving industry a larger role to play in the harmonisation process.

Before concluding this section, it is worthwhile to note that like in all other aspects of spectrum management, the eventual introduction of advanced wireless technologies, like software defined radio in particular, has the potential to render largely irrelevant the need for spectrum harmonization (see Box 16).

Box 14: ERMES

The enhanced radio messaging system (ERMES) was an initiative to create a Europe-wide mobile messaging system. The standard for ERMES was first agreed to in 1992 and two years later the band 169.4125 – 169.8125 MHz was harmonized for its application via CEPT decision.

However, in contrast with GSM's success, there has been no notable implementation of ERMES. As a result, CEPT is not in the process of carrying out a review among member states to assess the merits of retaining the harmonisation agreements for ERMES.

Source: Martin Cave, Review of Radio Spectrum Management, An independent review for Department of Trade and Industry and HM Treasury (2002) available at <http://www.see.asso.fr/ICTSR1Newsletter/No004/RS%20Management%20-%20title-42.pdf>.

Box 15: Harmonization and standardization in mobile communications

The development of first-generation analogue mobile systems was strongly influenced by the adoption of open and non-proprietary standards. Although AMPS (USA), TACS(UK) and NMT(Scandinavia) systems were based on different technologies, neutral manufacturers were allowed to adopt their standards, leading to the more wide-scale adoption of these technologies in neutral countries. Standards proprietary standards promoted by Japan, France and Germany, however, proved less successful. Although there was little coordinated international effort to harmonize spectrum use for these services, the frequency bands used by the successful standard gained a near-harmonized status (e.g. 450MHz for NMTS and 900MHz for TACS).

The development of the second generation of mobile systems, however, took place during a period when the European Community's desire for a single market came into prominence. The *Conférence des Administrations Européennes des Postes et Télécommunications* (CEPT) undertook the development of a set of common standards for a pan-European mobile network. Representations by the CEPT to the European Commission resulted in a directive requiring Member States to set aside spectrum in the 900MHz band for the eventual deployment of a pan-European mobile network based on the GSM standard. These conditions led to the emergence of an early installed subscriber base which was quickly added to by the rapid adoption of the standard by most countries worldwide. By the end of 1993, there were more than 1 million GSM users in Europe. By contrast, the American policy of not adopting a common standard or frequency led to a fragmented market and to substantial difficulty in exporting American technologies and standards.

Although competition for global adoption between UMTS and CDMA2000 technology characterized the development of an international framework for third-generation mobile systems, the success of GSM demonstrated the importance of global roaming in the eventual service delivery. Internationally, a core band of spectrum was allocated at around the 2GHz band for terrestrial systems in the IMT-2000 family.

Source: JL Funk and DT Methe, "Market and committee-based mechanisms in the creation and diffusion of global industry standards: the case of mobile communication", *Research Policy* 30(2001); Neil Gundal et al., "Standards in wireless telephone networks", *Telecommunications Policy* 27(2003); and Martin Cave, *Review of Radio Spectrum Management*, An independent review for Department of Trade and Industry and HM Treasury (2002) available at: http://www.see.asso.fr/ICTSR1Newsletter/No004/RS%20Management%20-%20202_title-42.pdf.

5.3.2 Interference management

On a global scale, interference management is largely dealt with through ITU. The most important principle of the Radio Regulations is that spectrum, being a limited resource, must be used efficiently and equitably. In order to achieve this, ITU Radio Regulations and recommendations determine how spectrum bands can be used while the Radiocommunication Bureau (BR) oversees a coordination procedure that requires the registration of systems that have been licensed by its Member States and the dissemination of that information to Member States that may be affected (see Box 17).

Box 16: Software-defined radio

Software-defined radio (SDR), refers to wireless communication in which the transmitter modulation is generated or defined by a computer, and the receiver uses a computer to recover the signal intelligence. To select the desired modulation type, the proper programs must be run by microcomputers that control the transmitter and receiver.

The most significant asset of SDR is versatility. Wireless systems employ modulation types, operating frequencies, bandwidths, and other protocols that vary from one service to another. Even in the same type of service, for example wireless fax, these characteristics often differ from country to country. A single SDR set with an all-inclusive software repertoire can be used in anywhere in the world. Changing the set's fundamental characteristics would involve simply selecting and launching the requisite computer program, effectively weakening the relationship between the equipment and frequencies.

Source: SDR Forum at <http://www.sdrforum.org>.

Box 17: Mission of the ITU-R

The mission of Radiocommunication Sector (ITU-R) lies within the broader framework of the purposes of ITU, as defined in Article 1 of the ITU Constitution and is, in particular, to "maintain and extend international cooperation among all the Member States of the Union for the improvement and rational use of telecommunications of all kinds".

The specific role of ITU-R within the framework of this mission is as follows. ITU-R shall:

- effect allocation of bands of the radiofrequency spectrum, the allotment of radio frequencies and the registration of radio frequency assignments and of any associated orbital position in the geostationary satellite orbit in order to avoid harmful interference between radio stations of different countries;
- coordinate efforts to eliminate harmful interference between radio stations of different countries and to improve the use made of radio-frequencies and of the geostationary-satellite orbit for radiocommunication services.

Source: ITU-R.

To a large extent, ITU's framework for interference management resembles that seen on a national scale. Its approach is much in line with the general rule of thumb that the best spectrum efficiency is obtained when services or systems with homogeneous characteristics share an allocation. In order to arrive at this homogeneity, the ITU Radio Regulations assign priorities to different services within a designated band. New assignments of spectrum to uses within the definition of the primary service of the band can be deployed without difficulty (subject to coordination requirements with neighbouring countries). If the assignment is to a use that falls within the definition of the secondary service of the band, the user will not be entitled to interference protection from current or future primary service users. Assignments of spectrum use, that deviate from the ITU frequency plan are only permitted "on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by station operating in accordance with the provisions of the Constitution, the Convention and these Regulations".⁴⁴

Given its broad service categories and emphasis on bilateral coordination, ITU's spectrum management framework can be considered to be more flexible than most national regimes that employ narrower allocations and assignments. Nevertheless, the framework still suffers from the same criticism that is levelled against national approaches that seek spectrum efficiency through administrative spectrum allocation. In addition, its operation also acts as a constraint on the spectrum management approaches that can be taken by national administrations to remedy these inefficiencies. In practice, if national administrations were to implement market based approaches that allow greater flexibility in spectrum use, spectrum usage in border areas would effectively be restricted to the services specified within that ITU frequency band. While this may not constrain geographically isolated countries, it would severely limit the spectrum management options open to small countries that share borders with many others.

Extrapolating from national experiences, there exist a number of alternative approaches to interference management that could be considered for international application. A radical alternative would be to repeal the entire system of spectrum allocation at the international level outside those bands required for the harmonisation of cross-border services. Bilateral coordination could be initiated without the constraint of service allocations. In these circumstances, each country could make an independent assessment of the trade-off between spectrum efficiency and the economic and social advantages of supplying inhomogeneous services at their border. As a complement to the process, a dispute resolution body could be established to facilitate the negotiation process. Although this approach would allow for greater flexibility than the present international regime, it would achieve that at the expense of certainty while risking increased delays as a result of protracted negotiations.

Another alternative, which would allow for more international regulatory certainty, could involve the setting of general service-neutral values for interference parameters across all frequencies at the geographic boundary of every country by way of a multilateral agreement. These parameters could then be subsequently varied through bilateral negotiations between neighbouring countries. Similarly, an organization like ITU may be delegated the authority to act as arbitrator in the event that dispute resolution is necessary.

5.3.3 Improving the international spectrum management framework

Although there exists a large scope for improving the international spectrum management framework, it is likely that entrenched interests, largely in the form of national interests in preserving incumbent systems on

one level and in perpetuating incumbent spectrum management frameworks on another, will tend to stand in the way of a comprehensive rethinking of the international spectrum management framework.

Nevertheless, with an increasing number of countries rethinking the management process by which spectrum efficiency can be achieved, the possibility of change on a global level grows steadily as can be seen from the initial steps taken by ITU-R Study Group 1 in the area of “Improving the International Spectrum Regulatory Framework”.⁴⁵

6 Conclusion

The spectrum management process is a mammoth task that governments are beginning to acknowledge they cannot tackle alone. Technological progress and marketplace change have placed an increasing strain on the traditional spectrum management approaches that governments have resorted to for almost 100 years. In the same way as the wave of liberalization, deregulation and privatization has swept over the telecommunications sector as a whole, the regulatory approach to spectrum management is poised to follow.

While the need for regime change is clear, there nevertheless does not appear to be one single spectrum management regime that would bring about complete technical and economic spectrum efficiency. Constant changes to the paradigm as well as inherent differences in each regime will mean that spectrum management reform may have to be pursued in a continuously progressive fashion, by adopting different approaches in different spectrum bands over different periods of time.

Endnotes

¹International Herald Tribune, "Toward a Network of Things", Oct 15, 2003 at <http://www.iht.com/articles/113815.html>.

² Resources on the early history of radio communications and its regulation can be found at "United states Early Radio History" at <http://earlyradiohistory.us/>; and Tribute to 100 years of Radiocommunications Regulation in New Zealand at <http://www.med.govt.nz/rsm/whatsnew/press/20030917.html>.

³ See in general: <http://www.itu.int/ITU-R>.

⁴ Regulatory framework for radio spectrum policy in the EC (COM(2000)407).

⁵ Although most countries consolidate all spectrum management functions in one body, some countries maintain a separate regulatory approach towards different categories of spectrum users. For example, in Canada and Australia, spectrum management is performed by one administration, however, the granting of broadcast licenses are regulated by a different administration.

⁶ For a discussion of the wide variety of approaches to national spectrum management, see for example the FCC's Review of Spectrum Management Practices at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-229047A1.pdf.

⁷ UMTS Forum at <http://www.umtsforum.org/>.

⁸ For more information on auctions and auction design see Melody WH, Spectrum auctions and efficient resource allocation: learning from the 3G experience in Europe. (2001) *Info*, 3:5-10.

⁹ See for example Hazzlett TW, 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. (2001) *Harvard Journal of Law and Technology*, 14:335-567 and Melody WH, Radio spectrum allocation: role of the market. (1980) *American Economic Review*, 70:393-397.

¹⁰ Annex 4 to ITU-R WP1B Chairman's Report, Working Document towards a Preliminary Draft New Report on Technical Convergence with Respect to Terrestrial Fixed, Mobile, and Broadcasting Interactive Multimedia Applications, Document 1B/16-E, 12 Nov 2003.

¹¹ In addition to the four principal modes, two other modes have also been identified by the RA as appropriate in particular circumstances, for example, during the refarming of a frequency band from one use to another:

- mode 5: custom designed trading as part of a strategic approach; for example, as part of steps taken to assist the replanning of a band, and
- mode 6: trading of "overlay licenses".

¹² Source: Implementing Spectrum Trading, A Consultation Document, July 2002, Radiocommunications Agency, United Kingdom available at www.ofcom.org.uk/static/archive/ra/topics/spectrum-strat/consult/implementingspectrumtrading.pdf.

¹³ Coase RH, The federal Communications Commission. (1959) *Journal of Law and Economics*, 2:1-40 and Coase, RH, The Problem of social cost. (1960) *Journal of Law and Economics*, 3:1-44.

¹⁴ See for example Martin Cave, review of Radio Spectrum Management, An independent review for Department of Trade and Industry and HM Treasury (2002) available at http://www.see.asso.fr/ICTSR1Newsletter/No004/RS%20Management%20-%202002_title-42.pdf

¹⁵ Principles for Promoting the Efficient Use of Spectrum by Encouraging the Development of Secondary Markets, FCC, Dec 2000.

¹⁶ C Bennet, Rural Telecommunications Group (RTG), Transcript of the Public Forum on Secondary Markets in radio Spectrum, May 23, 2000.

¹⁷ Spiller PT, Cardilli C, Towards a property rights approach to communications spectrum, (1999) *Yale Journal on Regulation*, 16:53-83

¹⁸ Overlay licenses give rights to use spectrum that currently contains an incumbent as soon as the incumbent has moved out (or rights to use a part as soon as the incumbent has vacated that part). The incumbent's security of tenure may be limited by license term so that they may be required to move out by a given date. Incumbents and new entrants may then negotiate over the price to be paid to bring the date forward.

¹⁹ For a more complete discussion on a step-by-step approach to introducing spectrum trading see: Implementing Spectrum Trading, A Consultation Document, July 2002, Radiocommunications Agency, United Kingdom available at www.ofcom.org.uk/static/archive/ra/topics/spectrum-strat/consult/implementingspectrumtrading.pdf.

²⁰ Stuart Minor Benjamin, Spectrum Abundance and the Choice Between Private and Public Control, New York University Law Review, Dec 2003.

²¹ See for example: Procedures Implementing Package Bidding for Auction No. 31, 65 FR 43361-01 (July 13, 2000); Auction of Licenses in the 747-762 & 777-792 MHz Bands, 15 FCCR 8809 (2000).

²² For a more complete discussion on license duration and security of tenure with regard to spectrum trading see: Implementing Spectrum Trading, A Consultation Document, July 2002, Radiocommunications Agency, United Kingdom available at www.ofcom.org.uk/static/archive/ra/topics/spectrum-strat/consult/implementingspectrumtrading.pdf.

²³ For a complete review of competition safeguards in the New Zealand market see Final Report: Allocation and Acquisition of Spectrum, Report Prepared for the New Zealand Ministry of Economic Development on Competition Safeguards in Relation to Initial Allocation of and Secondary Markets for Radiofrequency Spectrum in New Zealand at http://www.med.govt.nz/pbt/rad_spec/competition-safeguards/report/.

²⁴ See Chapter 8, Study into the use of Spectrum Pricing: The Case of New Zealand, NERA and Smith System Engineering, at www.ofcom.org.uk/static/archive/ra/topics/spectrum-price/documents/smith/smith8.doc

²⁵ See Futurepace Solutions, Comments on Implementing Spectrum trading, 2002 available at <http://www.ofcom.org.uk/static/archive/ra/topics/spectrum-strat/responses/ist/futpace.doc>

²⁶ See Analysys, Spectrum trading: increasing the efficiency of spectrum usage 2002 at http://www.analysys.com/default_acl.asp?Mode=article&iLeftArticle=992&m=&n=

²⁷ For a discussion of the CB Radio phenomenon from a regulatory perspective, see Carol Ting, Johannes M. Bauer, Steven S. Wildman, "The U.S. experience with non-traditional approaches to spectrum management" available at <http://quello.msu.edu/wp/wp-05-03.pdf>.

²⁸ According to the Yankee Group. See http://www.yankeegroup.com/public/news_releases/news_release_detail.jsp?ID=PressReleases/news_august012002_wmec.htm.

²⁹ Paris, the wireless wonder? *International Herald Tribune* (5 May 2003), reporting on a business plan to install Wi-Fi antennas outside of each Paris Metro station to create a single Wi-Fi network, turning Paris into a giant Wi-Fi hotspot. See also article on Spokane, Washington ISP creating a 220 square mile hotspot in that city (www.spokanejournal.com/spokane_id=article&sub=1611).

³⁰ Analysys report, Public WLAN Access in Western Europe and the USA, March 2002 at <http://www.analysys.com>. WLAN Hardware sales too were skyrocketing, fuelled mainly by sales in North America. By contrast, Central and Latin American hardware sales represented only 3 per cent of the market, according to an Infonetics Research, Inc. report issued in May 2003 at <http://www.infonetics.com/resources/purple.shtml?nr.wlanms.1q03.052103.shtml>.

³¹ http://www.isp-planet.com/research/2002/newtechs_020130.

³² This is predicted by International Data Corporation. See http://www.isp-planet.com/research/2002/newtechs_020130.html.

³³ For a full discussion on the topic, see Johannes M. Bauer, Spectrum Management and the Mobile Services Industry, 2003, Quello Centre Working Paper 04-03 at <http://quello.msu.edu/wp/wp-04-03.pdf>

³⁴ Stuart Minor Benjamin, Spectrum Abundance and the Choice Between Private and Public Control, New York University Law Review, Dec 2003.

³⁵ Faulhaber and Farber, Spectrum Management: property rights, markets and the commons. (2002) Paper presented at the 14th Biennial Conference of the International Telecommunications Society, August 18-21, Seoul, Korea.

³⁶ Jervis VA, De-regulating the Spectrum – Implications for Technology, 2003, AEGIS Systems Limited, available at <http://www.aegis-systems.co.uk/download/ieespectrum2.pdf>

³⁷ Michele C. Farquhar and Ari Q. Fitzgerald, Legal and regulatory issues regarding spectrum rights trading, Telecommunications Policy 27 (2003) 527-532

³⁸ Faulhaber and Faber.

³⁹ (FCC proceeding on software-defined radios).

⁴⁰ Donny Jackson, Spectrum Leasing is Dicey Proposition for Public Safety at:
<http://firechief.com/microsites/newsarticle.asp>.

⁴¹ Mark M. Bykowsky and Michael J. Marcus, “Facilitating Spectrum Management Reform via Callable/Interruptible Spectrum”, Sep 13, 2002 at <http://intel.si.umich.edu/tprc/papers/2002/147/SpectrumMgmtReform.pdf>.

⁴² For an exhaustive discussion of international constraints on national spectrum management in the context of the United Kingdom, see AEGIS Spectrum Engineering, Implications of international regulation and technical considerations on market mechanisms in spectrum management, 2001, available at <http://www.aegis-systems.co.uk/download/spreview.pdf>.

⁴³ See Gandal, Salant and Waverman, Standards in wireless telephone networks, Telecommunications Policy 27 (2003) 325-332.

⁴⁴ Section 4.4 ITU Radio Regulations.

⁴⁵ The website of ITU-R Study Group 1 is at <http://www.itu.int/ITU-R/study-groups/rsg1/index.asp>.