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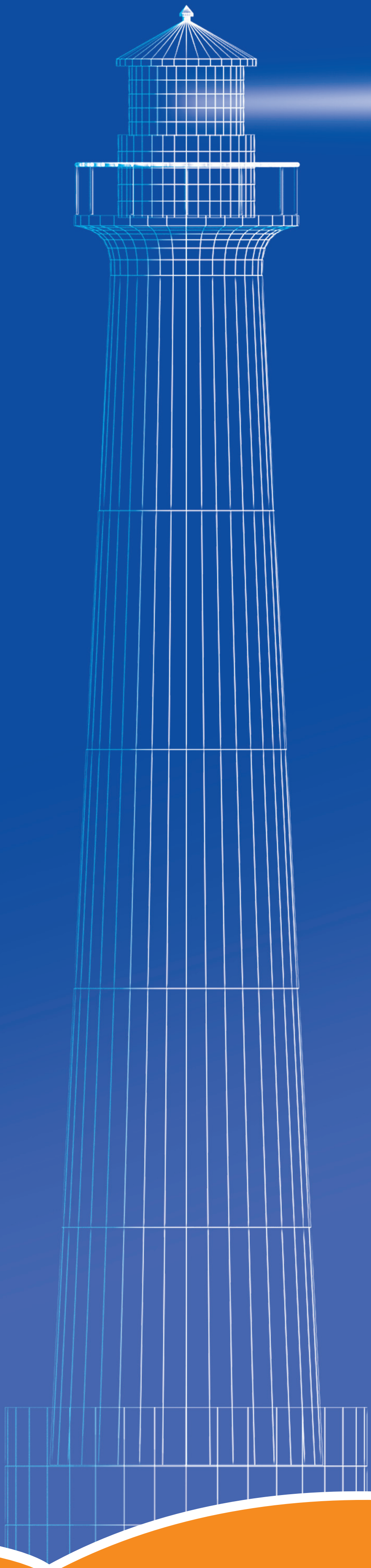

GSR 2005
DISCUSSION PAPER

BROADBAND SPECTRUM MANAGEMENT

Comments are welcome and should be sent by 5 December 2005 to GSR05@itu.int

International Telecommunication Union

GLOBAL SYMPOSIUM FOR REGULATORS

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Broadband Spectrum Management

Pragmatic Tradeoffs for Enabling
Broadband Wireless Access

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Comments are welcome and should be sent by 5 December 2005 to
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Broadband Spectrum Management

*Pragmatic Tradeoffs for Enabling Broadband Wireless Access**

1 Executive Summary

This chapter discusses the dawn of broadband wireless access (BWA). It does so from the perspective of the challenges faced by global spectrum regulators on how to allocate and assign spectrum rights in a manner that encourages the rapid and widespread deployment of BWA systems for the ultimate benefit and welfare of consumers. The spectrum regulator's main challenge is to provide for flexible, market oriented spectrum license rights---which theoretically create a positive investment climate for BWA services---while at the same time avoiding uneconomic hoarding and speculation in spectrum that could have the detrimental effect of delaying the availability of these services to consumers. The key point of this paper is that grants of increasingly flexible spectrum rights should be favored so long as the spectrum licensees' meet two absolute preconditions critical to the development of communications markets. The first precondition is that the grant of these new rights to the spectrum licensee, or in the case of unlicensed spectrum – the service enabler, must in some form or shape increase the competition for the benefit of consumers. The second precondition is the requirement that the licensee, or in the case of unlicensed spectrum---the service enabler, to experience the opportunity cost of using its spectrum allocation as a way of ensuring effective and efficient use of the spectrum.

This paper is not intended as an academic overview of spectrum issues; instead, it is designed to stimulate thinking on how to make effective and pragmatic spectrum management decisions without falling into dogmatic and theological approaches that have become the standard discourse on this issue.[1]

The paper begins by articulating the primary goals of broadband spectrum regulators and seeking to understand some fundamentals about the economics of wireless access systems based on the past 20 years of experience in mobile wireless markets. It follows with a review the fundamental technological advances that are making it possible for new spectrum resources to be available for broadband wireless services and applications. The traditional regulatory spectrum management models are then examined to determine whether they adequately address the challenges presented by these new advances in BWA technologies. After concluding that the current regulatory models are by themselves insufficient to address these changes, the paper outlines a more pragmatic framework for managing BWA spectrum resources to achieve the end goals. The paper continues on to discuss certain key spectrum management best practices that could be incorporated into this pragmatic approach to accelerate the rate at which BWA networks could be deployed. The final section of the paper reviews recent spectrum decisions demonstrating how best practices and a pragmatic outcome oriented spectrum policy framework can help encourage the rapid deployment of BWA systems.

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* This discussion paper has been prepared by John Muleta. The views are those of the author and may not necessarily reflect the opinions of the ITU or its membership.

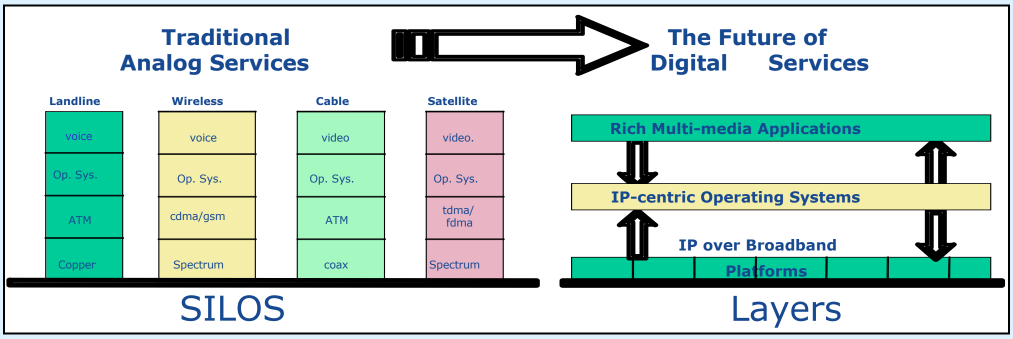
2 Introduction

In our modern world, broadband wireless services are poised to bring significant benefits to all parts of the world by bringing the Internet's power to educate and inform literally into the hands of billions of people around the globe. Unlike the past, these new services are likely to be uniform in that they will ultimately be providing "access" to the Internet and to Internet Protocol enabled services. Henceforth, the phrase "Broadband Wireless Access" or BWA will be used to describe the arrival of an era where it is possible to have the "Internet Everywhere All the Time." As the intent here is to find ways of increasing the rate of consumer adoption of BWA, the discussion of BWA addresses spectrum bands below 6 GHz where the physical characteristics of the spectrum are more conducive to consumer applications.

In this new era, the power of the Information Age to affect our lives will be exponentially multiplied by the freedom brought about by BWA networks. Wireless broadband technologies such as those defining BWA will fuel the engines of our global economies by enabling consumers to:

- freely access the Internet from the farm, the city, kiosks, cyber cafés, coffee shops, on moving trains, and in their own communities and backyards, in developed and developing countries alike.
- connect to the Internet seamlessly using a single device – to make phone calls, to access information, to vote, to access government services, pay taxes, pay bills electronically, and access entertainment.
- live in enlightened communities that are connected to broadband using spectrum based services – gaining access to a wealth of resources and opportunities not previously available.

Figure 1: The ultimate consumer broadband experience will be based on a multi platform IP network with BWA as its core



BWA networks' impact on consumers is even more heightened when it is combined with the advances made in other telecommunications platforms including wireline, cable, broadband-over-powerline (BPL) and satellites. *Ultimately, the broadband world is one where BWA networks, because they enable mobility and* portability*, are at the core of a variety of useful combination of broadband technologies that result in a rich multi-media consumer experience at nearly all times and all places.*

Of course, the opportunity for BWA services to improve our lives ultimately relies on the amount of spectrum rights made available by regulators. However, for the first time in spectrum's short history, it appears that advances in technology, independent of the action of the regulators, can increase spectrum capabilities and resources (i.e., allowing licensees to do more with the same spectrum or enabling new uses for spectrum not previously possible). As these advances become more widely adopted and new spectrum resources become available even more rapidly, regulators must consider whether traditional approaches to spectrum management are sufficient to address the resulting challenges and opportunities.

While contemplating the appropriate regulatory model for the evolving state of spectrum technology, broadband spectrum regulators must also be mindful of a number of key best practice concepts that have developed around spectrum management over the last two or three decades. The best practices listed below have, in varying circumstances, fostered the widespread adoption and deployment of an earlier generation of wireless services including cellular mobile radio, broadcast television, paging, and satellite services. They have also led to significant reduction to the cost of providing services and created the opportunity for entrepreneurs to develop innovative applications that have benefited consumers.

2.1 Spectrum Management Best Practices

Regulators participating in the 2005 Global Symposium have identified the following set of best practice guidelines for spectrum management to promote broadband access:

2.1.1 Facilitate deployment of innovative broadband technologies.

Regulators are encouraged to adopt policies to promote innovative services and technologies. Such polices may include:

a) Managing spectrum in the public interest.

b) Promoting innovation and the introduction of new radio applications and technologies.

c) Reducing or removing unnecessary restrictions on spectrum use.

d) Embracing the principle of minimum necessary regulation to reduce or eliminate regulatory barriers to spectrum access, including simplified license and authorization procedures for the use of spectrum resources

e) Allocating frequencies in a manner to facilitate entry into the market of new competitors.

f) Ensuring that broadband wireless operators have as wide a choice as possible of the spectrum they may access, and releasing spectrum to the market as soon as possible.

2.1.2 Promote transparency

Regulators are encouraged to adopt transparent and non-discriminatory spectrum management policies to ensure adequate availability of spectrum, provide regulatory certainty and to promote investment. These policies may include:

- Carrying out public consultations on spectrum management policies and procedures to allow interested parties to participate in the decision-making process, such as:
  - public consultations before changing national frequency allocation plans; and
  - public consultations on spectrum management decisions likely to affect service providers.
- Implementing a stable decision-making process that provides certainty that the grant of radio spectrum is done in accordance with principles of openness, transparency, objectivity--based on a clear and publicly available set of criterion which is published on the regulator’s website--and non-discrimination and that such grants will not be changed by the regulator without good cause.

– Publication of forecasts of spectrum usage and allocation needs, in particular on the regulator's website.
– Publication of frequency allocation plans, including frequencies available for wireless broadband access, in particular on the regulator's website.
– Publication of a web-based register that gives a complete overview of assigned spectrum rights, vacant spectrum, and license-free spectrum.
– Clearly defining and publishing radio frequency spectrum users' rights and obligations, including on the regulator's website.
– Clearly defining and publishing licensing and authorization rules and procedures, including on the regulator's website.
– Publication of legal requirements for imported equipment and foreign investment, in particular on the relevant government agency website.

2.1.3 Embrace technology and service neutrality

To maximize innovation, create conditions for the development of broadband services, reduce investment risks and stimulate competition among different technologies, regulators can give industry the freedom and flexibility to deploy their choice of technologies and decide on the most appropriate technology in their commercial interest rather than regulators specifying the types of technologies to be deployed, or making spectrum available for a preferred broadband application.

- Regulators can take into consideration technological convergence, facilitating spectrum use for both fixed and mobile services.
- Regulators can provide technical guidelines on ways to mitigate inter-operator interference.
- Regulators can ensure that bands are not allocated for the exclusive use of particular services and those spectrum allocations are free of technology and usage constraints as much as possible.

2.1.4 Adopt flexible use measures

Regulators are encouraged to adopt flexible measures for the use of spectrum for wireless broadband services. Such measures may include recognizing that:

- minimizing barriers to entry and providing incentives for small market players by allowing broadband suppliers to begin operations on a small scale at very low cost, without imposing onerous rollout and coverage conditions, to enable small market players to gain experience in broadband provision and to test market demand for various broadband services.
- wireless broadband services can be used for both commercial and non-commercial uses (e.g., for community initiatives or public and social purposes) and that broadband wireless spectrum can be allocated for non-commercial uses with lower regulatory burdens, such as reduced, minimal or no spectrum fees; regulators can also allocate and assign spectrum for community or non-commercial use of broadband wireless services.
- flexible licensing mechanisms of wireless broadband technologies can provide a full range of converged services.
- adopting lighter regulatory approaches in rural and less congested areas, such as flexible regulation of power levels, the use of specialized antennas, the use of simple authorizations, the use of geographic licensing areas, lower spectrum fees and secondary markets in rural areas.
- in markets where spectrum scarcity is an issue, the introduction of mechanisms such as secondary markets (e.g., spectrum trading) can foster innovation and free-up spectrum for

broadband use. If spectrum users can trade spectrum rights and change the use made of the spectrum, this will enable new broadband services to be introduced more speedily than if the regulator first revokes existing licenses and re-awards them for broadband applications.

- the role that both unlicensed (e.g. license-exempt) and licensed spectrum can play in the promotion of broadband services, balancing the desire to foster innovation with the need to control congestion and interference. One measure is to allow small operators to start operations using license-exempt spectrum, and then moved to licensed spectrum when the business case is proved.
- the promotion of shared-use bands, as long as interference is controlled. Spectrum sharing can be implemented on the basis of geography, time or frequency separation.
- Developing strategies for clearing bands for new services as appropriate.
- the need for cost-effective backhaul infrastructure from rural and semi-rural areas, regulators can consider the use of point-to-point links within other bands, including any bands for broadband wireless access

2.1.5 Ensure affordability

Regulators can apply reasonable spectrum fees for wireless broadband technologies to foster the provision of innovative broadband services at affordable prices, and minimize unreasonable costs that are barriers to entry. Increasing the direct and indirect costs of accessing spectrum further reduces the economic viability in rural and under-served areas. Auctions and tender processes can be managed to better meet these goals.

2.1.6 Optimize spectrum availability on a timely basis

Regulators are encouraged to provide effective and timely spectrum use and equipment authorizations to facilitate the deployment and interoperability of infrastructure for wireless broadband networks. Regulators are also encouraged to make all available spectrum bands for offer, subject to overall national ICT master-plans, in order that prices are not pushed up due to restrictive supply and limited amount of spectrum made available and so that opportunities to use new and emerging technologies can be accommodated in a timely manner. In addition, special research or test authorizations could be issued to promote the development of innovative wireless technologies.

2.1.7 Manage spectrum efficiently

Spectrum planning is necessary to achieve efficient and effective spectrum management on both a short-term and long-term basis. Spectrum can be allocated in an economic and efficient manner, and by relying to the greatest extent possible on market forces and economic incentives. Regulators can promote advanced spectrum efficient technologies that allow co-existence with other radio communications services, using interference mitigation techniques like dynamic frequency selection and spread spectrum technology. Regulators can provide swift and effective enforcement of spectrum management policies and regulations.

2.1.8 Ensure a level playing field

To prevent spectrum hoarding, especially by incumbents, regulators can set a limit on the maximum amount of spectrum that each operator can obtain, which would be no higher than the optimum amount of spectrum required for nationwide deployment.

2.1.9 Harmonize international and regional practices and standards

Regulators can, as far as practicable, harmonize effective domestic and international spectrum practices and utilize regional and international standards whenever possible, and where appropriate, reflect them in national standards, balancing harmonization goals with flexibility measures. This could include harmonization of spectrum for broadband wireless access that could generate economies of scale in the production and manufacture of equipment and network infrastructure. Likewise, global harmonization of standards to ensure interoperability between different vendor's user terminals and network equipment can be promoted. The use of open, interoperable, non-discriminatory and demand-driven standards meets the needs of users and consumers. Developing coordination agreements with neighbors, whether bilateral or multilateral in nature, can help speed licensing and facilitate network planning.

2.1.10 Adopt a broad approach to promoting broadband access

Spectrum management alone is inadequate to promote wireless broadband access. A broad approach, including other regulatory instruments; such as effective competitive safeguards, open access to infrastructure, universal access/service measures, the promotion of supply and demand, licensing, roll-out and market entry measures; the introduction of data security and users' rights, where appropriate; lowering or removing import duties on wireless broadband equipment; as well as development of backbone and distribution networks is necessary.

2.2 Key Emerging Global BWA Technologies

Technology is delivering innovation at an unheralded rate and its effect is being realized in wireless access technologies where a myriad of choices are presenting themselves. It is important to note that with the increasing harmonization of services across the globe, regulators should encourage the build-out of as many of these technological alternatives in order to maximize the options to the end-users. Some of the key emerging technologies are described below.

2.2.1 WiFI and HiperLan (Radio Local Area Network) Standards

The ITU's harmonization of the 5 GHz band in 2003 through the World Radio Conference has substantially increased the spectrum available for wireless local area networks (WLANs) worldwide. In addition to adding to the gross level of spectrum available, the ITU's consensus also permit the use of the IEEE standard 802.11 and ETSI Hiperlan standards, both widely deployed RLAN standards that have already achieved significant economies of scale in manufacturing and end-user distribution systems throughout the globe. The latest 802.11a standard has achieved maximum data rate of 54 Mbp/s, and many types of laptops and PDAs are now equipped to use the 802.11a standard. In the coming months and years, many new wireless mobile handsets will be incorporating dual chipsets (known as Unified Mobile Access "UMA" devices) that enable the handsets to seamlessly switch between wide area systems such as CDMA and GSM and radio local area networks such as those enabled by Wi-Fi networks. Similarly, the ETSI standard called HiperLAN2 has also been designed as a short range access mechanism that specifically complements UMTS networks (see below) and can also used for private wireless LAN system. HiperLAN2 is designed to offer high-speed (up to 54 Mbp/s) access to a variety of networks including the UMTS core networks, ATM networks and IP based networks. Both types RLAN systems provide competing benefits to the market and represent an opportunity for greater consumer choice.

2.2.2 UMTS & W-CDMA

Global system for mobile communications (GSM) is the largest mobile technology in the world, with 1.5 billion subscribers is evolving into a new high-speed standard known as Universal Mobile Telecommunication System (UMTS). This is the most subscribed to standard for third generation mobile networks. UMTS was launched in 2002 and is just now being fully implemented across developed country markets. UMTS is expected to deliver permanent internet access throughput of at least 384 kbp/s and up to about 2 Mbp/s. Wideband Code Division Multiplexing Access (W-

CDMA) and its related standard linked to UMTS, the High-Speed Downlink Packet Access (HSDPA), are mobile telephony protocols that permit data transmission downlinks ranging up to 2-8 Mbp/s using standardized 5 MHz bandwidth channels. These standards were created to enable a uniform global standard for real time multimedia services that enable seamless international roaming.

2.2.3 WiMAX

WiMAX utilizes the IEEE standard 802.16, has a data rate of between 10 and 100 Mbp/s, and provides large coverage areas of up to several kilometers. Wireless broadband networks that involve point-to-point or point-to-multipoint networks with individual network links that can provide last mile connectivity in metropolitan environments or can span distances of up to 30 miles are often referenced as WiMax systems. The IEEE currently is working to finalize the 802.16e standard which extends the WiMax standards to mobile applications. The WiMax 802.16 standard holds great promise for future developments in wireless broadband because it can be used for applications in both licensed and unlicensed spectrum, allows communications without the need for line-of-site connections, enables interoperability with different equipment using the same standard, and, in the near future, will encompass both fixed and mobile wireless applications. The developing world, much of which is not wired, is likely to embrace WiMAX as a substitute for cable or DSL broadband service. Although the WiMax standards can operate on both license and unlicensed spectrum, consensus appears to be in favor of a licensed approach with most countries allocating 2.5 GHz and 3.5 GHz bands for WiMax deployments.

2.2.4 WiBro

Wireless Broadband (WiBro) was developed by the Korean telecommunications industry, to operate on the 2.3-2.4 GHz frequency band. WiBro has a data rate of 30-50 Mbp/s and can cover a radius of up to five kilometers. This technology utilizes OFDMA, which allows signals to be divided into many lower-speed sub-channels to increase resistance to multi-path interference. Additionally, consistent with the ITU’s IMT-2000 allocations, WiBro systems under development emphasize hybrid satellite and terrestrial networks that are designed to optimize the delivery of new mobile applications such as mobile video and mobile broadband access.

2.2.5 Digital Television Broadcasting Standards

Digital Video Broadcasting on Terrestrial Networks (DVB-T) is a suite of internationally accepted, open standards for digital television maintained by an industry consortium supported by the European Telecommunications Standards Institute (ETSI), the European Committee for Electrotechnical Standardization (CENELEC) and European Broadcasting Union (EBU). Adoption has been widespread as these digital transmissions use the MPEG standard and are integrated in all set-top boxes commercially available in Europe.

In contrast, Qualcomm has developed a proprietary broadcast system designed to be complementary to CDMA and W-CDMA systems. Its Mediaflow chipsets are designed to use “forward link only” technology for multicasting video content to mobile handsets. This standard offloads high throughput applications onto a separate broadcast spectrum while seamlessly integrating the user experience to avoid latency and packet loss. Given its proprietary nature, it is unclear whether this approach will be able to provide significant advantages to end-user BWA experience in the short term outside of the few markets like the United States where CDMA has achieved significant market penetration.

2.2.6 UltrawideBand (UWB)

UWB is a wireless radio technology designed to transmit data within short ranges (up to 10 meters). It transmits at very high bandwidths (up to 480 Mbp/s) while using little power. UWB is ideal for exchanging data between consumer electronics (CE), PCs, PC peripherals, and mobile devices at very high speeds over short distances. For instance, it could transfer all the pictures on a digital camera's memory card to a computer in a few seconds. There are two standards competing for dominance currently leading to some level of uncertainty for end-users until UWB enabled devices are introduced into the market place in 2006 and thereafter.

Unlike conventional radio systems, UWB systems broadcast over very short distances using a broad spectrum band. Thus, instead of concentrating a powerful signal in a narrow band, the signal is spread over a very wide spectrum range at very low power levels. Of course the challenge of this approach to creating a new spectrum resource is that it encroaches on the rights of other licensees operating in the band. UWB supporters argue that the power levels and the distance limitations are such that the overlay of this technology will not result in harmful interference. Complicating this issue is also the different regimes adopted in Europe and the United States as to which bands UWB can be utilized. In the United States, UWB is limited to operate between 3.1 GHz and 10.6 GHz while in Europe the permitted range is above 4 GHz. Given the size of the United States market, European operators, especially those planning to use 3.5 GHz as the BWA platform, are concerned that UWB overlay systems could interfere with their systems in unexpected ways. Clearly, a more harmonized approach could avert a potentially protracted process of certifying UWB systems for use in different countries.

3 Goals for Broadband Spectrum Regulators

Outside of the political context of regulatory policy- making, spectrum regulators in the new broadband world should be advancing three separate but interrelated goals simultaneously. One primary goal should be to provide the proper incentives for spectrum licensees, both existing and new, to invest in broadband services. The second goal should be expanding consumer choices and welfare by enabling sustainable competition for similarly situated (e.g., “broadband”) services irrespective of the underlying transport platform. Finally, the regulators’ should consider implementing policies that discourage wasteful and potentially anti-competitive behavior resulting from uneconomic speculation and hoarding of the new spectrum capabilities and resources that result from the explosion of technological advances taking place in radio system design.

There are three conventional spectrum management methods. The first is a “command and control” model where strict operating parameters and service definitions provide the basis for defining licensees spectrum rights. An alternative licensing model is the “exclusive use” model where a licensee is afforded exclusive and, within limits, transferable and flexible use rights for a specified spectrum band within a defined geographic area and a fixed period of time. In the current understanding of the exclusive rights model, spectrum use rights and the supporting rules are primarily technical (as opposed to service based) in nature and are designed to protect the spectrum licensee from generating or receiving harmful interference.

The third regulatory model is the “commons or unlicensed” model which allows unlimited numbers of users to share a defined set of frequencies without having any defined set of individual spectrum use right. As such, permitted uses are defined by technical criteria that specify bandwidth and emitted power and provide no enforceable rights to protect against interference. A popular form of commons approach has been the deployment of wireless local area networks using the IEEE 802.11 standard (known as Wireless Fidelity or Wi-Fi).

These models do not sufficiently address today’s rapidly evolving world of broadband spectrum. In the case of command and control approach, the spectrum rights are granted on such narrow grounds that they are of limited utility for broadband opportunities and also require constant government intervention, with its attendant time lag, to change the operating parameter of licenses. The exclusive use model, despite having compelling arguments for providing market incentives to new entrants unfortunately also creates counter-incentives for incumbent licensees to engage in speculative or anti-competitive hoarding of spectrum as a way of thwarting real or perceived competition. Finally, the commons approach, which today provides low entry barriers for service providers to launch services and can result in significant scaling in terms of consumer adoption, also unfortunately becomes self-limited by the lack of enforcement mechanisms to manage and prevent overcrowding and overuse.

An alternative to these models is for the regulator to adapt these models in various combinations that permit him or her to condition the grant new spectrum resources or rights to licensees that demonstrate they will use these rights and resources to increase overall competition for broadband services across all platforms and that they will experience the real and quantifiable opportunity cost of using these spectrum rights. This pragmatic approach insures that a market-based approach is utilized to achieve a public policy goal of deploying BWA systems as rapidly and as efficiently as possible.

4 Defining Broadband Wireless Access

Although wireless services are redefining the limits of our world, there is still no universal definition of wireless broadband. Some countries have defined wireless broadband as the ability of the consumer to have a set of devices that seamlessly interconnect various messaging and communications platforms, including voice and data, and while using inexpensive, high speed connections while at a fixed location or on the road.

Box 1 :

Singapore's regulatory authority describes wireless broadband as "an access technology that offers high-speed data access over the air. A wireless broadband network, typically operating at frequency bands less than 6 GHz, provides broadband speeds ranging from 256 kbps to tens of Mbps. Each base station generally serves an area of up to several square kilometers. Wireless broadband networks can deliver network connectivity to fixed locations using standards like IEEE 802.16d, and in the near future, to mobile users using standards like IEEE 802.16e and IEEE 802.20."

Kenya's Communications Commission defines broadband fixed wireless access "as intentional radiators that use wideband digital modulation techniques and provide a wide array of high data rate fixed communications for individuals, businesses, and institutions."

Mauritius uses a three-part definition for BWA, in accordance with ITU-R Recommendations:

- Wireless Access systems are broadband radio systems that may be deployed either indoors or outdoors. These systems include:
- Fixed wireless access which may be defined as *"Wireless access application in which the location of the end-user termination and the network access point to be connected to the end-user are fixed"*.
- *Mobile Wireless Access* which may be defined as *"Wireless access application in which the location of the end-user termination is mobile"*
- *Nomadic Wireless Access* which may be defined as *"Wireless access application in which the location of the end-user termination may be in different places but it must be stationary while in use*

There is even less agreement as to what constitutes the proper throughput of wireless broadband technologies. For some countries, 200 kilo bits per second ("Kbp/s") generally defines broadband. Other countries embrace 1000 Kbp/s as the minimum throughput required to meet the definition of broadband.

Internationally, the ITU considers broadband wireless access (BWA) to encompass mobile or fixed access technologies that provide connections at speeds higher than the primary rate (e.g.

2 Mbp/s), encompassing technologies falling within the IMT-2000 family as well as newer technologies such as WiMax and WiBro.

Nonetheless, it is likely that each country will continue to make its own decision about the definition of BWA given its technological and economic development stage. In that context, a pragmatic definition of BWA would be to equate the minimum throughput for a BWA system to be one that lends to a seamless "look and feel" with the minimum throughput of a fixed wireline broadband alternative available in that particular country. Defining BWA to be the minimum throughput of the competitive wireline systems has the sensible benefit of setting the market's competitive dynamics so BWA systems have increasing incentives to add throughput in order to match, as closely as possible, wireline systems. This approach emphasizes the coming reality where broadband access is not a single platform but an amalgamation of platforms, with BWA systems at the core, that work together to deliver a set of relevant broadband features to the consumer.

4.1 The Economics of BWA

After two decades of wireless mobility, the economics of wireless access is now much better understood. The principal economic drivers of wireless systems are the availability and cost of spectrum, the cost of the end-user device, and the acquisition and maintenance of the end-user subscriber (ranging from network management to billing and customer service operations). For a BWA system to be successful, it must be competitive across each of these categories demonstrating to operators and end-users alike that it represents a viable value in the broadband marketplace, particularly when compared to the wireline or satellite alternatives which require significant capital expenditure to increase capacity or reach to the next available increment.

4.2 Spectrum as an Input

Spectrum, as discussed later on, is defined by the four parameters of which only two, power and bandwidth, are usually defined by regulators. These parameters determine the capacity and coverage that a particular spectrum band can deliver to an operator so the operator can deliver valued services to end-users. System capacity and coverage essentially determine the number, the size and the cost of the transmitters (including the supporting backhaul network) that an operator needs to deploy in order to deliver the desired set of services. These factors establish the return threshold of the operator wishing to deploy a competitive BWA network.

Box 2: Millimetre Bands

In comparison to spectrum below 3 GHz, millimetre wave spectrum bands (generally ranging above 20 GHz) represent the other extreme where the licensed bandwidth can generally provide significant throughput and data rates. For example, Mauritius has allocated 40 GHz spectrum for use in point-to-point and point-to-multipoint services. There are new developments in the marketplace expanding the throughput of these millimetre systems in excess of 80 Mbp/s which is competitive on a unit basis with fiber networks. However, the poor propagation characteristics of these spectrum bands limit coverage since base stations can only be deployed within unobstructed sight of each other. The economic effect of these line-of-sight limits means more base stations to cover more end-users devices thereby increasing overall operator costs. These bands are not effective for consumer applications and services on a standalone basis, but can provide complementary enabling backhaul services to consumer services deployed using non line-of-sight spectrum.

Spectrum in the range below 3GHz has propagation characteristics that enable wide coverage areas and can more easily overcome interference conditions including foliage, buildings and other obstructions using non line-of-sight technologies such as beam forming. The ability to provide non line-of-slight services reduces the number of base stations required to provide coverage in these bands. However, as we have learned from the experience with mobility services, the increasing the density of customers that comes from successful adoption of the service in the marketplace requires more base stations to meet the need for capacity. Ultimately, any viable BWA service will need to enhance both coverage and capacity but, in the first instance, it is more important to have greater coverage. It is unlikely that a new service category such as BWA that is just coming on in the market will have the necessary consumer adoption justifying a cost of a system designed solely for throughput and system capacity instead of reach and coverage. Over time, as consumer adoption increases, BWA systems will begin to emphasize throughput and capacity by reducing cell sizes and increasing the number of base stations.

There are a number of spectrum bands operating above 0.4 GHz and 5.5 GHz that could help foster the growth of BWA although each band represents necessary tradeoffs between capacity and coverage. In identifying these bands for new uses such as BWA, the general trend across the globe has been to reclaim the bands from incumbent licensees who have or will have the ability to deploy more spectrally efficient equipment that reduces their need for spectrum. One category of reclaimed spectrum comes from government and military operations (1.5-2.4 GHz as well as 5.1-5.8 GHz). In the commercial context, satellite (2.0-2.3 GHz) and fixed microwave systems (3.1-3.7 GHz and 2.1-2.2 GHz) provide an avenue for reclaiming spectrum since the increasing spectral efficiency of the latest technology for these systems and the widespread availability of substitute technology and services (e.g., submarine cables and fiber-optic networks) has reduced the demand for spectrum needed to deploy these services. The broadcast television bands including the UHF (400-700 MHz) and MMDS (2.5 -2.7 GHz) bands have also been the source for new BWA spectrum in various markets given the advent of spectrally efficient digital television broadcast standards.

Box 3: Spectrum Bands for BWA

- 450 – 500 MHz (Regions 2&3) and 600-1000 MHz (Region 1) could be used for broadband mobile access services given the significantly enhanced propagation characteristics of the band[1]; These bands are also under discussion as a candidate to be included as IMT-2000 bands during the 2007 ITU World Radiocommunication Conference (WRC).
- 1.5-2.5 GHz. Many of the bands in this range are currently identified as IMT-2000 bands as shown in Figure 3. They are also under discussion across all regions as part of the 2007 WRC harmonization process to be used for both fixed BWA and broadband mobile, meaning IMT-2000 and beyond (i.e., 3.5 and 4G). These bands are also identified for hybrid satellite and terrestrial wireless systems that permit seamless continental roaming for BWA operators;
- 3.4-3.7 GHz across all regions for licensed BWA services;
- 5.1-5.7 GHz across all regions as part of the WRC for license exempt BWA uses.

The process of identifying bands for new uses such as BWA can be achieved relatively easily, especially in the context of the global harmonization efforts that can provide guidance to the regulator about the most effective future use of a spectrum band. The difficulty lies in transferring these bands from an incumbent licensee to a new one. This paper seeks to help address these transitional issues in a pragmatic fashion by creating marketplace incentives that encourage licensees to transfer spectrum to its best and highest use while at the same time offering services that are competitive for the particular dynamics and context of each country (whether rural or urban, developed or developing markets).

4.3 End User Costs and Devices

End user adoption of wireless systems is largely a function of the cost of the end-user device and applications that work on the devices. Although it is common sense, it bears noting that the lower the cost of the end user device the greater the likelihood for significant adoption of the underlying service by consumers.

Over the last 20 years but increasingly over the last 5 years, the mobile marketplace has demonstrated that consumer adoption in developed markets has accelerated when device costs have been below the US$200 barrier. Although this threshold amount might not be practical for developing markets, it is important to understand that that mass adoption of end-user devices in developed countries has the positive scale effects that can easily translate to lower costs for end user devices distributed in developing economies. Additionally, wireless equipment manufacturers have also learned from the mobile market and are now offering end-user devices with limited functionality to developing country markets in order to further accelerate the manufacturing scale effect that reduces overall cost of making these devices.

4.4 Service Delivery and Management

Reducing the cost and complexity of applications and the associated service delivery mechanisms that work on wireless devices has a significant effect on consumer adoption and leads to accelerating the scale economies of manufacturing the devices. In all geographic markets, the advent of flat rate voice services and the use of prepaid services have increased the rate of adoption of wireless mobile devices thereby leading to significant scale of economies in manufacturing these devices. Additionally, the movement enabling internet protocol services on wireless devices will increase the rate of consumer adoption by making wireless access at the service layer indistinguishable from wired alternatives thereby increasing the value of these services to consumers.

The impact of the internet protocol mindset on BWA service delivery can be best understood by looking at the IEEE 802.16 WiMax standards development process currently underway. The key innovation of the 802.16 standards process has been to simplify the communications protocol stack so that economies of scale can take place in developing radios and the associated chipsets---the most expensive elements---while providing greater freedom for developing applications at the service layer.

5 The Technology Revolution Creating New Spectrum Capabilities

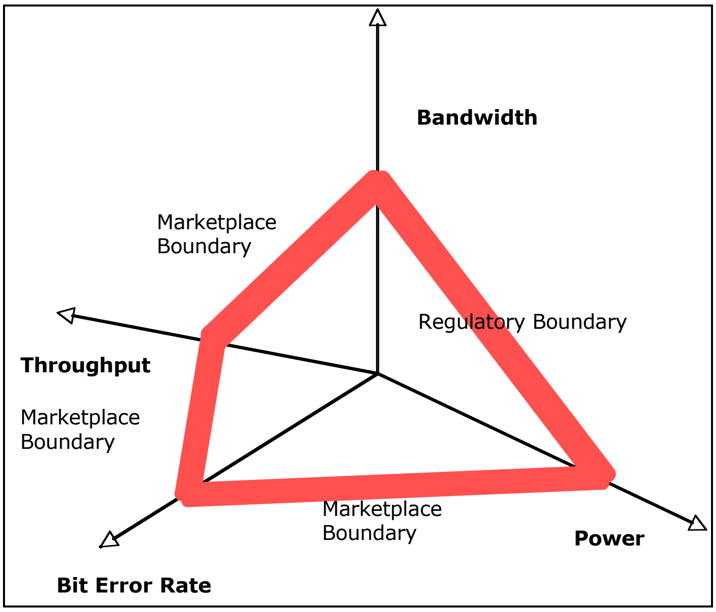
5.1 Applied Information Theory in Radio System Design

Spectrum represents the temporal and spatial opportunities to transmit information using the electromagnetic spectrum. The range of frequencies in the electromagnetic spectrum is typically divided into eight bands spanning from 3 Hertz to 300 GHz.

Frequency Range	Description
3 to 30 Khz	Very low frequency band (VLF)
30-300 KHz	Low frequency band (LF)
300-3 MHz	Medium frequency band (MF)
3 MHz-30 MHz	High frequency band (HF)
30 MHz-300 MHz	Very high frequency band (VHF)
300 MHz-3 GHz	Ultra high frequency band (UHF)
3 GHz-30 GHz	Super high frequency band (SHF)
> 30 GHz	Extremely high frequency band (EHF)

The characteristics of signal propagation depend on the frequency band on which the signal is transmitted and these signals are typically transmitted by an antenna device that transmits energy in one or multiple directions.

Shannon's capacity theorem, the fundamental theorem of radio communications design, establishes that the rate of information transfer by a radio is limited physically by the available spectral bandwidth and ratio of signal to noise within the band. Within this physical limit, the spectrum resources available to a radio are determined by four factors including specified bandwidth, the allowable power or energy emission within the band, the bit error rate acceptable to the end user and the throughput desired by the consumer. Most regulators have hereto only defined the power limits and the bandwidth and left the other two factors to be determined by the marketplace.

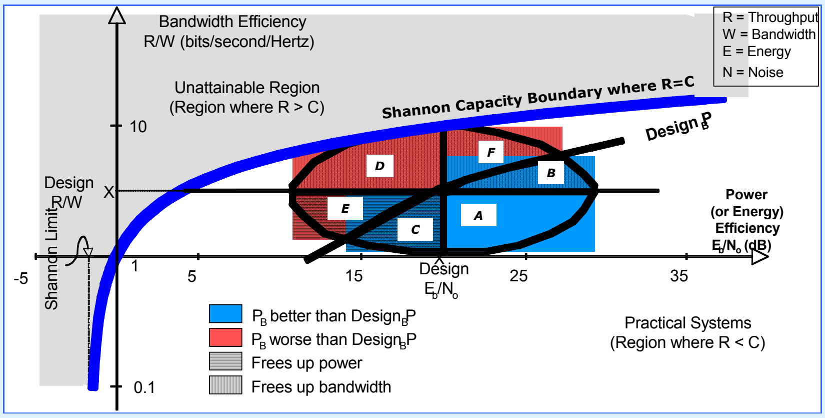


Traditional radio systems were designed using analog equipment and had limited computational power available to them. The results were radios that operated using very narrow throughput and bit error rate (i.e., quality of service demands) parameters and that were highly sensitive to the operating environment. Traditional radios were not flexible and could not be used to take on new tasks or operate in new environments making them unsuitable for broadband networks.

5.2 Advances in Microprocessor Technology and their Effect on Radio Designs

The advent of miniaturized and powerful computing resources available through digital signal processors (DSPs), non-programmable hardware computing components (ASICs) and field programmable gate arrays (FPGAs) has made it possible to create radio systems that can dynamically change along all four vectors (bandwidth, power, throughput, and bit error rate) that define spectrum. By using powerful microprocessors to dynamically change the four variables, radio system designers can now create new spectrum capabilities where none had previously existed. Figure 2 graphically describes the effect of applying these fundamental technologies as enlarging the operating parameters of the radio system from a single point on the design line to a much wider set of permutations among the four variables. By incorporating digital and microprocessor technologies into the design fabric of radio systems, engineers are now creating radios that can dynamically operate outside the constraint of a particular intersection of bandwidth and power limits normally set by regulators.

Figure 2: New technologies permit new spectrum uses to be created by trading off power or bandwidth with throughput and bit error rate dynamically on the same radio



For example, a radio designed to optimally perform at design P_B (in the middle of the circle) can now be redesigned on the fly to operate within any of the 5 possible regions surrounding the optimal point. Each of the 5 regions represent a tradeoff between power, bandwidth and throughput and bit error rate with the blue areas (those below the design line) representing increased performance in the form of either throughput or bit error rate in exchange for reduced power and bandwidth. In contrast, the red areas above the design line provide for increased power and bandwidth utilization but poorer performance in terms of throughput and bit error rate. Computing resources enable radios to make these tradeoffs virtually on the fly thereby increasing the flexibility of these systems to handle different types of market environments without the user having to have a different radio.

The net result of these advances is consumer radios that are becoming more flexible and highly adaptable. From a spectrum regulator's perspective, the additional flexibility and adaptability of the technologies means that new spectrum resources must be accounted for and usage rights eventually be assigned.

Box 4: Software Defined Radios, Adaptive Array Systems and Mesh Networks

Three exciting advances in radio technology have been made possible by the availability of computing resources to radio signal processing. These are software defined radios (SDRs), Adaptive Array Systems (AAS) and Mesh Networks.

Software defined radios (SDRs) describe an approach that uses both ASIC and FPGAs and other new technology to allow a re-configurable radio, which can be adapted at the point of use and for different applications. Software radio technology is a way of providing a multi-band, multipurpose radio. In the ideal software radio scenario, the radio signal is directly converted to digital signals at the antenna and all other radio functions are performed in the digital domain by software on the host platform which might be a flexible digital signal processing (DSP) chip, a computer or even a mobile telephone.

Unlike conventional antennas, where the energy is diffuse, AAS systems use computational algorithms to direct energy to a number of parallel and simultaneous channels within the same frequency bands. This exciting technology uses computing technology to combine a set of antennas (antenna arrays) and radio frequency energy in order to detect and calculate radio signals on a highly refined basis thereby suppressing interfering signals and automatically track desired signals leading to a significant increase in overall system capacity by enabling greater re-use of the same radio frequencies.

Mesh networks, developed through military communications technology research, and which are also known as ad-hoc and infrastructure free networks, are designed to maintain network quality of service in unstructured and/or harsh spectrum environments. Mesh networks eliminate the need for a spoke and hub radio network whereas traditional radios require remote units to constantly communicate with base stations using "big iron" infrastructure and control signals. Infrastructure free networks allow one subscriber to communicate with another while using the available spectrum without requiring synchronization from the base station. Ad-hoc networks rely less on device-to-device communication but on sharing messaging protocols so messages from one device can be passed on by another and so on without use of any public switched infrastructure. The ability to have sufficient computing resources to sample frequencies and process large amounts of data packets are key elements to making these types of mesh networks a commercial reality. Because mesh networks lack any common infrastructure, they represent new spectrum capabilities that are ungovernable from a central point and represent the latest challenge to regulators' ability to manage and allocate spectrum use rights

6 Can Conventional Regulatory Models Meet the Challenges of Broadband Spectrum?

6.1 Command and Control Model

The traditional process of spectrum management is referred to as the "command-and-control" model because of the strict definition of operating parameters applied to the use of spectrum. Some define the command and control model as a form of government control but a more honest assessment would consider the command and control approach to originate from the limits of conventional radio design during the last century. Ordinarily, the command-and-control regulatory model usually involves four, potentially bureaucratic, steps: allocation, adoption of service rules, assignment, and enforcement of rights.

In a command and control model, the regulator's task is never done. He or she must continually revisit and referee the radio environment as new radios are introduced into the marketplace. In order for a new radio system to enter the market, the regulator must address a wide variety of questions ranging from system configuration, co-channel and adjacent channel, power flux density, coding, out-of-band emissions, and innumerable other technical criteria relevant at any discrete point in time. *Of course, the cost of the regulator's involvement is the time it takes to transfer spectrum rights to their highest uses. Given the rapid rate of technological change, the time lag associated with government processes for allocating spectrum rights amounts to a significant cost to the ability of licensees to rapidly deploy new competitive BWA systems.*

6.2 Exclusive Use Model

The "exclusive use" model grants a licensee spectrum use rights that are generally exclusive, flexible, and transferable. These rights are bounded by interference related responsibilities and technical rules that are designed to protect the licensee from causing or receiving interference from out-of-band emissions. Under an exclusive use model in its purest form, licensees acquire an interest in a frequency band that is similar to a fee simple interest in the spectrum, with the right granted being exclusive for a set period of time. Few or no restrictions exist on the alienability of the spectrum including secondary market trading of the usage rights.

Proponents of the exclusive licensing approach tout the benefits of well-defined rights as providing licensees economic incentives for making the highest and best use of their spectrum rights. Detractors of this approach fear that it is quite possible that exclusive licensing models could lead to market failure in the form of hoarding or underinvestment by incumbent providers as a form of strategic behavior placing spectrum capacity out of reach of new entrants and/or competitive providers. *Furthermore, in the situation where technology continuously increases spectrum resources available to a licensee, it is not readily apparent that, absent significant competition, incumbents would be highly motivated to harness these new resources for the benefit of consumers. Left to its own devices, the exclusive model does not guarantee that licensees will use their spectrum rights to advance new innovative and competitive systems like BWA into the marketplace.*

6.3 The Spectrum Commons Model

In a spectrum commons model, spectrum is available to all users that comply with established technical standards for power limits and other criteria for operating spectrum devices with limited potential interference. Outside of equipment certification requirements, this regulatory regime requires no licenses and usually operates on a first in time sequence. The benefits of the commons model are that it provides users greater economic scale by reducing equipment costs and removing any direct cost of accessing spectrum.

The commons approach that provides for unlicensed spectrum significantly reduces a major barrier to entry for providing wireless services. Regulators wanting to jumpstart BWA deployment might choose to provide unlicensed spectrum, especially in rural and underdeveloped areas where other factors such as low population density and backhaul infrastructure might be limited. Of course, regulators must be careful to consider the inherent long term risks associated with this approach. In the long term, the limits to the spectrum commons model derive from its very success when increasing numbers of competing and interfering radios crowd out the available spectrum leading to an unstable environment for useful wireless services. This overcrowding phenomenon is more commonly known as the "tragedy of the commons" and can be mitigated by putting in place rules on power levels, modulation, back-off schemes, and other techniques. *Of course, the imposition of new technical rules by regulatory fiat to address these problems would effectively convert the commons approach into the more classical command and control model thereby defeating the very basis for establishing a commons model.*

Some regulators are using a mix of licensed and unlicensed spectrum to address the need for low cost broadband services in rural areas. Ireland, for example, allows small operators to launch services in rural areas using unlicensed spectrum. When such broadband providers establish a business case, they can migrate to licensed spectrum. See Box 5 below.

Box 5: Ireland's Contribution to the 2005 GSR Best Practice Guidelines on Spectrum Management to Promote Broadband Access

Principle Two: Balancing the Use of Licensed and Licence-exempt Spectrum.

A number of local initiatives have taken effect to provide broadband access using licence-exempt spectrum. In Ireland, from July 2002, wideband data transmission systems for the provision of fixed wireless access networks/metropolitan area networks (FWA/MAN) have been permitted in the 5.8 GHz (5725 – 5875 MHz) band on a licence-exempt basis, provided that the maximum radiated power does not exceed 2W eirp. This higher power level, over and above the current European harmonised standard, has increased the coverage achievable and hence the utility of the 5.8 GHz band.

This initiative provided some impetus for small market players to enter the market at very low cost, to gain some experience of broadband provision and to test market demand for various broadband services. A number of successful operations using the licence-exempt spectrum, having proved their business case, have now moved to licensed spectrum. ComReg has committed itself to continue to identify appropriate spectrum allocations, both licensed and licence-exempt, for Wireless Access Services which are supported by choice and availability of equipment.

Principle Three: Access to Cost Effective Backhaul Infrastructure.

Just as consumers in semi-rural or rural areas may not have access to ADSL, the providers of wireless broadband are hampered by the lack of cost-effective backhaul infrastructure, e.g., fibre. The alternatives such as satellite or point-to-point wireless fixed links are significantly more expensive compared to the costs of providing a wireless base station for broadband access.

In Ireland consideration is being given to permitting the use of point-to-point links within the broadband access spectrum to provide a cost effective backhaul operation. While this is difficult to accomplish from a spectrum management viewpoint, it is seen as a viable alternative to the traditional and more expensive alternatives.

Ireland's contribution to the 2005 GSR Best Practice Guidelines is available at http://www.itu.int/ITU-D/treg/Events/Seminars/2005/GSR05/consultation.html

7 A New Approach for New Times: A Pragmatic Approach for Managing Broadband Spectrum

In the broadband context, the fundamental future challenge for spectrum regulators is how to efficiently and effectively distribute new spectrum resources that technology is making available. A pragmatic model, unencumbered by having to subscribe to any particular spectrum theology--but still able to use any and all--to achieve the underlying policy goal-- seems to be the optimal way to meet this complex challenge. This secular approach takes into account the fact that technology is creating new spectrum capabilities and resources faster than most regulators' ability to redistribute these new rights using traditional means. The modern spectrum regulator needs a practical, outcome oriented policy framework that achieves results---in this case, the rapid deployment of broadband services---rather than seeking to resolve the grand theorem about the rights involved in spectrum use. The traditional spectrum management models---command and control versus exclusive rights versus commons---essentially focus on defining usage rights of spectrum licensees without articulating how these goals help achieve the underlying policy goals of the regulator.

High levels of spectrum license incumbency and limited level of inter-modal competition existing in most of today's broadband markets make the political and economic consequences of spectrum decisions significant. A pragmatic approach focusing on outcomes can make these factors more transparent thereby lending more authority to the regulator's decision-making process. A pragmatic approach which also rewards economic risk taking by spectrum licensees by offering market based incentives to deploy BWA mitigates the likelihood that licensees will occupy spectrum rights simply for its perceived scarcity value. *So what is a pragmatic approach? A pragmatic regulatory approach for increasing the affordability and availability of BWA services starts by offering to grant spectrum licensees maximum flexibility for their spectrum rights on the condition they meet two threshold obligations. First, licensees must demonstrate, a priori to the grant of their new spectrum rights, their commitment to increasing inter-modal broadband competition. Second, the licensees must agree to license conditions that positively enforce the opportunity cost of their newly allocated spectrum rights.*

7.1 Defining Flexible Spectrum Rights

Flexibility is defined herein as providing licensees significant degrees of freedom to manage the technical parameters of the spectrum within a boundary set of only having to avoid harmful interference with adjacent licensees. As the universe of wireless services expand, licensees must use these new found capabilities to address a set of service capabilities required to achieve broadband wireless services including:

- providing either portable or mobile services to increase the personalization of communication services and enhance societal and individual productivity,
- achieving spectral efficiency and overall network efficiency to create economic returns commensurate with the scale of investment
- reducing the form factor and cost of the customer premise and terminal end unit in order to encourage rapid and widespread consumer acceptance
- enabling and integration and convergence with other platforms to provide universal experience

With the advent of new technologies, licensees can make tradeoffs between power, bandwidth, throughput and bit error rate in order to enable each of these required features in the context of the broadband marketplace. Furthermore, flexible spectrum rights would allow the licensee the right to apportion and share those rights with others in order to facilitate the availability of BWA services and increased modal competition.

7.2 Flexible Spectrum Rights Necessary for Creating Competitive Broadband Markets

A practical approach to BWA spectrum licensing would call for granting spectrum licensees' unlimited (within the bound of avoiding harmful interference to adjacent licensees) technical flexibility to create more spectrum capabilities and resources and to have operational autonomy to enter new lines of service (as enabled by the current state of technology). The regulator would grant these additional rights to licensees so long as the licensees' meet two absolute preconditions. The first is that the grant of these new rights to the spectrum licensee, or in the case of unlicensed spectrum – the service enabler, must increase both inter and intra-modal competition for broadband communication services available to consumers. The second precondition is the requirement that the licensee, or in the case of unlicensed spectrum -- the service enabler, to experience the opportunity cost of using its spectrum allocation and assignment.

7.3 Preconditions for Providing Flexible Spectrum Rights

If the spectrum regulator simply granted technical and operational flexibility, he or she is providing the licensees significantly enhanced spectrum rights---unfortunately, it will not guarantee that the licensee will choose to deploy the most competitive services such as BWA (for example, choosing to invest in mobile voice as opposed to mobile broadband services). However, granting such rights with a concomitant obligation to provide competitive inter-modal broadband services would encourage spectrum licensees the positive incentives to enter and aggressively compete in the emerging markets like the one for broadband services.

The second absolute condition on the grant of flexibility as defined here is for the regulator to enforce the opportunity cost of using spectrum on the licensees. Generally, the goal here is to provide licensees price signals about the value of their spectrum holdings that discourage them from engaging in uneconomic hoarding of spectrum capabilities. Although this condition can be enforced by the regulator's right to recapture spectrum, there are other more positive mechanisms for enforcing the opportunity cost of spectrum. One of the more popular methods for enforcing opportunity cost of using spectrum in the last decade has been the use of auctions. Unfortunately, the effectiveness of auctions has diminished as a result of the growth of the wireless industry and the availability of large amounts of capital to the industry making the industry highly desensitized to price signals coming from standard auctions. Furthermore, the limited instances where auctions have been used to increase sovereign liquidity instead of a limited tool for enforcing market discipline has lead to unsustainable auction results creating uncertainty in the markets. Nonetheless, adjusting for these two factors, transparent auction processes are a viable method of enforcing the opportunity cost of using spectrum.

The Infocomm Development Authority (IDA) of Singapore, for example, successfully auctioned spectrum in the 2.3 GHz and 2.5 GHz frequency bands for broadband wireless access services in May 2005 in an effort to enhance competition in the island nation's broadband market. The starting price for each of the spectrum lots was Singapore Dollars 1,000 and the highest closing price bid was SD 550,000. IDA noted that it decided to grant successful bidders a ten-year spectrum right to provide investment certainty. Singapore's allocation of spectrum for BWA services was conducted in open and transparent fashion. IDA indicated that it had earmarked the 2.3 and 2.5GHz bands for wireless broadband services in February 2004. Then in April 2004, IDA launched a public consultation on spectrum allocation and the licensing framework for wireless broadband services. The regulators released licensing details for broadband wireless services in February 2005, notifying interested parties that it would hold an auction if demand exceeded the supply of available spectrum lots. In a similarly transparent fashion, Bulgaria's Communications Regulation Commission announced plans to auction BWA spectrum in July 2005.Similarly, enabling secondary markets for trading spectrum rights also has the effect of enforcing the opportunity cost of spectrum. By allowing for the rapid transfer of spectrum rights between private parties that value these rights differently with minimal governmental involvement, creates the price signals that encourage licensees to use the spectrum to provide competitive BWA services as they are the most valued in the current marketplace. Again, it is important to remember that BWA services are the core component of a general set of broadband services that consumers would utilize and providing the marketplace the flexibility to combine BWA services with other platforms increases the consumer welfare than by restricting such combinations.

Additionally, with the secondary markets for spectrum rights gaining greater acceptance with licensees and regulators, leading thinkers in the field are now considering how to combine auctions and secondary markets to create new mechanisms that rapidly drive spectrum to its highest and best use. Two-sided auctions, where the regulator and spectrum incumbents combine their spectrum resources into a simultaneous auction that transparently recalibrates both the geographic and technical limits on spectrum rights, are being developed as a way of smoothly restructuring bands to more useful purposes for providing new, innovative services like BWA.

Another more traditional but equally efficient method of enforcing opportunity cost would be to impose build-out and/or construction obligations on the licensees. Although these build-out obligations are effective in imposing costs, they tend to be blunt regulatory instruments because they are conditioned on ex-ante assumptions about marketplace conditions. However, combined with secondary markets for spectrum, these requirements become a valuable method of disciplining licensees from hoarding spectrum rights.

In shared license bands, the sharing rules developed by the regulators are the best method of enforcing the opportunity cost of using the spectrum. These rules generally determine the level of barriers to entering the shared bands, the level of interference permitted between and among users of the band and the power level permitted (and therefore the coverage range). These key parameters all help define the opportunity cost of using the spectrum. In the case of unlicensed bands, low power limits combined with the lack of interference management circumscribe the use of the bands and encourage a high degree of efficiency.

8 Complementary Best Practices

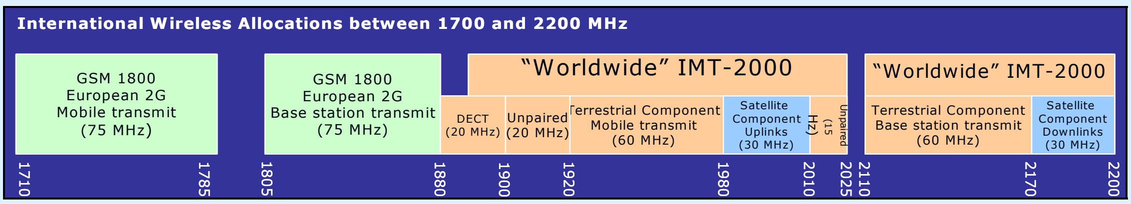
Spectrum regulators need also to look at a number of spectrum management best practices developed over the last two or three decades as tools that can be used to encourage BWA deployment. Earlier in this chapter, a summary of the Draft GSR Best Practice Guidelines on Spectrum Management to Promote Broadband were highlighted. This list has been narrowed down to a smaller set that the author believes are the most critical to implementing BWA services. Generally, these best practices reduce the cost of spectrum devices by reducing interference within spectrum bands. These best practices also permit for large economies of scale in the design and manufacturing of the end user devices and the development associated applications. In the spirit of pragmatism, each of these best practices will be reviewed to identify their benefit as well as their potential limitations in advancing the cause of consumer broadband services.

- Harmonizing spectrum allocation on a global basis to increase economies of scale at product and the service layers and reduce cost to the end-user.
- Fostering the use of standards based technology to increase economies of scale that reduce cost to the end-user.
- Allocating spectrum and develop technical rules that encourage adjacent spectrum users to have compatible technical characteristics as a way of limiting interference and maximize use of spectrum (“good neighbor” policies)
- For shared spectrum bands, encourage or mandate technical standards fostering cooperative systems designed to reduce harmful interference
- Develop efficient and transparent licensing rules and processes that allow for restructuring of incumbent spectrum bands in order to implement harmonization goals.

8.1 Global Harmonization of Spectrum Allocation

Broadband spectrum regulators can significantly drive down the cost of broadband wireless services and thereby increase the rate of adoption of these services by harmonizing their spectrum allocations globally. Global harmonization allows equipment manufacturers to benefit from significant positive scale effects associated for building radios that can operate across a large pool of users located in multiple countries.

Figure 3: Globally Harmonized Spectrum



Of course, harmonization to a global ideal as in the case of IMT 2000 described in the chart above will lead to a significant amount of incumbent dislocation with the attendant political cost to the regulator. This is especially true in developed countries that have a high level of incumbencies and more established exclusive model spectrum regimes. Harmonization is ideal although the efforts require transparent licensing systems and significant political will. Needless to say, participation in the ITU and other regional regulatory organizations can help provide the economic and political support enabling such transitions. For example, ITU-R Study Group 8 and its Working Party 8F are currently looking into BWA technologies including the IEEE's 802.16 family of standards (more commonly known as WiMax). Participation in these ITU groups as well as in the more commercial efforts at harmonizing this spectrum such as the WiMax forum enable regulators to learn about the global direction of these technological developments and put in place the appropriate spectrum regulations in anticipation of these standards becoming widely deployed.

Because manufacturing and services are increasingly global in scale, spectrum harmonization should be a goal for any allocation decision in order to lower costs for equipment manufacturers, software developers, and off-the-shelf solutions based on the potential of global deployment of these services.

8.2 Fostering Standards Based Technologies

In order to effectuate and magnify the results of their global spectrum allocation decisions, spectrum regulators must also closely follow and support the norms and recommendations of the following standards setting organizations: (a) Institute for Electrical and Electronics (IEEE); (b) European Telecommunications Standards Institute (ETSI); (c) Wi-Fi Alliance (for 802.11 products); and (d) WiMAX Forum (for 802.16 products).

Similar to global harmonization, the effect of embracing standards-based technology development is to significantly reduce the cost of the devices by reducing the number of proprietary components. This will lead to faster adoption of the devices and the associated services. *Although the benefits of a standards-based approach are many, it is also important to remember that it is a consensus driven process. If not managed carefully, the standards process essentially commoditizes innovation and could ultimately, especially if regulators embed the standards into their regulatory systems, become a benign form of economic regulation. Broadband regulators must be mindful that a standards-based approach, with its natural tendency towards compromise, could potentially lead to suboptimal results and therefore must understand that these unintended "costs" must be part of a broader policy tradeoff in embracing a particular standard into the regulatory scheme.* Generally, regulators should avoid embedding of standards unless there is a compelling policy goal to support such a move.

8.3 Operational Spectrum Best Practices

8.3.1 Good Neighbor Allocations

This best practice generally involves grouping spectrum allocations based on interference and other technical compatibility characteristics. Generally, this "good neighbor" practice would enhance the zoning of spectrum of uses including power and bandwidth limits, in order to maximize overall capacity and reduce transaction costs. In a similar fashion to the global harmonization of spectrum allocation, this practice also raises significant transitional costs and dislocation which must be accounted for in the regulator's decisional processes.

8.3.2 Voluntary Sharing Guidelines for Unlicensed Bands

For shared spectrum users such as those found in the unlicensed bands, a relevant best practice would be to encourage voluntary coordination among the end-users in order to better manage the interference and capacity issues. Users of these bands should be made to understand that the alternative to self-regulation would be a command and control model that is not only cumbersome but time consuming.

8.3.3 Infrastructure Sharing

Regulators can also enhance wireless broadband adoption by inducing licensees to share infrastructure such as towers and backhaul facilities. Infrastructure sharing between wireless systems to promote efficiency, reduce deployment costs and increase environmental sensitivity by avoiding the construction of duplicative facilities.

8.3.4 Different Power Limits for Rural Areas

Regulators should attempt to differentiate the rules for spectrum based on market types. In lower density environments such as rural areas or underserved communities, there is less opportunity for interference and it therefore makes sense to allow for increased spectral power. Similarly, regulators can increase the size of the bandwidth allocated to broadband services in these areas in order to increase capacity since there would be limited competition for the spectrum in these areas and granting this flexibility might provide better economic incentives for the licensee to deploy a BWA network. Ireland's efforts to grant rural BWA operators greater flexibility with regard to spectral power limits has enabled the country to meet the broadband demands of its rural population. (See Box 5.) In addition, Ireland has endeavored to keep licensing obligations as low as possible to reduce barriers to entry. See Box 6 below.

Box 6: Ireland's Contribution to the 2005 GSR Best Practice Guidelines on Spectrum Management to Promote Broadband Access

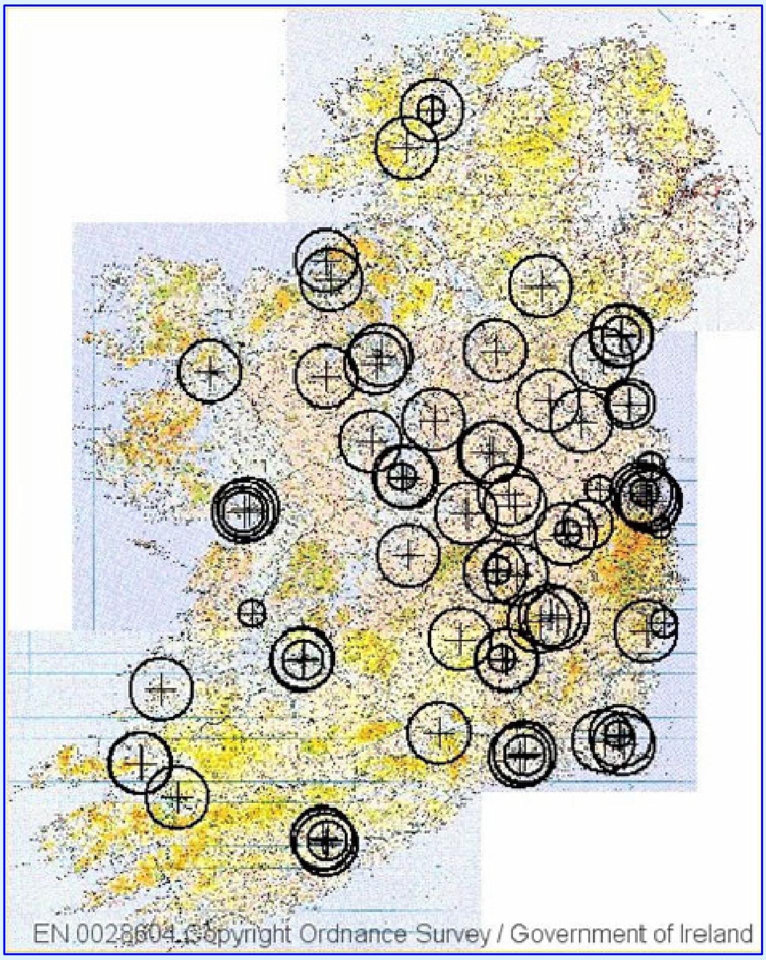
Principle One: Barriers to entry should be as low as possible

Our experience indicates that regulators should minimise barriers to entry in this area by allowing broadband suppliers to begin operations on a small scale, and not imposing onerous rollout and coverage conditions. Ireland has awarded national licences in the past for broadband wireless access that incorporated rollout and coverage obligations, however, none of the licencees were able to make a viable business case and consequently roll out of services was less than satisfactory.

In 2004 ComReg announced a new scheme for the licensing of broadband fixed wireless access services in local areas. Each local service area was defined by a 15km radius circle from a base station, with an interference zone extending to 30 km radius, at the perimeter of which a certain field strength should not be exceeded in order to limit interference into adjacent areas. Since its inception, 110 licences have been granted on a first-come, first-served basis. The success of this approach, compared with the earlier attempt at national licences, is reflected in an increase of 43% of customers in the last 6 months.

One of the key reasons for the success is that operators only take out licences for areas in which they are able to develop a viable business case and, as there is no national network rollout obligation, all attention is focused on the local area. Initial concerns that rollout would only occur in urban areas (due to high population) have proved to be unfounded as small entrepreneurs and local community groups have taken up the challenge to supply broadband access to many rural areas where ADSL is not available. Current rollout is shown in the following map.

Figure 4: Coverage area (Circles) of individually licensed broadband access services across Ireland



8.3.5 Transparent Licensing Systems and Processes

Establishing transparent and automated licensing procedures and records to reduce transaction costs associated with facilitating the highest and best use of spectrum rights. As part of the licensing efforts, regulators must also conduct periodic testing, analysis, and auditing of spectrum resources to measure the efficiency of the incumbent licensees use as well as the interference issues emanating from the use of the spectrum by the licensees. Regulators can use the collected information to form improved sharing and interference rules and regulations as well as expand the "spectrum" capabilities of that band to permit new forms of uses within the band for either the incumbent licensees or new licensees.

8.4 A Short Discourse on Technology Neutrality (as it applies the other Best Practices)

The last best practice concept to relate in this chapter is the confusing notion of technology neutrality as it applies to spectrum management. Technology neutrality is usually understood to be the concept where the regulators apply rules and regulations in a way that does not favor one type of technology over another. Clearly, when described in this manner, this particular concept is at odds with the other best practices such as harmonizing spectrum globally, adopting standards based technologies and applying good neighbor rules which by their very nature tend to favor particular technological choices.

From the perspective of the regulator as a resource manager, technological neutrality is an impossible goal since the desire to effectuate efficiency and rapid utilization of the spectrum resource ultimately requires a decision set that leads to a particular technology path. Promoting a standard or a particular spectrum band or its configuration, directly or indirectly, also obviates the notion of neutrality. Similarly, creating a harmonized spectrum band and associated service rules will also tend to favor particular technologies. Thus, there is an inherent conflict and contradiction between the goal of technological neutrality and the function of the spectrum regulator as a resource manager.

Fortunately, pragmatism once again comes to the rescue by understanding that a spectrum regulator has to play different roles that lead to different conclusions about technological neutrality. In the one case, the spectrum regulator is a resource manager concerned with optimizing the efficient use of a scarce resource. In the other case, the spectrum regulator is a policy advocate charged with enabling social policy goals such as universal access/service and reducing the digital divide among the myriad of other social goals required by modern society. A practical solution to the conundrum would apply technological neutrality only to the means used to achieve macro policy goals as opposed to the means for managing the spectrum resource.

Technological neutrality is paramount only to the means applied to achieve broad social policies. In achieving broad social policies such as providing universal broadband access to consumers, the regulator should use any combination of available technologies and resources to achieve the desired outcome in order to more rapidly deliver on the social compact that he has been charged with achieving.

One example of effective balancing between the goal of technology neutrality and pragmatism can be found in the public consultation process of the Office of Telecommunications Authority (OFTA) in Hong Kong, China, described in Box X.

Box 7: OFTA Consultation on Broadband Wireless Access Licensing

In August 2005, the Office of Telecommunications Authority (OFTA) in Hong Kong, China, issued its "analysis of comments received, preliminary conclusions and further consultation on a licensing framework for deployment of broadband wireless access." Comments on the further consultation were invited through 31 October 2005. The August consultation followed an initial BWA consultation launched in December 2004 on whether BWA should be licensed in Hong Kong, and if so, when. All contributions received have been published on OFTA's website.

In the August consultation, OFTA expressed the view that BWA spectrum should be assigned in 2006 on a technology-neutral basis:

Consistent with the technology neutrality principle and having considered the respondents' views, the TA is prepared to allow the deployment of any technology which conforms to recognised open standards, for the delivery of BWA services. Because BWA devices and equipment will be supplied competitively and only technology conforming to recognised open standards will be allowed, the TA considers it unlikely that end users will have insufficient choice in the selection of BWA devices.

OFTA also expressed the view that although BWA is currently being deployed as a fixed service, it should also be allowed for both fixed and mobile services once the technology is developed and cost-effective. Thus:the TA proposes that the scope of permitted services of the future BWA licences should be restricted to fixed telecommunications services initially and be expanded to include full mobility services after 1 January 2008. Fixed telecommunications service will include the conventional fixed services and telecommunications service of "limited mobility" nature. "Limited mobility" means no cell handoff capability will be permitted before 1 January 2008.

OFTA also expressed the view that it would issue unified carrier licences in order to accommodate the trend toward fixed-mobile convergence, since BWA can offer both.

It is therefore proposed that a new Unified Carrier Licence will be introduced. The validity period of this new licence will be fifteen (15) years, which is the same as that for the existing fixed/mobile carrier licences. Any interested party, including existing fixed/mobile carriers and new entrants, may bid for the BWA spectrum and, if successful, will be licensed under the Unified Carrier Licence which will permit the licensee to provide fixed telecommunications service using the BWA spectrum from the start of the licence and to provide both fixed and mobile telecommunications service starting from 1 January 2008.

OFTA has made clear that BWA licensees will be expected to invest in and rollout infrastructure to provide public services; they will not be allowed to enter the market solely as services-based operators. The consultation document may be accessed at http://www.ofta.gov.hk/en/report-paper-guide/paper/consultation/20050831.pdf

9 Spectrum Allocation Demonstrating A Pragmatic Approach

A Spanish proverb holds that "**experience** is not always the kindest of teachers, but it is surely the best." Thus, regulators that have yet to establish a comprehensive spectrum management plan embracing BWA networks should take the pragmatic opportunity to learn from the experience of their brethren that have already done so. To help with this process, this paper concludes by undertaking a comprehensive review of a major BWA allocation decision by the Mauritius Information and Communication Technologies Authority to advance different technologies and standards in support of rapid deployment.

9.1 Enabling BWA in Mauritius

In the first half of 2005, the Information and Communication Technologies Authority (ICTA) of Mauritius made the regulatory decisions establishing the future course of BWA on this fast growing island economy. Although it is too early to predict the success or failure of its allocation decisions, a brief review of the ICTA's processes and methodology shows a regulator that has adopted key best practices and made pragmatic tradeoffs that enable BWA to take root rapidly.

In the first instance, it is useful to note that unlike many regulatory bodies, the ICTA mission is more broadly defined by its name and its charter developed in 2001. Clearly, the goals of the ICTA are not simply to "manage" spectrum but to effectuate a broader goal of increasing the reach of information and communication services throughout the country. In considering BWA services, it is important to note that the ICTA also undertook a transparent public consultation process and arrived at its final decision within a commendable 180 days of its initial report.

In starting the process, ICTA identified the demand for BWA while also recognizing the need for its decision to be aligned with the global harmonization efforts in order to provide scale economies that would not be otherwise available to its economy. It also identified key market conditions that have had a deleterious effect on past BWA attempts such as the congestion in the "license exempt" 2.4 GHz band on the islands. According to its study, ICTA found that operators in this band were exceeding the designated power limits to use these license exempt systems for long-range systems contrary to their design and purpose. It also noted the continuing and significant demand from Internet Service Providers (ISPs) for wireless spectrum for deploying their services. Additionally, ICTA took note of other countries' decisions to define certain bands for BWA uses including 2.5-2.7 GHz, 3.3-3.5 GHz, 5.1-5.3 GHz and higher powered unlicensed use of 5.4-5.9 GHz. It also noted the advent of new standards such as WiMax, among others, for deploying BWA services integrated with computers and other ICT devices. The ICTA's ultimate decisions in each of these bands demonstrates a practical approach to resolving the various tradeoffs required to advance deployment of BWA networks in face of competing demands among operators and given a history of spectrum incumbencies.

9.1.1 Mauritius BWA in 5.4-5.8 GHz

ICTA determined that radar incumbencies in the 5.4-5.9 GHz band required it to postpone that decision until a later time although this band has been globally harmonized for higher powered unlicensed operations through the WRC 2003 multilateral negotiations process. It is likely that the complexity of the radar system operations coupled with their public defense mission requires a more deliberate transition for this band as demonstrated with the difficulty that the United States has experienced in implementing the necessary dynamic frequency selection (DFS) systems needed to protect sensitive military operations in that band in the United States.

9.1.2 Mauritius 2.4 GHz BWA License Exempt Band

In reviewing the status of the 2.4-2.483 GHz unlicensed band, ICTA came to the conclusion that the previous "commons" model had led to overuse and overcrowding. It found that existing operators in the band tended to exceed their power limits of 23 dam EIRP in order to extend for interference. Additionally, one can surmise that from ICTA's decision to define the distance limitation for this band that incumbent operators were increasing the power of their devices in this band in order to use it for longer distance applications than the radio local area networks it was originally intended for. In its decision, ICTA took some pragmatic steps to improve the functionality and longevity of the band:

- Mandated use of the bands for applications not to exceed 500 meters
- Mandated the emitted power to 20 dam while giving some transitory leeway for incumbent operators to stay at the 23 dam until 2010; and
- Required new systems to register thereby allowing ICTA to track the level of usage in the band and identify potential interference prone uses

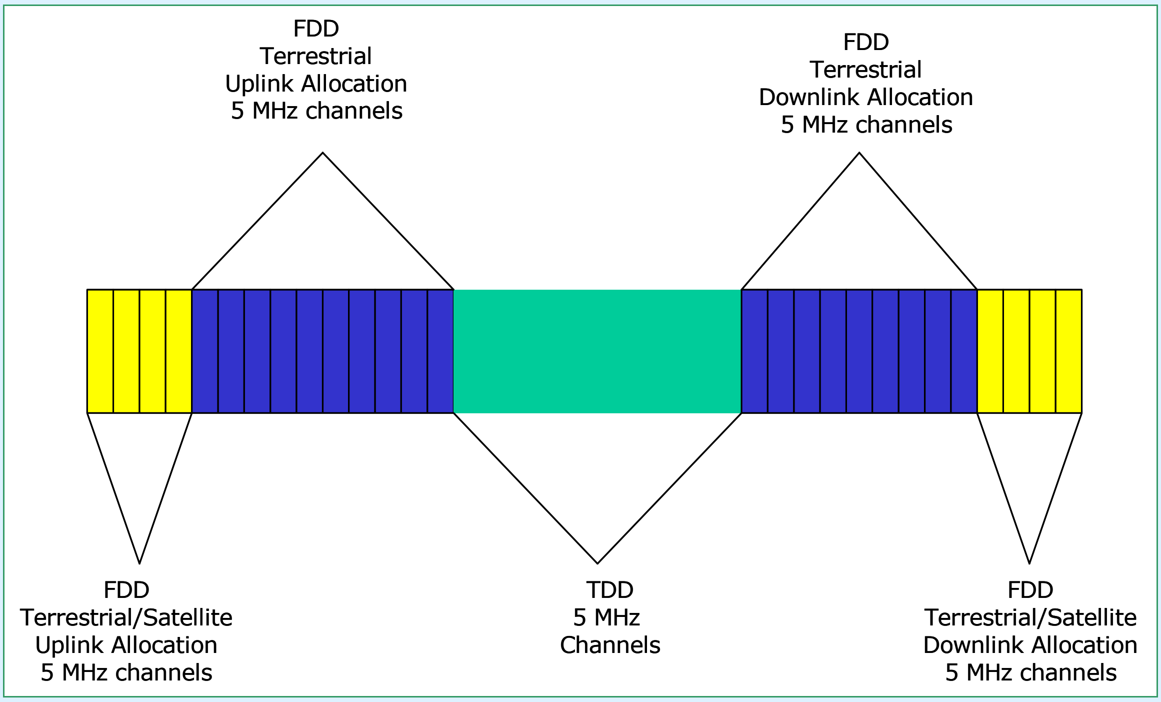
This set of decisions will certainly have the effect of extending the useful life of the 2.4 GHz license exempt band. Of course, these decisions also highlight the pitfalls associated with the commons approach as discussed earlier in the paper.

9.1.3 Mauritius 2.5-2.7 GHz BWA Band

This band was previously allocated for multi-channel, multi-point distribution service (MMDS). ICTA's decision harmonized the band with the IMT 2000 allocation enabling three distinct types of BWA systems to eventually operate in the band. Implicit in the decision was the determination that the incumbent MMDS use was not as relevant as the future potential of BWA systems to be offered in the band. In reviewing the decision and the supporting analysis, there was not an explicit determination about the value of MMDS relative to BWA. ICTA seemingly relied on the lack of input from market participants---where only one respondent to its public notice advocated the continued use of the band for MMDS---as indicating the relative utility of the two services.

Other aspects of the ICTA's decision about this band were significant. First, it determined that only licensed operators could provide BWA services in this band. Second, it made sure to create a channelization plan for the band that permitted the grouping of like systems together---instead of the interleaving familiar to broadcast bands---so both TDD and FDD wideband systems could be deployed to deliver BWA (the channel sizes were also changed to 5 MHz from 8 MHz segments better suited for wideband systems like those being developed by the IEEE 802.16 groups). ICTA also allocated 40 MHz---20 MHz for uplink operations and 20 for downlink operations---to be used for hybrid satellite and terrestrial services. Finally, ICTA also allocated a significant transitional period for incumbent operators by making the band available for BWA services described above in January 2010. It leaves open for voluntary transition with language suggestion that the timeline for transition might be accelerated based on "market conditions."

Figure 5: Mauritius 2.5-2.690 GHz BWA Allocation



9.1.4 Mauritius 3.4-3.6 GHz BWA Band

The ICTA reallocated this band from primarily a fixed satellite service band to co-primary as a terrestrial BWA band deploying point to point and point to multipoint links in harmony with other global allocation decisions. Fixed link services were favored in this band in order to provide protection for incumbent VSAT operators. Despite this limitation, BWA advocates such as the WISPs (wireless internet service providers) were able to obtain the benefit of higher powered use since ICTA allowed for 15 W EIRP systems to operate in the bandICTA also decided that in assigning frequency channels in these bands it would giver priority to public operators (although not conclusively); that licenses were mandatory and the permitted point-to-point and point to multipoint links must be registered. Finally, ICTA allowed the aggregation of multiple 25 kilohertz channels while requiring a minimum of 100 MHz separation for avoiding interference of duplex operations in the band.

9.1.5 Mauritius 5.150-5.350 GHz BWAS Band

Consistent with WRC 2003 agreements, Mauritius ICT Authority has opened up this band for mobile license exempt use using equipment specifications consistent with IEEE 802.11 standards. Given the challenges presented by radar incumbencies in this band, the ICTA determined that the use shall be limited to indoor use only. Additionally, in order to prevent overcrowding and overuse and to stop potential interference with incumbent operations, the ICTA requires the equipment in this band to use dynamic frequency selection (DFS)--- an automated mechanism detecting the presence of signals from other systems, notably radar systems, and avoids co-channel operation---- and transmit power control (TPC)----an automated mechanism that regulates a device's transmit power in response to an input signal or a condition---features as part of the equipment registration and approval process that it plans to put in place for this band.

The limitations imposed on the use of this band reflect the tradeoffs ICTA believed necessary to advance BWA while accommodating the sensitive operations already incumbent in the band. Both DFC and TPC systems are early in their development and have not yet fully demonstrated their ability to protect incumbent operations. Nonetheless, they are clearly part of the technological advances taking place enabling the rapid deployment of BWA services.

10 Conclusion

The ability of broadband wireless access networks to improve our lives ultimately relies on the amount of spectrum rights made available by regulators for BWA. However, for the first time in spectrum's short history, it appears that advances in technology, independent of the action of the regulators, can increase spectrum capabilities and resources (i.e., allowing licensees to do more with the same spectrum or enabling new uses for spectrum not previously possible). As these advances become more widely adopted and new spectrum resources become available ever more rapidly, regulators must consider whether traditional approaches to spectrum management are sufficient to address the resulting challenges and opportunities.

A sensible approach for BWA spectrum licensing calls for granting spectrum licensees' unlimited (within the bound of avoiding harmful interference to adjacent licensees) technical flexibility to create more spectrum capabilities and resources and to have operational autonomy to enter new lines of service (as enabled by the current state of technology). The pragmatic regulator sgrants these additional rights to licensees so long as the licensees meet two absolute preconditions important to the development of communications markets. The first is that the grant of these new rights to the spectrum licensee, or in the case of unlicensed spectrum – the service enabler, must increase both inter and intra-modal competition for broadband communication services available to consumers. The second precondition is the requirement that the licensee, or in the case of unlicensed spectrum -- the service enabler, to experience the opportunity cost of using its spectrum allocation and assignment.

While contemplating the appropriate regulatory model for the evolving state of spectrum technology, broadband spectrum regulators must also be mindful of a number of key best practice concepts that have developed around spectrum management over the last two or three decades. These best practices fostered the widespread adoption and deployment of an earlier generation of wireless services leading to the significant reduction in the cost of providing services and the creation of innovative applications. The same best practices could be used to help deploy BWA networks thereby increasing the potential significantly increase the welfare of consumers in the modern information society.

In reviewing a recent comprehensive BWA allocations in Mauritius, one traces the outlines of the practical tradeoffs necessary for using BWA spectrum in order to achieve the broader policy goals of the regulators. The lessons one should draw from these types of complex allocation decisions is not in the particular merit of any particular allocation decision or outcome. The lessons come from having a better understanding the challenges required to properly balance the demands of effectively and efficiently allocating the new spectrum rights and capabilities brought about by rapid changes in technology while simultaneously advancing the broader social goals of increasing consumer welfare and economic productivity which have been entrusted to the modern spectrum regulator.

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[i] The thoughts outlined herein are based on the author's experiences as the chief of the United States Federal Communications Commission Wireless Telecommunications Bureau between 2003 and 2005.

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