The 2.6 GHz Spectrum Band

Unique Opportunity to Realize Global Mobile Broadband

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Scott Fox – Chairman and CEO
Martyn Roetter - Vice President – Research
Jeffrey Walkenhorst - Vice President – Research
Peter Rysavy – Vice President – Technology Research

Global View Partners
Creating Value in Wireless

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Global View Partners
Creating Value in Wireless

San Diego, CA U.S.A.
www.GlobalViewPartners.com

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Executive Summary

The primary purpose of this report is to (1) factually report on the current status of worldwide licensing of the 2.6 GHz spectrum band and (2) assess the viability and implications of the three ITU band plan Options. The report includes analysis of technological trends in wireless equipment and terminals, industry traffic trends, interference coordination challenges, and broadband policy objectives and principles as well as discussions with and reviews of non-confidential material from mobile operators, technology vendors, and regulators.

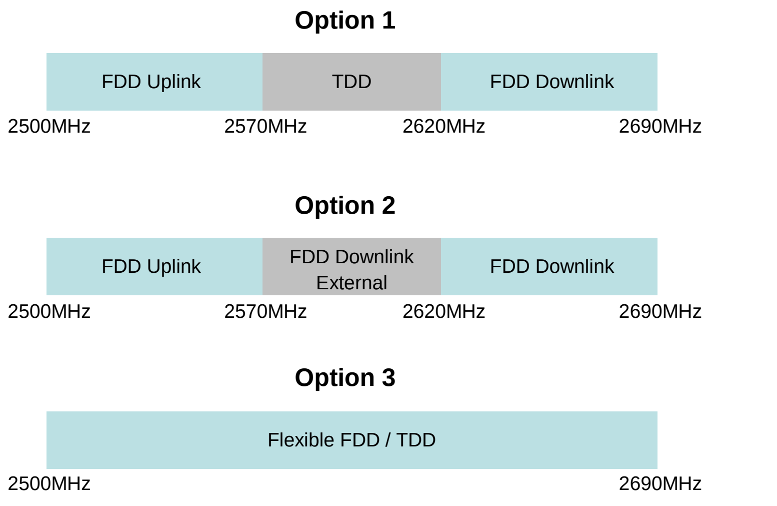
As mobile voice and data traffic increases, wireless operators around the world will require additional spectrum. However, as a finite public commodity, few bands remain available for new allocation to mobile wireless services and even fewer exist for global harmonization of wireless spectrum assets. The 2.6 GHz band is one exception.

The 2.6 GHz band (2500-2690 MHz), sometimes also referred as the 2.5 GHz band, was allocated by the World Radiocommunication Conference (WRC) in 2000 for terrestrial mobile communications services. The band provides an opportunity to meet rapidly rising demand for capacity to deliver mobile broadband services on a widespread, common basis across the world. This possible outcome – a rare opportunity in the frequency domain – would be beneficial to customers worldwide and support national policy objectives to achieve (1) the direct economic benefits of economies of scale (i.e. maximum affordability and coverage of broadband services) as well as (2) ease of roaming and (3) interoperability of services on a global basis. To date, the 2.6 GHz band is unique in that the band includes a substantial amount of spectrum (190 MHz) that has been allocated on a primary basis in all three ITU regions for terrestrial mobile communications (please see Appendix A on WRC). All other spectrum bands up to 3.5 GHz include significantly smaller amounts of spectrum for terrestrial mobile communication, and/or are not available for this service as a primary allocation in the same frequencies in all regions (e.g. AWS, 1800 and 1900 MHz, 3.5 GHz).

Still, controversy exists surrounding the extent to which and how the 190 MHz available in the 2.6 GHz band plan should be divided between paired and unpaired spectrum suited to FDD and TDD modes of operation respectively. The International Telecommunications Union (ITU) presents three possible options:

- Option 1 - Preconfigured allocations of paired (FDD) and unpaired (TDD) spectrum.
- Option 2 - Paired spectrum only with the uplink portion of some pairs in another undetermined band.
- Option 3 – Flexibility, allowing the bidders for spectrum to decide how they want to allocate the spectrum they acquire to paired (FDD) or unpaired (TDD) operation.

Figure 1: ITU Options for the 2.6GHz Band



Summary findings of the extensive research of this report include the following:

- **Public policy that supports the 2.6 GHz band also supports economic growth.** Regulators understand that rapidly growing wireless traffic will require incremental spectrum over time, and ample research now supports the positive correlation between wireless penetration and economic growth. The sizable 2.6 GHz band represents a rare opportunity to both allocate and harmonize airwaves.

- **Licenses have been issued in several countries to-date, notably Norway, Sweden, Finland, Singapore, Hong Kong, and the United States, and more 2.6 GHz auctions are anticipated over the next one to two years in multiple national markets.** Recent licensing carries a bias toward Option 1 with slight differences related to country-specific situations. More auctions are expected in Europe as well as in major emerging markets such as Brazil and South Africa. Substantial 2.6 GHz spectrum is licensed in the United States, although allocation and utilization are less than ideal for unique, non-reproducible historical reasons that predate the allocation of this band to mobile communications.

- **Evidence generally indicates more demand for paired than unpaired spectrum at 2.6 GHz.** There is greater interest in paired spectrum in the 2.6 GHz band among established cellular operators than in unpaired spectrum, and provided there are several such operators, higher prices will be paid for the former than the latter. The reason for the greater interest is to facilitate backward compatibility with existing FDD networks through the least expensive terminals.

- **The implied goal of most, if not all, regulators is to create an environment that stimulates operators to exploit the 2.6 GHz band to expand the capabilities and coverage of affordable broadband wireless access.** The ITU Option 1 band plan is well suited to meeting this goal by enabling technology neutrality and competitive "4G" wireless equipment choices for both FDD and TDD operation to mobile operators (including both LTE and WiMAX). Importantly, ITU Option 2 can be rejected since this configuration does not accommodate demand for unpaired spectrum and, therefore, violates the principle of technology neutrality (e.g. excluding current WiMAX systems) while also neglecting some demand for unpaired spectrum.

- **ITU Option 3 presents many challenges.** With ITU Option 2 ruled out, the choice is between Options 1 and 3. The free-for-all scenario under Option 3 is likely to lead to multiple different national band plans and other challenges. Specifically, relative to the advantages of an internationally harmonized band plan, Option 3 appears to involve complex and economically disadvantageous implications with respect to: (1) interference management, (2) regulatory burdens, and (3) costs and availability of equipment.

- **Growing momentum to adopt ITU Option 1 in Europe.** During the past two years, measurable progress was achieved toward allocating the 2.6 GHz frequencies according to the ITU Option 1 band plan. There is widespread agreement at national levels as well as at the European Union and its Commission that this objective will best be fulfilled in a manner that is harmonized and coordinated across all countries in the region.

- **LTE advantage over WiMAX in 2.6 GHz.** Major global vendors such as Ericsson, Nokia Siemens Networks, Huawei, and Alcatel-Lucent among others are committed to deliver LTE equipment and terminals when necessary for any 2.6 GHz spectrum awarded in the fourth quarter of 2009 or later, which will likely be deployed from end-2010 at the earliest, to 2012. Several major operators, such as TeliaSonera and Telenor, plan to launch LTE networks in paired 2.6 GHz spectrum during 2010. By contrast, with the exception of a small regional player in Norway, there have not been any public announcements to deploy TDD networks (of any type) on a major scale in the spectrum already auctioned in Norway and Sweden. More LTE announcements appear likely over the next year given the 3GPP framework and its unparalleled economies of scale, as spectrum is made available.

- **Rational analysis concludes that ITU Option 1 best meets all stakeholder objectives.** The choice of ITU Option 1 band plan with pre-configured allocations of paired and unpaired spectrum is most likely to achieve the desirable outcome of the widest possible national and global coverage of affordable, next generation mobile broadband services. Networks deployed within this band structure will benefit from minimum costs to technology developers, operators, customers, and regulators, and the greatest assurance that equipment, devices, and support capabilities will be competitively available in the short term, and enhanced along a solid development road map over the long term.

Introduction: The Regulator Perspective and Rational Objectives for Spectrum Policy

The choice of an optimum 2.6 GHz band plan involves weighing multiple factors that individually do not necessarily favor the same solution. For example, specific national circumstances in terms of current installed bases and frequency allocations/attributions may require special considerations by local regulators. Further, in making the decision to allocate the 2.6 GHz band according to a specific plan, regulators must consider several important aspects, including:

- How will the country and national users benefit from licensing? What is the best economic and social use for the band?
- Will the band be important to improve broadband access? Why? Where?
- Is the band demanded by operators?
- Is the band available? If occupied, what will make the spectrum available? What have others done? How much spectrum does an MMDS operator need to operate?
- What technologies will work? What are the requirements? Is equipment available in the band?
- How much spectrum should be allocated to existing users and how much to others? What are the options for allocation?
- Should the country have new, upstart entrants in the band? If so, how much spectrum FDD or TDD should be allocated to them?
- When is the right time for licensing? Are there any helpful case studies? Where have others gone wrong?

Combining Regulator View with Rational, International Objectives

In addition to the above questions, regulators should consider “Primary” and “Secondary” goals for spectrum policy. In this case, Secondary goals support, or are a means for achieving, the Primary goals.[1]

A. Primary Goals

- Stimulating the timely expansion of **affordable broadband access in national markets** by attracting a wide range of current and potential operators, and being well suited to the timely deployment of emerging popular broadband wireless technologies.
  - This goal is particularly important in developing markets where wireless-based broadband access will carry more weight than in developed markets where fixed broadband access infrastructure is already widespread.
- Maximizing, through **regional** and **global** harmonization of the use of a band the:
  - **Economic** and **social** benefits to be derived from economies of scale of common network technologies and ready accessibility to common services for as many customers and geographies as possible.

[1] The basis for all goals is derived from widely supported national, regional and global policy statements and recommendations that have been expressed in many forums. These forums include recent WRCs, the European Commission and its Directives on electronic communications, the work of the ITU on wireless standards and markets, the two United Nations-sponsored conferences "World Summit on the Information Society" (WSIS), and a growing number of national expressions of intent such as the U.K.'s 2009 "Digital Britain" report. All of these goals are intended to serve the fundamental objective of maximizing public welfare.

  - Potential for **economic reuse and sharing** of the substantial existing physical (e.g. cell sites) and proven operational (e.g. roaming) infrastructures of 3GPP and 3GPP2 mobile operators. This factor can reduce the high capital investments needed to deploy new wireless networks with wide coverage.

- Supporting **service neutrality** to facilitate innovation in services for the benefit of customers.

B. Secondary Goals

- Facilitating effective and efficient **competition** between equipment, device, and applications and services vendors to the benefit of customers.

- Allowing **technology neutrality** with respect to use of FDD and TDD operation and deployment of competitive wireless systems.

- Enabling integrated or coherent **management of spectrum allocations** and attributions across all the frequency bands that can be exploited and are available to deliver terrestrial wireless broadband access services.

This paper seeks to address key regulator questions pertaining to the 2.6 GHz band while also considering Primary and Secondary objectives.

2.6 GHz Band Overview and Potential Roles

History and Development

The 2.6 GHz band is referred to as the 2.5 GHz band in some countries (e.g. Brazil and the United States) and is generally considered to cover the frequency range between 2500-2690 MHz, although there are some minor national variations. This band was designated for mobile terrestrial services at WRC-2000.[2] Other applications of the frequencies in this band, which vary by country and region, include satellite services - fixed, mobile, and broadcast - as well as terrestrial video broadcasting (e.g. MMDS). In certain countries, frequencies in this band are still occupied by non-commercial entities, such as the military.

Following the original designation of the 2.6 GHz band, questions arose about the conditions under which interference could be avoided between commercial mobile communications and other services. Arrangements have been made, or are being proposed, in various countries to ensure fair and smooth transitions in clearing currently occupied frequencies for the deployment of presumably more valuable commercial mobile communications networks

The 2.6 GHz band is often referred to as the “IMT-2000 expansion band” and is sometimes called the 3G expansion band. When original 3G spectrum was allocated (the 1.9/2.1GHz 3G core band at the WRC held in 1992), 3G services were expected to grow so rapidly that operators would soon need additional spectrum. Hence, the 2.6 GHz band was earmarked for more 3G services.

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[2] More specific information on the outcomes of three WRCs (in 2000, 2003, and 2007) pertaining to the 2.6 GHz band is provided in Appendix A.

However, as noted, this band remains partly used by other services. A key issue that arose at WRC-03, held three years after the original designation of 2.6 GHz frequencies for terrestrial mobile services, was the formulation of provisions and transition mechanisms and other steps that needed to be taken to resolve sharing, compatibility, and interference issues between IMT-2000 and other services in this band.

Several studies were undertaken to generate suggestions regarding these topics. Two major items covering the 2.6 GHz band were placed on the agenda for WRC-07. The principal outcome of WRC-07 for the band was that more stringent power limits were placed on satellite systems operating in this band. Furthermore, the mobile satellite system allocation for this band was removed for Europe, Africa, and the Americas, while satellite systems using the band were to be limited to national or regional, and not allowed global coverage. A more important role was retained for satellite systems in the 3.5 GHz or broader C-band (3.4-4.2 GHz). The WRC-07 decided against the global identification for IMT, including WiMAX, in any part of the satellite C band (3.4-4.2 GHz), i.e. against changes in the ITU table of frequency allocations. However, a limited number of countries in favor of change (allocation of 3.5 GHz to IMT) were identified in an opt-in footnote.[3] As a result, the 3.5 GHz band is not globally harmonized for IMT. The WRC further restricted IMT, including WiMAX, in the C-band by imposing stringent requirements for the protection of existing and future satellite services in the band, including transborder protection. **Hence, the 2.6 GHz band is now in a unique position to be exploited as a common band for commercial mobile broadband access services on a global basis.**

ITU Band Definition (2500-2690) and Options

The ITU has defined (Recommendation ITU-R M.1036-3) three band plan options for 2.6 GHz, as summarized below and in Table 1:

- ITU Option 1 includes a mix of paired and unpaired spectrum in a standardized configuration and has been formulated to avoid interference problems between resulting FDD and TDD modes of operation.

- ITU Option 2 does not include unpaired spectrum and leaves the second member of each pair undetermined. That is, the upper, center, and lower bands are paired spectrum (downlink), but the location of the other pair member (uplink) is not specified.

- ITU Option 3 allows freedom of choice about the respective amounts of spectrum in the band that are attributed to paired (FDD operation) and unpaired (TDD operation) blocks.

[3] Specifically, in Region 2 (the Americas), there is no identification for IMT, just an upgrade in 14 countries, through a footnote, of the mobile service allocation in 3.4-3.5 GHz. In Region 3, only 8 countries inserted their names to the footnote identifying IMT in this band. Only in Region 1 was there broad support from countries to be included in the footnote identifying IMT for national use at 3.5 GHz.

Table 1 - ITU Recommendations for 2.6 GHz Band

Frequency Arrangement	Mobile Transmitter (MHz) – UL (Uplink)	Center Gap (MHz)	Base Station Transmitter (MHz) – DL (Downlink)	Duplex Separation (MHz)	Center Gap Usage
Option 1	2500-2570	50	2620-2690	120	TDD
Option 2	2500-2570	50	2620-2690	120	FDD DL (external)*
Option 3	Flexible FDD/TDD				

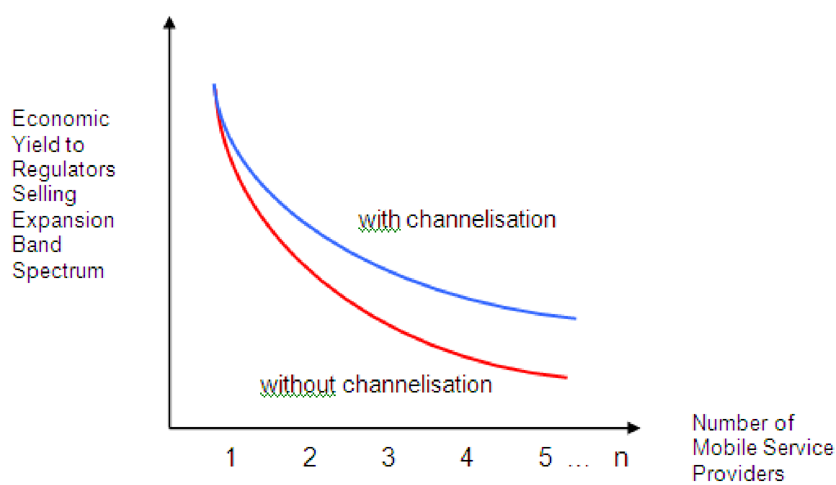
Notes: (FDD: Frequency Division Duplex, TDD: Time Division Duplex)
*FDD UL outside 2.6 GHz band

For most efficient use of current technology capabilities a channel width of 20 MHz is recommended for FDD (2x20 MHz) as well as TDD (a 20 MHz block is sufficient).

Note: Licensing should be based on a structure of 5 MHz channel blocks to allow support for 5, 10, 15 or 20 MHz channels dependent on spectrum availability and each market's competitive situation. Future technology evolution (4G) will most likely be based on combining multiple channels with 20 MHz being an optimal building block.

The third option, where no channel specific arrangements are made, increases the need for guard bands and could drive costs up for spectrum owners since they would need to negotiate with each other to ensure efficient coexistence and sacrifice spectrum to use as guard bands. If TDD and FDD technologies are mixed, then the economic yield for regulators in selling the extension band spectrum is lower due to the impact of interspersed guard bands as illustrated in figure 2 below that shows the relationship of economic yield to regulators selling expansion band spectrum with or without an associated channel specific structure.

Figure 2 - Economic Yield to Regulators Selling Expansion Band



Source: Northstream

Technical management of spectrum is an important and proven method for achieving efficient spectrum use in mobile systems. Allocating spectrum to specific uses is a key component in interference management. This is best achieved by allocating specific channel plans for FDD and TDD systems. Due to out-of-band emissions that all systems experience, guard bands need to be allocated which impact spectrum use efficiency and economic yield.

Roles of the 2.6 GHz Band: Capacity Needs

The outcome of WRC-07, in which global IMT harmonization was established for the 2.6 GHz band, enhanced the importance and value of the band for the deployment of terrestrial mobile broadband services. The importance of timely, customer-friendly and competition-friendly attributions of 2.6 GHz frequencies is especially critical as an enabler for the next wave of growth in wireless broadband access and services. Anticipated demands for additional mobile wireless spectrum are substantial, as shown in Table 2.

Table 2 – Future Spectrum Requirements

Demand Scenario	Total Spectrum Requirement (MHz)			
	2010	2015	2020	2025
High Demand Setting – ITU(1)	840	1300	1720	N/A
Low Demand Setting – ITU(1)	760	1300	1280(3)	N/A
High Urban Demand – U.K.(2)	430	1270	1200(3)	1310
Low Urban Demand – U.K.(2)	200	210	520	550

Source: Arthur D. Little, "Mobile Broadband, Competition and Spectrum Caps" ADL 2009, January 2009. http://gsmworld.com/documents/Spectrum_Caps_Report_Jan09.pdf .
Notes: 1. ITU-R Report M.2078 (2006); 2. Analysis Mason, "Spectrum demand for non-government services 2005–2025," report to the U.K. Independent Audit of Spectrum Holdings, http://www.spectrumaudit.org.uk - total capacity for mobile use in 900 MHz, 1800 MHz, 1.9/2.1GHz and 2.6 GHz bands in the United Kingdom is assumed to be 540 MHz; 3. Decrease due to deployment of more efficient systems beyond current and near-term IMT-2000 systems.

Roles of the 2.6 GHz Band: Economic and Social Benefits

In addition to meeting anticipated traffic needs, compelling evidence now supports the economic and social benefits of wireless communications. Numerous academic scholars and industry analysts have built a body of research that quantifies the benefits.[4]

- Professor Waverman (2005) of the London Business School concluded that each additional 10% in mobile penetration increases Gross Domestic Product (GDP) by an average of 0.59% per year.

[4] See Ovum, "The economic contribution of mobile services in the European Union before its 2004 expansion," December 2004; Leonard Waverman, "The Impact of Telecoms on Economic Growth in Developing Countries," Vodafone Policy Paper Series, no. 2, March 2005; Ovum, "The economic benefits of mobile services in India," January 2005; Ovum, "The Economics and Social Benefits of Mobile in Bangladesh," April 2006; McKinsey & Co., "Wireless Unbound—The Surprising Economic Value and Untapped Potential of the Mobile Phone," September 2006; Deloitte, "Economic Impact of Mobile Communications in Serbia, Ukraine, Malaysia, Thailand, Bangladesh and Pakistan," January 2008; LECG, "3G mobile networks in emerging markets" The importance of timely investment and adoption," January 2009; McKinsey & Co., "Mobile broadband for the masses: Regulatory levers to make it happen," February 2009, http://www.gsmworld.com/documents/McKinsey_Mobile_Broadband_for_the_Masses.pdf.

- McKinsey (2006) performed field work in China, measuring increases in productivity and improvements in social life thanks to the mobile phone, concluding that mobile telecommunications had an impact in 2005 that was equivalent to 4.9% of China's total GDP. In the Philippines, McKinsey concluded that improvements in mobile penetration drove the mobile industry's share of total GDP to 7.5% in 2005 alone.

- Deloitte (2008) expanded the analysis of indirect impacts of mobile industry growth to estimate that a 10% increase in mobile penetration can lead to a 1.2% increase in long-term growth per annum. Also, Deloitte estimated that the mobile industry contributed between 3.7% and 6.2% of GDP in 2007 in a six-country study of Serbia, Ukraine, Malaysia, Thailand, Bangladesh and Pakistan.

The surprisingly high numbers—sometimes two to four times above the usual estimates of mobile representing approximately 2.5% of a country's total GDP—are a result of modeling not only direct effects of mobile telecommunications (network build out and service provision), but also indirect effects, such as foreign direct investment, productivity increases, and human capital formation. The indirect effects promote economic activity across sectors because of more reliable communications infrastructure and connectivity, thereby enabling increased knowledge, skills, and economic growth. Thus, evidence now implies that a higher mobile penetration most likely drives maximum economic and social benefits that accelerate GDP growth. Based on the evidence, operators and regulators are highly incentivized to lower the minimum cost of ownership (MCO)—the upfront and ongoing minimum payments that consumers must make to stay connected—in order to expand mobile penetration.

Focus now shifting to mobile data/broadband. The initial analyses of the economic and social impact of mobile were primarily focused on GSM networks that provided voice and SMS. As the GSM family of standards moved into GPRS, EDGE, and—more importantly –to HSPA, HSPA+, and LTE the debate has shifted greatly to mobile's role as a supplier of broadband via mobile broadband. A forecast by Ovum and Ericsson in 2007 found that by 2012 the world will have 2 billion broadband connections, 65% of which will be mobile broadband.

Mobile broadband critical to growth in developed and emerging markets. In developed countries, broadband had a major impact in increasing economic productivity and driving economic growth. More recently, mobile broadband contributed to driving new applications and content. In emerging markets, the impact is even more pronounced, as limited existing copper infrastructure and low penetration of cable TV leave mobile broadband as the only feasible option to cost-effectively increase broadband penetration.

Potential benefits for emerging markets. McKinsey (2009) concluded that bringing broadband penetration levels in emerging markets to today's Western European levels (54%) could potentially add $300 billion to $400 billion in global GDP and generate 10 to 14 million new jobs across emerging economies. The study also concludes that only mobile broadband can achieve this goal. Today, broadband penetration in most developing countries is below 5%. Moreover, a recent World Bank econometrics analysis of 120 countries concluded that for every 10-percentage-point increase in the penetration of broadband services, there is an increase in economic growth of 1.3 percentage points (Qiang 2009). This growth effect of broadband is significant and stronger in developing countries than in developed economies, and it is higher than that of telephony and Internet. The impact can be even more robust once the penetration reaches a critical mass.

Economic conditions should spur further action. In the face of significant global economic challenges in 2009, mobile industry leaders believe increasing the availability of spectrum is the single most important contribution that governments can make to help drive economic recovery. In a letter to the G-20 meeting in London last April, they wrote:

> *"We ask the G20 leaders to consider the vital contribution that mobile technology can make to global economic recovery and recognize the importance of these key enabling actions by government. The mobile industry stands ready to support the efforts of governments to stimulate sustainable economic recovery, through its unique ability to invest in long-term productivity enhancing technology that is also a powerful catalyst for entrepreneurial initiative, social capital, low carbon development, and digital inclusion*." [5]

Roles of the 2.6 GHz Band: Building a Business Case

An important consideration is the extent to which the 2.6 GHz band can be complementary and/or competitive in business and technical contexts. The 2.6 GHz frequencies have relatively short propagation ranges and inferior in-building penetration characteristics compared to lower frequencies. As an example, the band is not very suitable for providing coverage in rural areas. On the other hand, the short propagation range and the large amounts of bandwidth (190 MHz) available in this band make it ideal for operators seeking to offer high network capacity and improve the speeds of mobile data transmission they can deliver to users in urban and suburban areas.

Looking ahead, the shorter 2.6 GHz wavelengths can achieve greater improvements in performance through increased use and capabilities of smart antenna techniques such as MIMO and beam forming than is possible at lower frequencies[6]. Thus, the gaps between environments in which 2.6 GHz can be used economically and efficiently relative to those where frequencies below 1 GHz are better suited may be somewhat reduced in favor of 2.6 GHz.

Nevertheless, an ideal combination of spectrum holdings for an operator trying to provide efficient national coverage for mobile broadband (except in city states such as Hong Kong and Singapore) might include a mix of low (<1 GHz) and high (around and above 2 GHz) frequencies from among those made available for terrestrial mobile communications.

New entrants versus incumbent mobile wireless operators. Pressure exists in some countries, such as the Netherlands and Colombia, to reserve spectrum in the 2.6 GHz band for new entrants so as to increase the competitive intensity of the mobile broadband market. However, given the characteristics of the band, new entrants will face challenges in building viable and competitive nationwide business cases based on spectrum in this band alone. In particular, it will be difficult and challenging economically for such entrants to serve rural areas and thus help overcome the broadband "digital divide", which is a frequently cited social and political goal that will not be achieved without affordable rural broadband coverage.

Comprehensive, balanced spectrum framework. The formulation of national and regional spectrum policies, including conditions of eligibility of access to 2.6 GHz spectrum, should be carried out within an integrated framework across all available bands, rather than on a fragmented or independent band-by-band basis. The distributions of operators' spectrum

[5] Mobile industry leaders' letter to the G-20 meeting in London, April 2009.

[6] The longer wavelengths of frequencies below 1GHz make it difficult to achieve the physical, wavelength-dependent separation between antennas that is required for these techniques to be effective, especially where small handheld terminals are involved.

holdings across future (for the most part) “digital dividend” frequencies (designated in different countries as 700 or 800 MHz), and the original 2G 850/900 MHz and 1800/1900 MHz bands, as well as AWS (1.7 GHz-1.9 GHz) and core 3G (1.9 GHz-2.1 GHz) and the 2.6 GHz bands will be a significant factor in competitiveness. Portfolio holdings will affect operator ability to offer services as widely as possible across a mix of urban, suburban, and rural areas with widely varying demographics and terrain. Not all frequencies are created the same. They should be evaluated in a comprehensive framework taking account of their different relative merits and limitations in order to create an operators’ supply side in which expansion of affordable broadband coverage can be fostered in the most economical and efficient manner.

Wide channels necessary for best wireless broadband performance. The channel bandwidths needed for efficient operation of “4G” technologies are significantly larger than for their predecessor (3G) wireless systems (e.g. 2x20 MHz for FDD operation rather than 2x5 MHz). LTE and WiMAX can exploit 20 MHz of contiguous spectrum to deliver their highest spectral efficiency and highest throughputs. The 2.6 GHz band makes such allocation possible.

Global 2.6 GHz Licensing Experience To-Date

Some countries have already attributed frequencies in the 2.6 GHz band for terrestrial mobile communications as an outcome of spectrum auctions. More auctions for this spectrum are anticipated over the next year in multiple national markets, notably in Europe, and are being actively considered with a likely later timetable in major emerging markets such as Brazil and South Africa.

Substantial spectrum in this band has also been attributed in the United States, originally in licenses for terrestrial applications other than mobile communications. These licenses are also now being increasingly used in the United States for the latter purpose. However, the manner in which the 2.6 GHz band is being utilized in the United States does not facilitate the efficient and rapid deployment of new broadband wireless access capacity to the greatest possible number of customers.

Awareness and interest in the use of the 2.6 GHz band for mobile broadband communications has grown substantially in recent years, and will be the focus of upcoming attributions of 2.6 GHz frequencies. The trends and outcomes of the earliest auctions and attributions of 2.6 GHz frequencies provide useful insights into the key factors that regulators and policy makers in other countries should take account of in formulating their spectrum policies.

Auctions: Singapore, Norway, Sweden, Finland, Hong Kong

This review examines the outcomes and implications of four 2.6 GHz auctions held between May 2005 and January 2009 in Singapore, Norway, Sweden, and Hong Kong (the earliest first). Of particular interest are:

(a) The evolution of prices paid for this spectrum over time;
(b) The differences between the prices paid for paired and unpaired spectrum; and
(c) The numbers of bidders and winners and the technologies which they intend to deploy in these frequencies, as well as the time lines of their planned network deployments. The prices paid in these auctions, and for comparison for frequencies in other bands and geographies, are shown in Table 3:

Table 3 – Prices Paid for Spectrum

AUCTION and DATE		PRICE (€/MHz/POP)
2.6 GHz Band		
Finland	November 2009	0.0038
Hong Kong	January 2009	0.24
Sweden	May 2008	0.13
Norway	November 2007	0.0325
Singapore	May 2005	0.0089
2.1 GHz Band (core 3G)		
U.K.	April 2000	3.53[1]
Germany.	August 2000	3.35[1]
AWS Band (1.7/2.1GHz)		
United States	September 2006	0.42
Canada	July 2008	0.98
Digital Dividend (700MHz)		
United States (Aloha sale to AT&T)	October 2007	0.75
United States	March 2008	0.78
3.5 GHz Band		
U.K.	June 2003	0.004
Germany	December 2006	0.005

Source: Public records. Currency conversions to Euros at exchange rates prevailing at times of auctions.
1. Exceptionally high prices paid for the 2.1 GHz band occurred at the height of the "dot.com bubble" and are not indicative of spectrum value today.

Singapore

In May 2005 an auction was concluded for a total of 50 MHz in the 2.3GHz band and 90 MHz in the 2.6 GHz band (designated as 2.5 GHz in Singapore to be used for Wireless Broadband Access, or WBA). A WBA network is defined as operating at frequencies below 6 GHz, and providing access at speeds of 256 kbps and above, to both mobile users and fixed locations. Out of seven applicants, six were successful bidders. The applicants paid an average price for the 2.6 GHz lots (numbers 11 to 25) of US$ 0.0113 or 0.0089 € per MHz per POP, using exchange rates as of May 2005. Although separate bids had to be submitted for each lot, both MobileOne and SingTel acquired lots (for a total of 48MHz out of the 90 MHz on offer) that can be paired with 120 MHz of separation (as in ITU Option 1 for this band). More information is available in Table 12 in Appendix C.

Norway

Norway held an auction of frequencies in the 2.6 GHz band, as well as15 MHz between 2010-2025 MHz, in November 2007, with a mix of paired and unpaired spectrum blocks offered in regional licenses for 6 regions. A diagram is available in Table 14 in Appendix C. The Norwegian band plan differed from ITU Option 1 by the unpaired blue blocks at the higher frequencies in the upper and lower sub-bands. The winning bidders are also included in the Appendix.

Telenor acquired two thirds of the additional unpaired blocks compared to ITU Option 1. It will be able to use this spectrum in paired mode with 120 MHz separation, thereby bringing the outcome of this auction close to the structure of the ITU Option 1 band plan. The average price paid by the winners was 0.0325 € per MHz per POP. Spectrum in the Oslo area fetched a 50% higher price than in rural areas, reflecting the much higher mobile traffic density in urban areas.

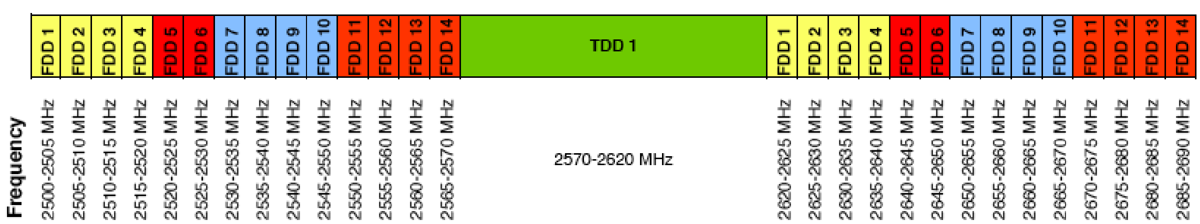
The results of the auction in Norway also reflect the unusual structure of its cellular market, with only two established operators in contrast to the more usual competitive structure of at least three or more cellular telephone operators. Thus, the price paid for paired spectrum was lower (0.028 € per MHz per POP) than for unpaired spectrum (0.036 € per MHz per POP), which was unusual. However, since completion of the auction, the winner of the largest amount of unpaired spectrum – the Canada-based Craig Wireless – sold 50% of its holding in February 2009 to a venture capital firm at a price which seems to be significantly below 50% of the amount it originally paid for this spectrum. This step would indicate that the perceived value of unpaired 2.6 GHz spectrum in Norway has declined since the auction.

Sweden

Sweden held a 2.6 GHz band auction in May, 2008, using the ITU Option 1 band plan with 5 MHz blocks and national licenses. Intel Capital was awarded the entire 50 MHz TDD spectrum, while for the paired spectrum the winners were the four existing mobile operators, namely TeliaSonera Mobile, Telenor, and Tele2 all with totals of 40 MHz, while H3G acquired the remaining 20 MHz. The average price paid was 0.13 € per MHz per POP, with paired spectrum at 0.16 € per MHz per POP and unpaired spectrum much lower at just under 0.04 € per MHz per POP, a result that reflects the high demand for paired spectrum from the four established mobile operators. More information is available in Appendix C.

Figure 2: Swedish 2.6 GHz Band Auction

(Source: PTS, Swedish Post and Telecom Agency)



Finland

Finland introduced an auction procedure for its 2.6 GHz spectrum using the ITU Option 1 band plan. The spectrum arrangement is fully compliant with the European Conference of Postal and Telecommunications Administrations (CEPT) Decision (05)05 in Sweden approximately 18 months ago, which was equivalent to ITU Option 1.

Finland's auction was held and completed over five days in late November 2009. The spectrum sales totaled 3,797,800 euros with bidding results as follows:

FDD Spectrum:

- DNA, lowest 2 X 20 MHz, 2500 – 2520 MHz (Channels 1-4) – 675,700 euros

- TeliaSonera Finland, mid 2 X 25 MHz ie. 2520-2545 (Channels 5-9) – 819,200 euros
- ELISA, highest 2 X 25 MHz, 2545-2570 (Channels 10-14) – 834,700 euros

TDD Spectrum:

- Pirkanmaan Verkko (an affiliate of the Finnet group) 1 x 50 MHz, 2570-2620 MHz – 1,468,200 euros.

The prices paid were much lower than in its Scandinavian neighbors with the unpaired spectrum selling for a higher price (€0.0055/MHz/POP) than the paired spectrum (€0.0032/MHz/POP). Several factors contributed to the outcome, particularly a low level of competition. More information is available in Appendix C.

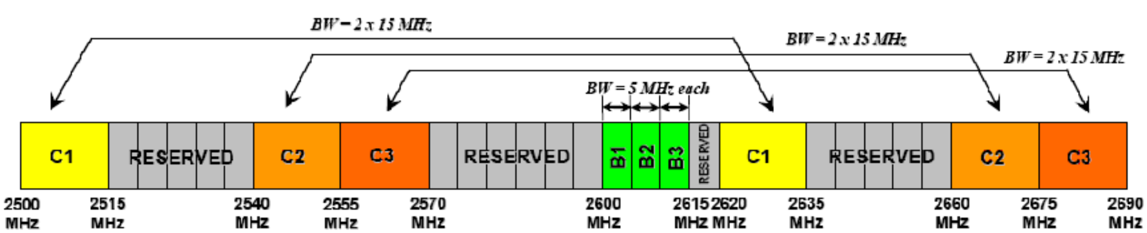
Hong Kong

Hong Kong concluded an auction of 2.3 and 2.6 GHz band frequencies in January 2009. Three bidders won paired spectrum totaling 90 MHz in the 2.6 GHz band, paying a significantly higher price for paired spectrum than in the other 2.6 GHz auctions, i.e. €0.24 per MHz per POP. A summary is available in Table 16 in Appendix C.

The paired spectrum corresponds to the same total 90 MHz bandwidth and 5 MHz lots within the ITU Option 1 plan for this spectrum. However, Hong Kong did not include the frequencies of 2515-2540 MHz and 2570-2600 MHz in the auction since these frequencies require coordination with mainland China. The frequencies of 2635-2660 MHz, which may be used for mobile TV services, were also not included. Still, none of the available lots of unpaired spectrum offered were sold, indicating a low level of interest in such spectrum. Also, only three licenses were sold in this auction, fewer than the number of existing mobile operators (five) who submitted bids.

Figure 3: Hong Kong's Band Plan for 2.5-2.69 GHz Spectrum Band

(Source: OFTA, Hong Kong's Office of Telecommunications Authority)



Implications of Recent 2.6 GHz Auctions

Several conclusions can be drawn from the outcomes of the 2.6 GHz band auctions to-date, as well as auctions for other frequency bands. Some conclusions are general in nature, i.e. they apply to all frequencies, whereas others are particularly relevant to the circumstances surrounding the 2.6 GHz band. Among the general factors which influence interest in and hence the prices paid for spectrum are:

- Intensity of current and anticipated competition between operators
- Beliefs about the likely demand (volume, growth rate, and timing) for broadband wireless services
- Attractiveness of the spectrum, which is a function of: (a) the propagation characteristics of the frequencies, (b) the structure of the band plan, (c) the availability and costs of technology that can be efficiently deployed at the frequencies and in the channels on offer, as well as (d) restrictions, if any, on the range of services that can be offered by licensees operating at these frequencies (e.g. fixed services only, versus service neutral)
- Other regulatory factors (e.g. rules - and the likely effectiveness of their enforcement – regarding key aspects such as interconnection, roaming and sharing agreements, and extent and timing of coverage obligations)

Findings that are specific to the 2.6 GHz band include:

- There is greater interest in paired spectrum in the 2.6 GHz band among established cellular operators than in unpaired spectrum, and provided there are several such operators and these operators foresee existing spectrum holdings as inadequate within a few years, then higher prices will be paid for the former than the latter (established cellular operators have also deployed far more networks in paired than in unpaired spectrum in other bands)
- Several major operators, e.g. TeliaSonera and Telenor, have already made commitments to deploying LTE networks in paired spectrum within the typical schedules for deployment after they acquire a spectrum license in the 2.6 GHz band, a choice that should become even more obvious and attractive for the winners of future 2.6 GHz auctions
- Winners of TDD spectrum in the 2.6 GHz band who are new entrants to the mobile market and have planned to deploy mobile WiMAX networks may delay their deployments compared to the winners of paired spectrum because, in the absence of an existing customer base, they may not have access to sufficient sources of outside investment[7]. As of October 2009 there had been no public announcements, by the major winners of unpaired spectrum (Craig Wireless and Intel Capital respectively) of plans to deploy TDD networks at 2.6 GHz frequencies in Norway (auctioned almost two years earlier) and Sweden (auctioned almost 18 months earlier), in contrast to the FDD LTE plans of Telenor and TeliaSonera.

Technology Considerations: LTE, WiMAX, and ITU Option 1

Tremendous development effort and innovation have produced several families of extremely capable wireless technologies. Appendix B includes a detailed overview of the primary wireless technologies available for the 2.6 GHz band, including 1G to 4G cellular migration, Third Generation Partnership Project (3GPP) technology evolution, and details of High Speed Packet Access (HSPA) and its roadmap of enhancements, Long Term Evolution (LTE), and WiMAX

[7] This observation would probably not apply to mobile entrants who are owned by a business with other major sources of revenue, such as a large cable MSO.

evolution. Going forward, the most broadly deployed broadband-wireless technologies will be HSPA, LTE, EV-DO, and WiMAX.

Summary highlights:

- **Superior performance for LTE versus WiMAX.** The expected performance of LTE networks deployed in the 2.6 GHz will be substantially superior to current versions of mobile WiMAX and even superior to the mobile WiMAX systems that will be ready for deployment in the next 2 to 3 years based on the next WiMAX system profile. Even HSPA+, in its most enhanced versions, will largely match the capabilities of current WiMAX networks. Still, neither current LTE nor WiMAX specifications meet the "4G" performances defined by ITU in the ITU-Advanced project. It will require subsequent generations of these technologies to address 4G requirements and these are not likely to be available earlier than 2012. Beyond performance, LTE provides additional value in its compatibility with a large installed base of mobile networks.

- **Both FDD and TDD formats supported making technology neutrality a non-issue, but interference is a critical consideration.** LTE and WiMAX have been designed to operate in both FDD / TDD formats and will be available in both variants in the near- to medium-term. As a result, the principle of technology neutrality becomes a non-issue since the two alternatives are not affected by the relative proportions of 2.6 GHz spectrum allocated to unpaired and paired spectrum. However, TDD and FDD systems cause mutual interference problems that are so severe that they cannot operate next to each other.

- **Massive trend toward LTE.** Mounting evidence suggests most existing mobile operators will favor LTE rather than WiMAX, thanks to the huge installed base of networks in the 3GPP mobile ecosystem and the value of maintaining operational compatibility across succeeding generations of networks. Major non-3GPP operators, notably Verizon Wireless, have also chosen LTE for their next generation system. The compatibility benefits customers and supports sustainable rates of investment in new facilities. Operators can offer services with the widest possible national and international coverage during the transition periods while they are building out next-generation networks which initially only provide limited coverage.

LTE Performance

3GPP LTE is the highest performing OFDMA system defined, with peak theoretical rates of 326 Mbps in a 20 MHz, 4X4 MIMO configuration. Throughputs as high as 246 Mbps have been measured in test networks.[8] Work on LTE began in 2004, and 3GPP Release 8, which specifies LTE, was completed in early 2009. Importantly, LTE is a stepping stone to LTE Advanced, which will meet IMT-Advanced (4G) requirements.

Since LTE development began after WiMAX, engineers were able to implement enhancements that were either not available or not understood when WiMAX development occurred. Consequently, LTE is expected to outperform WiMAX Release 1.5 version which will become

[8] LTE/SAE Trial Initiative Latest Results from the LSTI, Feb 2009.

available in the same approximate time frame as LTE. Some specific technical reasons for LTE's superior performance include:

1. LTE uses 1 msec subframes whereas WiMAX uses 5 msec subframes. Shorter subframes reduce channel quality feedback delays and also result in shorter user data delays.
2. LTE uses incremental redundancy for error recovery whereas WiMAX uses Chase combining. Incremental redundancy achieves a given error rate at a lower signal-to-noise ratio (SNR) and hence is more efficient.
3. LTE uses a closed-loop system for MIMO whereas WiMAX in TDD mode does not. Though this is available in FDD mode, all currently planned WiMAX deployments are TDD.

Notably, vendors have been able to demonstrate LTE capabilities in various test networks, e.g. Huawei for Telenor in Oslo, Motorola's involvement in TD-LTE trials with China Mobile, and Ericsson and Alcatel-Lucent trials with Vodafone.

Interference Considerations

Current versions of mobile WiMAX networks operate in TDD, though future profiles specify FDD operation. LTE is also specified to operate in both TDD and FDD modes, though most operators are likely to use the FDD mode as it provides greater consistency with existing 2G and 3G deployments. The net result is that WiMAX deployments, at least for now, will favor TDD and LTE deployments will favor FDD.

Interference issues involving TDD and FDD occur under the following scenarios:

1. FDD network in a band adjacent to a TDD network, for example two licensees in the same country.
2. FDD network in the same band as a TDD network, for example two licensees in neighboring countries with networks along the border.

Both scenarios require a significant amount of coordination. In the first instance, a sufficient amount of guard band must be allocated so that the TDD and FDD networks do not interfere with each other. ITU Option 1 benefits this scenario considerably, as the boundaries between TDD and FDD are well defined and only occur in two parts of the spectrum.

The second scenario is much more problematic. TDD and FDD systems cause mutual interference problems that are so severe that they cannot operate next to each other. The result is loss of coverage.

The complexity of managing FDD and TDD interference is examined in detail in the white paper "Final Report for the WiMAX Forum, Cross Border Trigger Limits and Case Study for TDD/FDD Border Coordination in Europe," dated 14 April 2009, and written by Analysys Mason. The paper acknowledges the FDD/TDD difficulty in the following statements:

- "*In both cases, FDD and TDD networks are using the same frequency, but in different countries. The coordination problem then depends on the respective operators coordinating their sites in border areas to ensure that sufficient isolation exists between respective sites, or a minimum separation distance is adhered to*."

- "*For an HSPA to WiMAX coordination scenario, for example, it is possible that the coverage area can be increased by using mitigation techniques, but it is quite difficult to achieve 100% coverage*."

In contrast, if the systems on both sides of the border are based on the same technology, they can be coordinated to provide continuous coverage at the border. Neighboring systems operating in the same band that are both based on TDD can be coordinated through selective use of subcarriers. Similarly neighboring systems that are both based on FDD can be coordinated through approaches such as use of preferential codes with WCDMA.

Further, the risk and impact of interference are increased if the technologies employed in FDD and TDD modes are not designed to be fully compatible[9]. This consequence leads to an incentive in a flexible spectrum allocation scheme to define just one technology for use within this spectrum, a direct violation of the principle of technology neutrality. Such action, contradicts the core of the justification that has been advanced in favor of allowing flexibility in spectrum allocation. Fortunately, ITU Option 1 -- if widely adopted -- cleanly addresses the TDD/FDD interference problem.

Technologies with Global Scale for Broadband Penetration

Despite considerable industry discussion about the capabilities of the various wireless technologies, all of today's emerging wireless technologies are quite efficient. In fact, all are approaching the Shannon bound, a physics principle that dictates the available spectral efficiency relative to signal to noise ratios. This applies equally to CDMA and OFDMA approaches.

Success in the market is defined by not only the capabilities of the technology, but also by deployment expense, the cost of user equipment, and the degree of innovation in the market to compel purchases of devices, services and applications. Market dynamics will determine the success and adoption of different technologies. While there are only 75 million subscribers projected for WiMAX by 2014 – compared to an estimated *four million* today – there are already over 4.0 billion combined GSM/3GSM subscribers, and over 460 million 3GSM subscribers.[10] Putting current forecasts in context, WiMAX may struggle to achieve global market share comparable to that of CDMA2000 in 2G and 3G environments, which currently accounts for approximately 15% of global mobile services subscribers. This represents a tremendous difference in market scope. The vibrant GSM ecosystem has already delivered 1,500 3G devices globally.[11]

There is a history of wireless technologies whose marginalization led to either their demise or discontinuation of further development. This includes:

- Metricom Ricochet. A wireless data service in the US that offered superior speeds to alternative systems but failed as a business.

[9] TDD and FDD LTE are designed with compatibility in mind, but for example FDD LTE and TDD mobile WiMAX are not.

[10] Sources: "WiMAX and Broadband Wireless Access Equipment Market Analysis, Trends and Forecasts, 2009-2014," Maravedis, June 1, 2009 and 3G Americas, August 2009; "4GCounts Quarterly Report – Issue 9", Maravedis, October, 2009, www.4Gcounts.com.

[11] Source: GSMA press release, July 21, 2009.

- EIA/TIA-136 (US TDMA standard), mostly replaced in the US with GSM, with some operators migrating to CDMA2000.
- Ultra Mobile Broadband (UMB), 3GPP2 OFDMA approach, discontinued due to CDMA operators choosing LTE as their preferred path.
- IEEE 802.20. OFDMA mobile broadband standard with no adoption.
- Flarion Flash OFDM. Some initial deployment (e.g. Finland). Technology now owned by Qualcomm. No further development.

Today's wireless networks and devices are some of the most complex technological achievements of all time. Such complexity, however, requires tremendous investment in research and development, costs that can only be amortized through huge sales volumes. 3GPP technologies have a huge advantage in this respect over all competing technologies.

WiMAX has developed sufficient momentum to attract sizeable investments and to see deployment in a number of countries globally. The technology is credible and the performance of initial networks is impressive. Many deployments to date, however, have been for fixed systems that are simpler than mobile systems. Relative to the GSM mobile ecosystem technologies, current trends suggest that WiMAX is increasingly likely to become a niche technology. Most GSM/3G HSPA operators have chosen LTE for their technology evolution, as have many CDMA2000 operators.

Today's cellular operators have a hugely successful voice business model which provides a foundation for deploying mobile broadband data services. In contrast, many WiMAX operators are emphasizing a data-only business model, which remains largely unproven. WiMAX may be simpler to deploy in a new deployment that does not involve a prior wireless technology (Greenfield scenarios), especially for a data-centric network. However, ultimate success still depends on global economies of scale and global coverage, wherein WiMAX is at a competitive disadvantage.

A Closer Look: ITU Option 1, Economies of Scale, and LTE versus WiMAX

ITU Option 1 is structured in a way that will facilitate and accelerate the maximum global deployment of wireless systems. In this case, LTE is forecast to be the major technology adopted in next generation mobile broadband networks. Hence, Option 1 will bring the benefits of economies of scale to the costs of LTE equipment and terminal devices for operators and broadband wireless subscribers.

Considering LTE market development to-date:

- **Large market size.** An independent forecast[12] estimates that global LTE subscribers will reach 440 million by 2015, at which time there will be 1.1 billion HSPA/HSPA+ customers, and only just under 100 million WiMAX subscribers[13].
- **Current HSPA networks move to LTE over time.** In the near term, broadband wireless equipment markets are becoming dominated by the HSPA/HSPA+

[12] "Wireless broadband forecasts for 2008-2015: HSPA, HSPA+, EV-DO, LTE and WiMAX" Analysys Mason, July, 2008.
[13] This number is notably much smaller than the current number of CDMA2000 subscribers, at over 450 million.

technology stream. However, in the medium to long term (2012-2020), markets will likely become increasingly dominated by LTE as installed HSPA networks evolve along the migration path. The vast majority of mobile network operators that today operate GSM or GSM/HSPA networks will follow the route from WCDMA to HSPA to HSPA+ and then LTE.

- **Numerous commitments to LTE by CDMA2000 and other technology camps.** The CDMA2000 air interface – the principal alternative technology to GSM and WCDMA – has been a significant factor in commercial mobile communication since the 1990s, particularly in the Americas and Asia. Still, major CDMA2000 operators have decided to deploy LTE, including Verizon Wireless (United States) as well as Bell Mobility and Telus (Canada). The Canadian operators are deploying HSPA in the interim prior to widespread LTE commercial availability. Even NTT DoCoMo (Japan) moved onto the 3GPP WCDMA platform in its 3G FOMA (Freedom of Mobile Multimedia Access) network. NTT DoCoMo's decision was notable because the operator shifted to the GSM path from its 2G TDMA Japanese digital standard, Personal Digital Cellular (PDC). Finally, China Mobile, the world's largest operator, also opted for LTE (presumably TDD version) as a successor to its TD-SCDMA 3G deployment.
    - **Accelerated LTE development fueled by Verizon Wireless's decision to adopt LTE and launch networks in 2010.** In addition, the selection of LTE by the multinational alliance of operators, NGMN (Next Generation Mobile Network), as the basis for its "4G" platforms. The NGMN includes operators who account for over 50% of today's global mobile subscribers.
    - **Verizon provided the following LTE update on 26 October 2009: "**_Verizon Wireless marked a significant milestone in its LTE network deployment plans in August with the successful completion of the first LTE 4G (Long Term Evolution, fourth generation) test data calls over its 700 MHz spectrum in Boston and Seattle. The company also released updated specifications for wireless devices that will run on the LTE network. Verizon Wireless plans to offer commercial LTE-based service in the United States in 2010 in up to 30 markets_."[14]

- **Near term LTE deployments announced in the 2.6 GHz and 700 MHz ("digital dividend") bands.** Also, LTE is likely to be of interest in other bands (e.g. 1800 MHz in Finland and Hong Kong).

- **Expected 2010 LTE launches.** According to recent data from 3G Americas, at least 120 mobile network operators have announced plans to deploy LTE in the coming years (across spectrum bands). Table 4 below provides a summary of expected 2010 launches and a full listing is included in Appendix C.

Table 4 – Near-Term LTE Launches

(Source: 3G Americas)

[14] Verizon Communications corporate earnings release, October 26, 2009, http://newscenter.verizon.com/press-releases/verizon/2009/verizon-wireless-and-fios.html.

#	Country	Operator	Expected Launch (year)	Expected Launch (quarter)
1	USA	CenturyTel (700)	2010	2010
2	USA	Cox Communications (7/21)	2010	2010
3	USA	Verizon Wireless (7/21)	2010	Q1 2010
4	China	China Mobile	2010	Q2 2010
5	UAE	Etisalat	2010	Q2 2010
6	Bahrain	Zain	2010	Q3 2010
7	Saudi Arabia	Zain	2010	Q3 2010
8	Canada	Roger Wireless	2010	Q4 2010
9	Italy	Telecom Italia	2010	Q4 2010
10	Japan	NTT DoCoMo (2100)	2010	Q4 2010
11	South Korea	KT (KTF)	2010	Q4 2010
12	South Korea	SK Telecom	2010	Q4 2010
13	South Korea	LG Telecom	2010	Q4 2010
14	Sweden	Tele2	2010	Q4 2010
15	Sweden	Telenor Seden	2010	Q4 2010
16	USA	Metro PCS	2010	Q4 2010

Considering WiMAX market development to-date and known challenges:

- **Niche market participant.** As mentioned above, market forecasts imply that WiMAX will not break out of its niche status. The latest forecast by Maravedis[15], a market research firm, predicts an accumulated global total of 75 million WiMAX subscribers (all versions, fixed and mobile, pre-standard as well as standard) by end-2014. Presumably, most of these subscribers will be connected to standards-based mobile WiMAX networks at this time. The forecast represents a reduction from 2008 estimates of 110 million WiMAX subscribers by end-2014, a decrease ascribed to the combined impact of the general economic downturn and the progress of LTE. Notably, many deployments to-date serve only a very small number of subscribers (e.g. fewer than 10,000).

- **Time-to-market argument losing credibility.** Earlier expectations of launching substantial commercial mobile WiMAX services by 2008-2009 – let alone those with visibly superior capabilities compared to existing cellular networks, notably HSPA – have been frustrated by a combination of:

    - Delays in new spectrum allocations in major countries for which WiMAX equipment is available.

    - Rapid deployment of HSPA networks with comparable performance to first generation WiMAX technology.

[15] "WiMAX and Broadband Wireless Access Equipment Market Analysis, Trends and Forecasts, 2009-2014.", Maravedis, June 2009.

  - More intense development of LTE than was anticipated earlier.

- **True "next generation" or "4G" WiMAX not on track to precede LTE.** The roadmap for true "next generation" or "4G" WiMAX – 802.16m – is not on a timeline for earlier availability than commercial deployments of LTE. Moreover, initial LTE versions may offer substantially greater performance than the WiMAX systems in service by 2010-2011. The statements that today's mobile WiMAX networks are "4G" are incorrect in terms of performance and refer only to their use of the OFDMA air interface that is generally accepted will be the basis (at least in the downlink) of all "4G" networks. As of late 2009, mobile WiMAX remains only available for TDD operation and may not be available with true "4G" capabilities for a few years to come.

- **Risk that the mobile WiMAX roadmap may not have a long life commensurate with licenses.** Legitimate reasons exist for considering the risk that the mobile WiMAX roadmap – in contrast to LTE – may not have a life commensurate with the typical length of mobile licenses, e.g. 15 years. Evidence for the possibility of this outcome is found in recent developments such as:

  - Decisions by major vendors to abandon their own WiMAX developments (Nokia Siemens Networks (NSN) and Nokia itself for handsets) or to emphasize LTE over WiMAX (Alcatel-Lucent and Motorola).

  - The lack of headway of WiMAX-based services in Korea (or WiBro as it is known there) in competition with HSPA. Korea has been a WiMAX pioneer in which the technology received strong Government support and encouragement and was deployed early, yet as of mid-2009 HSPA accounted for almost 22 million subscribers while WiMAX counted fewer than 300,000.

  Unless this situation is dramatically reversed, the level of support for developing equipment and terminals based on future mobile WiMAX standards may fall below a critical mass. In this scenario, existing mobile WiMAX networks will presumably migrate to LTE, similar to plans of CDMA2000 operators.

Conclusion: Technology Market Development Favors LTE

Analysis of market developments reveals that LTE will enjoy a substantial volume advantage over mobile WiMAX. The conclusion is supported by:

- Market forecasts of broadband wireless subscribers.
- Information about and insights into operators' interests and likely choices of technology as already revealed in 2.6 GHz auctions.
- Allocations of R&D resources by technology developers.

Therefore, the best choice for a 2.6 GHz band plan should facilitate and enable as many countries as possible to both enjoy, and contribute to, the economies of scale of LTE. The desirable band plan should include, as ITU Option 1 does, a substantial amount of paired spectrum rather than run the risk that LTE may be excluded from or severely limited for deployment at these frequencies. This is the current circumstance in the United States where the 2.6 GHz band is dominated by TDD operation. Of course, FDD WiMAX will also be free to compete for deployments in paired 2.6 GHz spectrum as well, and TDD LTE will be available for deployment in unpaired spectrum.

Assessing the ITU Band Options in View of Policy Goals & Technology

With a foundational understanding of spectrum policy goals and technology, all three of the ITU Options can be objectively evaluated. Again, the ITU presents three broad alternatives for the 2.6 GHz band plan:

- Option 1 – Preconfigured allocations of paired (FDD) and unpaired (TDD) spectrum.
- Option 2 – No unpaired spectrum – entirely paired spectrum with the uplink portion of some pairs in another undetermined band.
- Option 3 – Flexibility, as the bidders for spectrum can decide how they want to allocate the spectrum they acquire to paired (FDD) or unpaired (TDD) operation.

ITU Option 2 for the 2.6 GHz band plan is similar to Option 1 except that the 50 MHz center band is allocated to downlink FDD operation, with paired uplink spectrum in another band**.** Technological neutrality for spectrum implies that there should be a minimum of constraints applied on the wireless technologies that are deployed, while ensuring that interference is dealt with as efficiently and effectively as possible in the interests of spectrum users. Accordingly, Option 2 can be quickly rejected since it violates technology neutrality and does not accommodate demand for unpaired spectrum by TDD operators. Thus, discussion hereafter primarily focuses on the two remaining viable Options, choices 1 and 3. Unlike Option 1, Option 3 refers to a free choice of FDD and TDD operation throughout the 190 MHz in the band.

Working Backwards: Advantages and Disadvantages of ITU Option 3

An alternative approach to Option 1 – adopting a pre-configured globally harmonized 2.6 GHz band plan – is to leave the outcomes for the 2.6 GHz band "up to the market to decide" (i.e. the bidders or winners of the spectrum). That is, the market would determine the amounts of FDD and TDD spectrum allocated as well as the size of individual bandwidth holdings.

Advantages of this approach include:

- **No curbs on innovation.** Specific rules under Option 1 might inhibit innovation and, ultimately, optimum solutions for customers and society. In principle, competitors motivated by commercial forces produce "better" outcomes than public sector regulators or government-employed bureaucrats who are not subject to market disciplines.

- **No forecasting error.** Ex ante decisions should be avoided wherever possible since uncertainty in forecasting market demands and, therefore, spectrum requirements is inevitable.

- **Potentially more attractive to additional entrants.** A substantially unstructured approach to the band plan may attract more bidders for the spectrum in contrast to a pre-configured plan which is perceived as favorable to incumbent mobile wireless operators. However, the techno-economic realities of bandwidth limit the number of mobile operators who can operate efficiently in an area. Hence, this advantage is not relevant in countries where there are three or more established cellular operators, and others are visibly prepared to bid for new spectrum.

Disadvantages include:

- **Market forces alone can run astray.** Recent events and behavior in the global economy and financial sector raise significant questions regarding the “free-for-all” market philosophy as a universally applicable or immutable law of nature and human affairs. No clear 2.6 GHz framework would likely result in substantial national and regional variations in the operation of wireless systems in this band. At the extreme, purely national and/or unique band plans might emerge.

- **Global research and development efforts might be stymied.** Contrary to concerns surrounding innovation, fragmented (smaller) markets might reduce or even eliminate technology research initiatives.

- **Potential interference both within and between countries.** Adjacent FDD and TDD operations need to be separated in frequency and space to avoid interference. Neighboring countries with different configurations of FDD and TDD operation in the band will likely experience loss-of-coverage conditions in border areas that will not arise if they impose the same configurations.

- **Potential for wasted spectrum.** The final allocations of paired and unpaired spectrum may lead to significantly greater “wasted space” in the band if additional guard bands (compared to those required in ITU Option 1) have to be introduced between FDD and TDD operation.

- **More complex valuations and related business decisions.** Operators will have trouble valuing the spectrum they would like to acquire in an auction. Even if operators submit a winning bid or bids, they will not be able to predict how much usable spectrum they will eventually acquire until the outcomes of all the attributions and the results of subsequent negotiations about guard bands are settled (e.g. which entity has to absorb them within their attributed spectrum).

- **Lack of global coordination and global scale**. Allowing a totally free choice of spectrum by market agents in each country undermines the principle that has made mobile telecommunications successful: large economies of scale for similar technologies in similar spectrum bands across as many countries as possible lowering costs and increasing affordability.

ITU Option 1: Advantages and Disadvantages of a Harmonized Band

On the other side of the coin, the pros and cons of Option 3 are nearly inverted for Option 1.

Advantages include:

- **Harmonization can be a "good" standard for innovation and competition.** A standardized platform can lead to a virtuous cycle of innovation and economies of scale that maximize social benefits and economic productivity. Rules and procedures provide a framework for coordinated action by many global industry participants, particularly with regard to interference management or frequency coordination. Just as "clearing houses" can avoid the need for a very large number of customized bilateral billing and roaming arrangements between all conceivable pairs of a few hundred operators, so a harmonized band plan will greatly reduce the likely number of customized arrangements for frequency coordination that have to be established.

- **Global approach best for scale and scope of deployment.** Related to the first point, a harmonized band plan appears better suited to the deployment of common, but competitively supplied technologies based on the most intense worldwide R&D investments. Resulting technologies will enjoy the greatest benefits of economies of scale. In addition the networks will maximize the scope of interoperability at the services level that is valuable to customers, both between countries as well as between "next generation" and earlier mobile networks.

- **Minimum complexity of frequency coordination and wasted ("guard band") spectrum.** Operators and regulators face fewer challenges related to interference both within and between countries, improving social and economic links.

- **More efficient valuations and business decisions.** Spectrum valuations, allocation, and utilization are all simplified through improved transparency.

- **Supports principle of service neutrality.** ITU Option 1 band plan is consistent with the principle of service neutrality in licenses, which is a fundamental condition for ensuring the most effective competition in electronic communications markets for the benefit of customers.

- **Allows national authorities considerable flexibility with respect to setting conditions.** Policymakers still have the ability to adjust requirements/rules in a manner specific to local situations. For example, national authorities might:

    - Set conditions on the amounts of spectrum an operator may be able to bid for or otherwise hold within the 2.6 GHz band or in total.

    - Specify and limit the ways in which 2.6 GHz spectrum can be traded or infrastructure shared (active and passive).

    - Reach decisions based on independent and locally informed judgments as to whether such steps will be beneficial for the purpose of ensuring and sustaining a competitive market, taking account of the configuration (e.g. number and distribution of market share of mobile competitors) of competition when 2.6 GHz frequencies are offered.

Disadvantages of a harmonized plan include:

- **Unduly restricts the freedom of maneuver of national or regional regulators and public policy makers.** Existing uses in the band and/or other local motives could require certain decisions at the national level, even amidst national markets at comparable stages of economic development with similar social conditions. Admittedly, a national plan that deviates from a globally harmonized approach might be better in the short term in some purely national contexts. For example, a country specific plan could reduce delays in and lower costs of transition from existing uses of the band.

- **The attribution of a minority of bandwidth to TDD operation could be relatively wasteful of spectrum, if future traffic patterns are highly asymmetric.** The growing popularity of image and video communication from mobile subscribers and the role of social networking make this scenario unlikely. In addition, popular high bandwidth downloads (e.g. major sporting events) to mobile terminals that may be a source of substantial traffic asymmetry can be accommodated via mobile TV standards and channels rather than broadband cellular networks.

ITU Option 1 versus Option 3 – Bringing it All Together

The following compares Options 1 and 3 side by side taking into account the principle of technology neutrality and the goals of meeting the interests of customers, while not imposing unreasonable burdens on operators and regulators.

Constraints

- ITU Option 1 does not impose any constraints in terms of the radio access technologies that are expected to be significant contenders for next generation networks. According to respective advocates (the GSM mobile ecosystem and the WiMAX Forum) both these technologies (LTE and mobile WiMAX) will be available for deployment in paired and unpaired spectrum within the timescale in which future holders of 2.6 GHz spectrum will deploy new mobile broadband networks. The only constraint that is imposed is the quantity of capacity that can be deployed respectively in TDD and FDD modes of operation.

- Similarly, ITU Option 3 imposes no constraints on each individual operator regarding its choice of LTE or mobile WiMAX, or the mix of FDD and TDD systems the operator wishes to deploy in the frequencies it acquires. However, to manage interference, each operator will in practice inevitably be constrained by the decisions of other operators in this regard who win spectrum in adjacent frequencies and/or in the same or adjacent frequencies in neighboring areas (either in-country or cross-border). In other words, individual freedom will be constrained by bi- and multi-lateral obligations with respect to frequency coordination. Furthermore, under this Option a regulator cannot choose to award licenses via a beauty contest, which is possible under Option 1, since there are no established spectrum configurations against which bidders can submit proposals.

Interference

- ITU Option 1 involves only two interfaces between FDD and TDD spectrum. Clear rules have been established for frequency coordination and interference management in this scheme. Provided that ITU Option 1 is adopted by all neighboring countries these same rules apply both cross-border and in-country between regions, if licenses are offered on a regional basis.

- ITU Option 3 may introduce significant complications into interference management, for example between multiple diverse TDD and FDD spectrum blocks, that will entail loss of coverage and reduction in usable spectrum below that achieved with the level and type of interference management required in ITU Option 1.
  - There can be no guarantee that the outcomes of bids for 2.6 GHz spectrum in neighboring countries will be the same.
  - Furthermore, since 2.6 GHz spectrum will be attributed at different times in different countries, a 2.6 GHz operator and its regulator may be confronted with successive new issues of cross-border frequency coordination as and if its neighbors award this spectrum at later times.
  - As noted earlier, in any auction for awarding 2.6 GHz spectrum it may be unreasonably difficult for a bidder to assess the value of the spectrum blocks it seeks to acquire, so its bid is likely to be lower. The amount of usable bandwidth within the attributed spectrum may not be apparent until after the completion of the awards when the final configurations of paired and unpaired spectrum are established, and agreements about how to manage interference have been confirmed by the respective operators and the regulator.
  - A beauty contest under the conditions of Option 3 is unfeasible since there is no established configuration of spectrum on which bidders can submit offers.

Economics and Other Impacts on Customers

- ITU Option 1 offers an opportunity to achieve international harmonization of use of the 2.6 GHz band, whereas ITU Option 3 does not. ITU Option 3 is likely to lead to multiple different national band plans. As a consequence, ITU Option 1 is more supportive of the goals of minimizing the costs of equipment, hence retail prices and affordability, thanks to the increased global market size. In contrast, ITU Option 3 will require country-specific equipment that may be more expensive and late to market since development will not attract a high priority from technology vendors. In addition, international roaming will be facilitated between countries that have a harmonized band plan.

Conclusions: ITU Option 1 Superiority

ITU Option 1 turns out to be substantially superior to ITU Option 3 since the latter involves significantly more complex and economically disadvantageous implications related to: (1) interference management, (2) regulatory burdens, and (3) the costs and availability of equipment relative to numerous other advantages of an internationally harmonized band plan. Adoption of ITU Option 1 involves constraints on operators regarding the deployment of technologies that are different from, but in practice less burdensome than those flowing from ITU Option 3. Furthermore the effects of these constraints in ITU Option 1 are predictable by bidders for spectrum and by regulators, whereas those in Option 3 are not, and will lead to economic and other consequences that are not in the interests of customers.

Industry Commentary Supports 2.6 GHz Band Plan and Harmonization

Operators and vendors are supportive of a harmonized 2.6 GHz band plan as conversations and public statements reveal the following:

- *"TeliaSonera aims to be one of the first operators in the world to not only launch 4G/LTE, but to leverage the important 2.6 GHz band in doing so. We are working toward a commercial launch in 2010 and have received extensive support from many major infrastructure vendors. We believe global 2.6 GHz harmonization under ITU Option 1 accelerates both equipment availability and coverage." says Lars Klasson, SVP and CTO Mobility Services, TeliaSonera.*

- *"Telenor views the 2.6 GHz spectrum auction was the most important event since the 3G frequencies were distributed. Moreover, we see the opportunity for global harmonization as a major positive for the industry and for end users. Telenor Sweden now has the ability to build high-quality 4G networks and provide our customers with the many possibilities provided by next generation mobile services and Long Term Evolution (LTE) technology. With this spectrum, we will be able to provide high-quality mobile broadband with speeds of up to 300 Mbit/s, a major leap forward in serving our customers." said Johan Lindgren, CEO of Telenor Sweden.*

- *"Qualcomm believes the 2.6 GHz band provides operators with an excellent opportunity to grow their mobile data services through the use of harmonized, global spectrum. We are fully committed to providing LTE and HSPA/HSPA+ chipset solutions supporting 2.6 GHz. Our first chipsets to support this band will sample in 2010, volumes will follow in 2011, and over time we plan to integrate this band into our entire line of LTE and HSPA/HSPA+ chipsets," said Alex Katouzian, Vice President of Product Management, Qualcomm CDMA Technologies.*

- *"Ericsson is actively supporting early European LTE network build-outs in the 2.6 GHz band. We look forward to accelerated deployments in 2010 as more spectrum is allocated. LTE FDD and TDD solutions across our portfolio will ensure rapid, additional 2.6 GHz coverage and bring the benefits of high capacity, mobile broadband networks to consumers throughout the world. We applaud the efforts of regulators to harmonize the 2.6 GHz band in a 2x70 MHz FDD and 1x50 MHz TDD arrangement (ITU Option 1), which makes life easier for vendors and operators alike." - Mikael Halén, Director, Government & Industry Relations, Ericsson Group"*

- *Ericsson has been actively deploying LTE in the 2.6 GHz band for TeliaSonera in Sweden with service slated for early 2010. In October 2009, Ericsson and Samsung together announced the world's first successful end-to-end interoperability test in TeliaSonera's live LTE network.*

- *Ericsson has announced contracts for commercial LTE deployments which include Verizon, MetroPCS, TeliaSonera and NTT DoCoMo in the US700, AWS, 2.6GHz and 2.1 GHz bands. In addition to these four bands, Ericsson expects commercial deployments of LTE in the European 800 MHz band and also of TD-LTE in the 2.3 GHz band to follow soon after.*

The ITU Option 1 is the only band plan structure proposed that fulfills the key objectives and criteria, including the all-important industry objective of global harmonization. Further, the plan enjoys the distinct political and administrative merit of having been adopted by the ITU. Importantly, as a consequence of deliberations and decisions over the past decade – including the series of WRCs (2000, 2003, and 2007) – ITU Option 1 enjoys widespread recognition and support among regulators and public policy makers, as well as wireless technology vendors and developers.

Current Trends in 2.6 GHz Allocation - Regional/Country Examples

This section analyzes and summarizes the situation and trends in the allocation of the 2.6 GHz band in several major regions and key countries of the world. A combination of hard evidence and analyses of the consequences of alternatives are steadily pushing the world toward ITU Option 1.

The 2.6 GHz Band in Europe – Momentum to Adopt ITU Option 1

During the past two years the outlines of the outcome for the use of the 2.6 GHz band in Europe have become clearer. Measurable progress has been achieved along the path of allocating these frequencies according to the ITU Option 1 band plan. Powerful forces and a growing body of evidence are encouraging further progress in this direction. They are working to overcome the remaining uncertainty, and degree of confusion and misunderstanding, that persist among some participants as to the best means to achieving widely agreed 2.6 GHz goals.

There is widespread agreement at national levels, as well as at the level of the European Union and the European Commission, in favor of exploiting the 2.6 GHz band's 190 MHz for efficient, effective, and timely deployment of new terrestrial mobile broadband wireless networks and services. To this end, most parties agree that the objective will best be fulfilled if the band is used in a manner that is harmonized and coordinated across all countries in the region. In particular, regulators understand the numerous benefits previously outlined, including access to compatible[16] broadband wireless services across both frequencies and national borders. Progress toward ITU Option 1 has been further reinforced by the weight of contributions from operators, equipment vendors, and other stakeholders to public consultations.

Three European countries, Norway, Sweden, and Finland, have already held auctions in the 2.6 GHz band., while several other countries in the European Union (EU), including Austria, France, Germany, Italy, the Netherlands, Portugal, Spain and the United Kingdom are preparing for auctions of these frequencies in the near future (late 2009 through 2010) in anticipation of growing needs for next generation mobile broadband networks. Table 5 below provides a non-exhaustive list of planned auctions, as of October 2009, although more delays may well occur.

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[16] Ideally a customer will readily and seamlessly enjoy access to exactly the same features and capabilities of broadband wireless access – within a single subscription – whatever their location when traveling within Europe (and even elsewhere as well, to the extent use of the 2.6 GHz band is harmonized globally, as foreseen by the ITU).

Table 5 - Listing of European 2.6 GHz Band Auctions *(not exhaustive)*

Country	Auction Schedule	Comments
Austria	Late 2010	Leaning to ITU Option 1[1]
Denmark	Early 2010	Leaning to ITU Option 1[2]
Finland	Completed November 2009	ITU Option 1 band plan
France	2010	Regulator[3] seems to be leaning towards ITU Option 1, and is considering coordinated spectrum management across 2.6 GHz and digital dividend spectrum
Germany	2010	Leaning to ITU Option 1[4]
Italy	Possibly 2010	Undecided, public consultation asked for comments on alternative band plans[5]
Netherlands	Early 2010	Intent to allow more TDD spectrum than in Option 1[6]
Norway	Completed November 2007	Band plan ended up as ITU Option 1, although more TDD spectrum allowed at outset[7]
Portugal	Q4 2010	Leaning to ITU Option 1, after conclusion of public consultation[8]
Spain	2010	Majority of responses to public consultation favor ITU Option 1[9]; consultation also covered 900 and 1800 MHz and 3.5 GHz bands
Sweden	Completed May 2008	ITU Option 1 band plan[10]
U.K.	Probably 2010	Already delayed over 18 months; earlier intent of Ofcom to allow more TDD spectrum than in Option 1 to encourage WiMAX deployment unlikely to be followed; coordinated spectrum management across multiple bands including 2.6 GHz is under consideration

Source: Regulators' websites – but auction timelines have tended to slip and the dates quoted should not be regarded as firm commitments due to potential legal and political interventions.

1. Awaiting decision of regulator after public consultation (http://www.rtr.at/en/komp/Konsultation2G6HzStn/Auswertung-Konsultation-2G6-2009.pdf) concluded in March, 2009; most respondents agreed that it would be more efficient to coordinate frequency use with neighboring countries.
2. See Information Memorandum from regulator NITA for public consultation (comments received until Sept. 8, 2009) - http://en.itst.dk/copy_of_frequencies/licences/Auctions-and-calls-for-tenders/2-5-ghz/filarkiv/Draft%202.5GHz%20Information%20memorandum.pdf
3. http://www.arcep.fr/uploads/tx_gspublication/consult-thtdebit-mobile-050309-eng.pdf
4. See http://www.bundesnetzagentur.de/media/archive/13877.pdf
5. See http://www.agcom.it/Default.aspx?message=visualizzadocument&DocID=2563
6. See http://www.ez.nl/dsresource?objectid=158559&type=PDF
7. Aggressive FDD LTE deployment plans announced; no deployment plans announced yet (Sept. 2009) by winner of most TDD spectrum
8. "Análise da consulta pública sobre direitos de utilização da faixa de frequências 2500-2690 MHz", ANACOM - http://www.anacom.pt/streaming/relatoriodireitosutilizacaofrequencias2_6ghz.pdf?contentId=959099&field=ATTACHED_FILE
9. See http://www.mityc.es/telecomunicaciones/Espectro/consulta/Resumen/Consulta_publica.pdf; Dow Jones reported an interview with the Deputy Communications Minister in June, 2009 that stated the Government's intent to allocate 2.6 GHz spectrum by the end of 2009, but this has not been confirmed as of end September, 2009 - http://br.advfn.com/noticias/Spain-Plans-To-Auction-2-6-Ghz-3-5-Ghz-Spectrum-B_38259012.html
10. Aggressive FDD LTE deployment plans announced; no deployment plans announced yet (Oct. 2009) by Intel Capital, winner of all TDD spectrum

Licensing challenges. In June 2008, the European Commission made a seemingly inconsistent decision (2008/477/EC) supporting flexibility for national regulators and bidders with respect to the configurations of paired and unpaired spectrum that can be implemented. This approach – in effect ITU Option 3 – was justified primarily on the grounds of "technology neutrality" as supporting technological innovation and competition. However, as previously detailed, ITU Option 3 does not best fulfill policy objectives, and would likely lead to a number of problems, including market inefficiencies.

Other potential challenges include the presence of current 2.6 GHz users, litigation, and spectrum auction/attribution structure. For example, France's Ministry of Defense has rights to the band until 2015, though it may be able to abandon use by 2010. Similarly, Italy's military also utilizes 2.6 GHz. In Germany, prior user licenses expired in 2007, yet litigation postponed setting an auction date. Lastly, the U.K. regulator Ofcom intended to complete a 2.6 GHz auction rapidly, but delayed the auction twice (scheduled for 2008 and then March 2009) as result of objections from some likely bidders.

Nonetheless, despite various local issues, France, Germany, and the U.K. are leaning toward the adoption of ITU Option 1 as indicated in Table 5 above.

The 2.6 (2.5) GHz Band in the United States and Canada

Current 2.6 GHz use. By virtue of its market size and historical roles in introducing technology and policy innovations, the United States is often viewed as a leading example in many areas of technology-intensive telecommunications (and other) developments and regulation. However, with respect to the 2.6 GHz band and mobile services, the current situation in the United States is not one that recommends itself to other countries.

The 2.6 GHz band in the United States is currently dominated by one entity (Sprint Nextel and its 51%-owned affiliate Clearwire). This entity controls at least 120 MHz of the 190 MHz available in this band. This outcome is the result of a series of very specific events and initiatives in the United States, that derive from earlier allocations of this band at a time that predates its recognition and international WRC allocation as a very valuable resource for broadband wireless telecommunications services. Furthermore, TDD WiMAX technology was chosen for deployment in this band, with initial networks occupying 30 MHz of bandwidth. As a consequence:

- The extent and timing with which the majority of this band will be used to deliver broadband wireless services to customers is subject to the financial strengths and business success of only one operator, which has encountered significant business problems and lost market share in recent years

- The deployment of other technologies such as LTE in the 2.6 GHz band which would be favored by other operators is for the moment blocked.

Fortunately, the likely waste or further delays in the effective exploitation of the 2.6 GHz band for the benefit of customers may not be very harmful in the United States context over the long run. Other United States mobile operators already hold significant amounts of spectrum in bands such as AWS and "digital dividend" where they can deploy new broadband wireless networks in the near future. Nevertheless, at some point it may well become desirable to make better overall use of the 2.6 GHz band in the United States than is represented by the current investments of Clearwire and Sprint Nextel.

Importantly, there are many countries in which operators have smaller spectrum holdings than in the United States. It would be harmful to the development of affordable broadband wireless coverage if the 2.6 GHz band were to be allocated in ways that favored suboptimal outcomes. For instance, it would be highly undesirable to allow allocations in which more spectrum than the minimum had to be utilized for guard bands, and/or unnecessary handicaps were placed in the way of deploying evidently mainstream technologies such as LTE.

The United States example for the 2.6 GHz band is not an appropriate model for other countries. Adoption of ITU Option 1 rather than a framework that may lead to a structure similar to the way in which the 2.6 GHz band is being utilized (or rather under-utilized) in the United States today is much better suited to meeting anticipated demands for broadband wireless services.

Canada. In a comparable manner to the United States, Canada embarked on the process of transitioning the 2.6 GHz band from its current licenses and licensees to BRS (Broadband Radio Service), with a target date for the transition of March 31st, 2011. Like the United States arrangement, the current plan is inconsistent with ITU Option 1 and may lead to interference and roaming challenges. However, an October 2009 report, "Stakeholder Proposal Development: Incumbents' Views on the 2500-2690 MHz Band Plan for Broadband Radio Service"[17] clearly shows strong support from incumbent operators for ITU Option 1. The report highlights several key advantages consistent with benefits discussed earlier:

- Global harmonization, supporting equipment availability
- Spectral efficiency
- Accommodates both FDD and TDD operations

The favorable feedback may move Canada toward adoption of ITU Option 1. The country should take note of not only incumbent commentary, but also considerations based on the emerging global technology and market environments which were not factors in the outcome for the 2.6 GHz band in the United States. So long as the need to avoid cross border interference is satisfied, Canada would benefit by adopting the ITU Option 1 band plan. More information on Canada is available in Appendix C.

The 2.6 GHz Band in Latin America – ITU Option 1 at Forefront

The 2.6 GHZ spectrum band represents a tremendous opportunity for regulators throughout Latin America to make some informed decisions and set the stage for this important region to align with the rest of the world. For this reason, the Inter-American Commission on Telecommunications (CITEL) approved the PCC.II-Radio Recommendation 8/2004 on channel arrangements for IMT systems in the 2.5-2.69 GHz band recommending ITU Option 1 because it allows duplex separation of 120MHz.

The following table (Table 6) provides a vision of expected timelines for licensing and current situation of the band in key selected countries of the region.

[17] "Stakeholder Proposal Development: Incumbents' Views on the 2500-2690 MHz Band Plan for Broadband Radio Service", Industry Canada, October 2009, http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09683.html.

Table 6 - Listing of Latin American 2.6 GHz Band Licensing Prospects *(not exhaustive)*

Country	Licensing Schedule (estimated)	Comments
Argentina	2013	2.6GHz band licensing is currently in Secom's agenda although priorities are now focused on the AWS band which is ready to be auctioned soon. The band needs to be cleared before licensing. As of today, it is underutilized with some police equipment and MMDS operators using the band.
Brazil	2012-2013	Brazilian regulator ANATEL has presented a consultation proposal to assign 140 MHz (2 X 70 MHz) for mobile services in the 2.6 GHz band. 2 X 60 MHz would be assigned by the end of 2012 and additional 2 X 10 MHz by the end of 2015. Mobile operators in Brazil have supported the assignment but asked for its acceleration, a total of 2 X 70 MHz for January 1, 2012, aiming at launching LTE by 2013.
Chile	2010	Subtel, suggested possible bidding for 2.6 GHz band before yearend, although we estimate this will not occur until early 2010. Subtel already structured the band following ITU option 1 with two blocks of 76 MHz of paired spectrum and one block of 42 MHz for TDD.
Colombia	2010	The Ministry of Information Technologies and Communications has opened the process for a tender that will license around 90 MHz in the center of the 2.5-2.69 GHz spectrum band. The spectrum allocation and type will be contingent on the number of interested applicants and their preference for bandwidth and for FDD or TDD spectrum. The auction is intended to allow entrants in the mobile broadband market and aims to license remaining spectrum later by end-2010.
Mexico	2010-2011	Cofetel and SCT are studying the renewal licenses granted to MMDS operator Multivision in the 2.6 GHz band that holds almost the whole band with very limited use. They intend to have a significant portion of this spectrum cleared and ready to be licensed following ITU option 1 by 2010.
Peru	N/A	The Peruvian regulator recently granted 2668-2692 MHz of spectrum in Lima, Callao, Trujillo and Lambayeque areas to the Russian mobile WiMAX operator Yota. This TDD spectrum allocation was argued to be "technologically neutral" but clearly does not allow for FDD technologies in the band. The allocation at the top of the band harms its optimal use and reduces the chances for the country to enjoy the benefits of international harmonization.

Source: public releases from and conversations with regulators.

Brazil

Current 2.6 GHz use and regulatory actions. The current situation in Brazil is that the 2.6 GHz spectrum is allocated for primary use to MMDS (Multimedia Distribution Services). The Brazilian regulator ANATEL is now considering how to accomplish the transition of the 2.6 GHz band towards the goal of allocating more bandwidth for mobile broadband, converging the band plan in Brazil to ITU's Option 1 over the next few years. A public consultation was launched on August 3rd 2009 and concluded October 16th, 2009. ANATEL is now assessing more than 500 contributions to prepare a final decision on this issue.

Given the role of Brazil as the largest economy and country in Latin America, as well as a leading emerging market (e.g. one of the "BRIC" countries), the content of the public consultation is encouraging. The effort recognizes that the 2.6 GHz band offers a valuable and rare opportunity for the deployment of mobile broadband services in a globally harmonized approach. This opportunity would be foregone to the detriment of the development of broadband access if the 2.6 GHz band were left in the hands of MMDS licensees, some of them having a monopolist role in fixed broadband, or with the majority of its bandwidth structured as unpaired spectrum.

The Brazilian President, Luís Inácio Lula da Silva, has created a committee at the presidential level to create a National Broadband Plan. Mobile broadband is expected to play a critical role.

Need for more spectrum and addressing "digital divide". At the end of 2007, Brazil issued 3G licenses in the core 3G band of 1.9/2.1 GHz, increasing the spectrum cap for an operator from 60 to 80 MHz. Nevertheless, shortages of spectrum for delivering broadband wireless services are already becoming apparent, with mobile operators warning that large cities such as São Paulo will face shortages of spectrum for mobile broadband by the end of 2010. Accordingly, future attributions of frequencies in the 2.6 GHz band are imperative.

ICT and broadband penetration in Brazil are also unevenly distributed across the territory and population ("digital divide"), reflecting wide economic disparities within the country. The challenge of how best to extend affordable broadband coverage to all areas and segments of the population (e.g. by use of a universal services fund and other incentives for and obligations on operators) remains a formidable one, but there are solutions at hand. Broadband wireless has a major and indispensable role to play if ambitious targets for broadband penetration are to be achieved in the short- and long- term.

Potential penetration targets. According to a 2008 forecast from Anatel, the 2010 broadband penetration target for Brazil represents only a modest rate of growth – a near-term annual growth rate of approximately 12.7% -- to 15 million connections. This figure is an upward revision from an earlier target of 10 million by this date immediately after the launch of mobile broadband. As of the end of June 2009, Brazil's fixed broadband connection totaled close to 11 million, a 5.4% penetration per pop.[18]

One recently published estimate for global mobile broadband penetration produced a forecast of over 2 billion users by 2014, compared to 181 million in 2008.[19] Among this number were forecasts of 53 million laptop PC and 325 million handset broadband users in China, thanks to the advent of 3G and later 3G+ networks in that country. Brazil's population is about 15% of China's, while its GDP/capita on a PPP (purchasing power parity) basis is currently over 60% greater, although its GDP growth rate is lower.[20] Hence, provided other factors such as coverage and affordability of mobile broadband access and terminals are equal, which today they are not, it might be expected that mobile broadband users in Brazil - a country of comparable geographic size to China - might amount to as many as 55 million or so by 2014-2015, including about 8 million PC users (e.g. 15% multiplied by China estimate of 53 million).

[18] Anatel
[19] Ovum: "Mobile Broadband to be worth $137 billion by 2014", March, 2009.
[20] Population, GDP and growth estimates sourced from the CIA World Factbook, https://www.cia.gov/library/publications/the-world-factbook/.

Sensible spectrum allocation and measures to enhance affordability would make targets achievable. The above analysis suggests that new broadband capacity would play a key role in achieving broadband target penetrations of two to three times the 2010 target of 15 million connections by 2015. A target of three times the 2010 goal for broadband subscribers by 2015 is equivalent to a compound annual growth rate of about 25% over the five year period from 2010 to 2015. The allocation and attribution of 2.6 GHz frequencies in ways that facilitate the deployment of a global standard such as LTE appear highly desirable. As Brazil debates a National Broadband Plan, mobile broadband in the 2.6 GHz band is an essential contributor to achieving these goals.

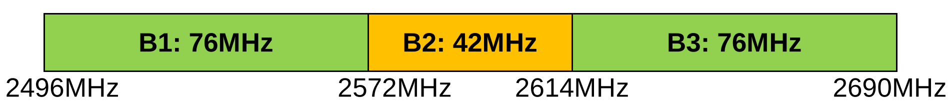
Chile

Current 2.6 GHz status and plans. Chile's Subsecretaría de Telecomunicaciones (SubTel) is planning to allocate frequencies in the 2.5-2.69 GHz in the near future as the band is seemingly cleared and already channelized following ITU option 1. SubTel's head announced in September 2009 that Chile will launch a public tender for this spectrum once terminal equipment, namely handsets, is commercially available. They expect LTE networks to launch in 2010 in both 700 MHz and 2.6 GHz bands.

Proactive action by regulator. The Chilean case is noteworthy because the regulator provided clarity to operators and equipment vendors by clearing and channelizing the band well before issuing licenses. Subtel structured the band following ITU option 1 through two administrative resolutions: 479/05 and 733/07. As illustrated in Figure 3 below, Subtel assigned two blocks of 76 MHz in the upper and lower sub-bands for FDD technologies while leaving a block of 42 MHz in the center for TDD. The 2.6 GHz band in Chile has been defined between 2496 MHz and 2690 MHz and is technically ready to be licensed.

Figure 4: Chilean Band Plan

(Source: Subtel Resolutions 479/05 y 733/07)



Other Country Examples - South Africa

Current 2.6 GHz use and plans/opportunities. The band plan in South Africa for 2500-2690 MHz includes 50 MHz attributed to the operator of the country's broadcast network Sentech[21] (2500-2550 MHz) which however has not been given the funds needed to deploy a network at these frequencies, 15 MHz (2550-2565 MHz) attributed to WBS (i-Burst), and the remainder available for trial licenses. The regulator ICASA has been involved in an ongoing consultation on "Decisions Regarding The Licensing of the 2.6 and 3.5 GHz Bands", following criticism of its intent announced in May 2008 to award six nationwide licenses of 20 MHz in this band through auction, with candidates first having to pass a beauty contest before they could enter the bidding process. Advocates of WiMAX have argued that they need licenses of 30 MHz in order to be able to deploy TDD broadband wireless networks efficiently as the basis of a viable

[21] The Government owned commercial enterprise that was originally the signal distributor for South African broadcasters and now can also offer telecommunications services.

business plan (as noted Clearwire in the United States is initially deploying its 802.16e networks in 30 MHz of bandwidth in the 2.6 GHz band).

However, as noted in the United States analysis, the 2.6 GHz band offers a special and timely opportunity for the deployment of emerging LTE systems in paired spectrum. South Africa has the opportunity to allocate the 2.6 GHz band in a manner that would make the country an early LTE adopter. Such a move could expeditiously expand affordable broadband coverage and set an example that could be emulated by the rest of Africa. By contrast, an outcome similar to that of the United States in which the band became effectively limited to TDD operation would represent a significant waste of the band's potential to meet or exceed the country's overall broadband goals.

National band plan is inconsistent and would create numerous challenges. In July 2009, the regulator ICASA announced a set of criteria[22] for allocating 2.6 GHz spectrum that, if followed, would likely leave the country with a non-standardized and even unique band structure. The ICASA criteria explicitly reject the globally harmonized ITU Option 1 that includes 140 MHz of paired spectrum and 50 MHz of unpaired spectrum. This outcome would be bad for South Africa's broadband and economic development, as well as its consumers.

ICASA's thinking is inconsistent. On the one hand it emphasizes that it favors "technology neutral" licenses, yet decisions and comments, such as that it would be an "untenable" situation if the 50 MHz of spectrum allocated to Sentech at the bottom end of the band were to be rearranged, effectively violate this principle. Absent such a rearrangement, the possibility presented by ICASA that operators could bid for paired spectrum (one member of such a pair would have to lie within the Sentech spectrum) is inaccurate. It also ignores the adverse consequences of the potentially lengthy negotiations and waste of spectrum that might be required to cope with interference if blocks of paired and unpaired spectrum were somehow nevertheless allocated within the band in a manner that, as ICASA intends, is not specifically prescribed before bids have to be submitted.

It is an obvious and revealing oxymoron[23] that the 2.6 GHz band is often referred to in South Africa as "WiMAX spectrum", whereas it has been defined by the ITU as the IMT-2000 extension band, for which several technologies are suited, of which WiMAX is only one and by far not the most popular alternative. Among the several less than optimum and avoidable consequences of the likely implementation of the proposed ICASA criteria would be higher costs than necessary for the wireless equipment required (base stations and most importantly subscriber terminals), and at most limited international roaming capabilities for subscribers to the networks that would be deployed.

ITU Option 1 remains best course of action. The ITU band plan is suited to the deployment of the probably most popular and widespread next generation LTE systems in FDD operation, while allowing room at the same time for TDD systems such as TDD WiMAX and TDD LTE. The ITU band plan is indeed more faithful to the principle of technology neutrality than the effect of the proposed ICASA conditions which effectively exclude FDD operation, although evidence from other auctions of 2.6 GHz spectrum (Hong Kong, Scandinavia) has demonstrated that paired spectrum is more highly in demand than unpaired spectrum.

[22] Findings on the Criteria for Awarding Radio Frequency Spectrum in the 2.6 GHz and 3.5 GHz Bands, ICASA, July 22, 2009, http://www.icasa.org.za/Home/tabid/36/ctl/ItemDetails/mid/388/ItemID/373/Default.aspx.
[23] The oxymoron is "Technology neutral WiMAX".

Countries that wish to expand the coverage of affordable broadband wireless services as rapidly and as widely as possible should adopt harmonized band plans unless there are compelling local reasons not to do so. There do not appear to be any such reasons for South Africa to isolate itself in this manner. It would be more sensible for ICASA and other public sector stakeholders with the interests of the South African economy and society as their responsibility to develop a transition plan towards ITU Option 1 for the 2.6 GHz band as Brazil seems to be doing.

Conclusions

Analysis of technological trends in wireless equipment and terminals, industry traffic trends, interference coordination challenges, and broadband policy objectives and principles as well as discussions with and reviews of non-confidential material from mobile operators, technology vendors, and regulators, points to the following:

- Public policy that supports the 2.6 GHz band also supports economic growth.
- Licenses have already been issued in several countries and more 2.6 GHz auctions are anticipated over the next one to two years in multiple national markets.
- Evidence generally indicates more demand for paired than unpaired spectrum at 2.6 GHz.
- The implied goals of most, if not all, regulators are to create an environment that stimulates operators to exploit the 2.6 GHz band in a manner which will expand the capabilities and coverage of affordable broadband wireless access.
- ITU Option 2 can be ruled out and Option 3 presents many challenges.
- Growing momentum to adopt ITU Option 1 has developed in Europe.
- LTE's advantages over WiMAX in the 2.6 GHz band and the overall mobile broadband market have become increasingly evident.
- Rational analysis concludes that ITU Option 1 best meets all stakeholder objectives.

In conclusion:

- ➢ **A harmonized band plan such as ITU Option 1 has the merit of having received global recognition, supports technology and services neutrality while allowing considerable freedom of action to national regulators and authorities.**
- ➢ **Importantly, Option 1 is consistent with sustaining healthy and intense competition among both services providers and equipment/device vendors, thereby bringing continued substantial cost/performance improvements in wireless communications for customers.**
- ➢ **Reasonable, standardized allocations of paired and unpaired blocks of spectrum will permit vigorous competition between alternative wireless technologies such as LTE and mobile WiMAX. These technologies, both of which will soon be available for FDD and TDD modes of operation, will be free to compete to win**

favor with operators for future mobile broadband wireless network deployments as 2.6 GHz band licenses are awarded.

Glossary

Table 7: Definition or Meaning of Terms

Term	Definition or Meaning
1G	Analog cellular.
2G	First digital cellular.
3G	Digital cellular networks meeting requirements of ITU IMT-2000.
3GSM	3G version of GSM, also called Universal Mobile Telecommunications Systems (UMTS) and also sometimes referred to as Wideband CDMA (WCDMA).
4G	Digital cellular networks meeting requirements of ITU IMT-Advanced.
3GPP	Third Generation Partnership Project. The organization that develops GSM, 3GSM, LTE and related specifications.
3GPP2	Third Generation Partnership Project 2. The organization that develops CMDA2000 specifications, including integration capabilities with LTE.
CDMA	Code Division Multiple Access.
EDGE	Enhanced Data Rates for GSM Evolution.
EPC	Evolved Packet Core. Core network for LTE networks.
EPS	Evolved Packet System. System architecture for LTE.
EV-DO	Evolved Data Optimized. A 3G data service for CDMA2000 networks.
FDD	Frequency Division Duplex.
GSM	Global System for Mobile Communications.
HSPA	High Speed Packet Access. Data service for 3GSM networks. Combination of HSDPA and HSUPA.
HSDPA	High Speed Downlink Packet Access.
HSUPA	High Speed Uplink Packet Access.
IMT-2000	International Telecommunications Union 2000. Defines 3G requirements.
IMS	IP Multimedia Subsystem.
ITU	International Telecommunications Union. The United Nations body that sets international communications standards.
Kbps	Thousand bits per second.
LTE	Long Term Evolution. OFDMA radio technology defined by 3GPP.
Mbps	Million bits per second.
MIMO	Multiple Input Multiple Output.
OFDMA	Orthogonal Frequency Division Multiple Access. A high-performance radio method used by both LTE and WiMAX.
QAM	Quadrature Amplitude Modulation.
Shannon Bound	Mathematically defines the theoretical limit of spectral efficiency (bits per second per Hertz) that is possible relative to signal to noise interference.
SMS	Short Message Service. Text messaging service for wireless networks.
TDD	Time Division Duplex.
TDMA	Time Division Multiple Access
UMB	Ultra Mobile Broadband. OFDMA technology defined by 3GPP2.
UMTS	Universal Mobile Telecommunications System.
VoIP	Voice over IP.
WCDMA	Wideband Code Division Multiple Access.
WiMAX	Worldwide Interoperability for Microwave Access.

Appendix

Appendix A: Outcomes of World Radiocommunication Conferences for the 2.6 GHz Band ("IMT Extension")

WRC-07

Agenda Item 1.4 - *to consider frequency-related matters for the future development of IMT-2000 and systems beyond IMT-2000 taking into account the results of ITU-R studies in accordance with Resolution228 (Rev. WRC-03)*

Agenda Item 1.9 – *to review the technical, operational and regulatory provisions applicable to the use of the band 2 500-2 690 MHz by space services in order to facilitate sharing with current and future terrestrial services without placing undue constraint on the services to which the band is allocated;*

Outcome/Results at WRC-07
This agenda item dealt with new regulatory provisions to be applied to satellite systems to protect terrestrial systems in the band 2500-2690 MHz.
The new regulatory provisions adopted by WRC-07 can be summarized as follows:

- More stringent power flux density limits of -136 / -125 dB(W/m2) for all space stations in the broadcasting, fixed and mobile-satellite services (BSS, FSS and MSS) except to specific space stations from China, India, Indonesia, Japan and Saudi Arabia;
- A limitation for all satellite systems in this band to be national or regional, as opposed to world-wide systems; and,
- The removal of the MSS allocation in Europe, Africa and the Americas.

WRC-03

No change of frequency allocations was made at WRC-03 since studies on the spectrum requirements could not be finalized by WRC-03.

Future development of IMT-2000 systems and beyond
IMT-2000 systems are third-generation (3G) mobile systems, which provide access to a plethora of services supported by fixed telecommunication networks, such as the public switched telephone network (PSTN), integrated services digital network (ISDN) and the Internet Protocol (IP).

As the industry moves beyond IMT-2000 systems, the demand for multimedia applications, such as high-speed data, IP-packet and video are expected to increase. ITU has reaffirmed its support for the continuing development of mobile wireless communications by recognizing the need to provide a global vision for the future development of IMT-2000 and systems beyond IMT-2000. As part of this commitment, ITU will study technical and operational issues on how these systems will evolve, and develop Recommendations as required. It will also study, in time for WRC-07, frequency-related matters for the future development of these systems. The studies will focus on the:

- evolving user needs, including the growth in demand for IMT-2000 services;
- evolution of IMT-2000 and pre-IMT-2000 systems through advances in technology;
- bands currently identified for IMT-2000;
- time-frame in which spectrum would be needed;
- period for migration from existing to future systems;
- extensive use of frequencies below those identified in the Radio Regulations for IMT-2000.
- These studies will take into account the particular needs of developing countries, including the use of the satellite component of IMT-2000.

RESOLUTION 228 (Rev. WRC-03)

Studies to consider frequency-related matters for the future development of IMT-2000 and systems beyond IMT-2000 as defined by ITU-R

The World Radiocommunication Conference (Geneva, 2003), *considering*

a) that International Mobile Telecommunications-2000 (IMT-2000) systems started operation in the year 2000;

b) that Question ITU-R 229/8 addresses the future development of IMT-2000 and systems beyond IMT-2000;

c) that the future development of IMT-2000 and systems beyond IMT-2000 is being studied within ITU-R;

d) that the technical characteristics of IMT-2000 are specified in ITU-R and ITU-T Recommendations, including Recommendation ITU-R M.1457 which contains the detailed specifications of the radio interfaces of IMT-2000;

e) that it was eight years ahead of the IMT-2000 initial deployment that WARC-92 identified the spectrum for IMT-2000 in No. **5.388** and in Resolution **212**;

f) that the review of IMT-2000 spectrum requirements at WRC-2000 concentrated on the bands below 3 GHz;

g) that information technology and telecommunication markets evolve rapidly;

h) that adequate spectrum availability is a prerequisite for the market and technological success of the future development of IMT-2000 and systems beyond IMT-2000;

i) that a continuing and accelerating growth in the demand for multimedia applications such as high-speed data, IP-packet and video by mobile communication systems is forecasted;

j) that the future development of IMT-2000 and systems beyond IMT-2000 is foreseen to address the need for higher data rates than those currently deployed for IMT-2000;

k) that an orderly process of change and development of IMT-2000 towards the capabilities and functionalities of systems beyond IMT-2000 are needed;

l) that, for global operation and economy of scale, which are key requirements for success of mobile communications services, it is desirable to agree on a harmonized timeframe and common technical, operational and spectrum-related parameters of systems, taking account of relevant IMT-2000 and other experience;

m) that it is therefore timely to study market, technical, spectrum and regulatory issues pertinent to the future development of IMT-2000 and systems beyond IMT-2000;

n) that sharing and compatibility should be addressed between existing services and the future development of IMT-2000 and systems beyond IMT-2000;

o) that Question ITU-R 77-4/8 is to consider the needs of developing countries in the development and implementation of mobile radiocommunication technology, *noting*
a) that the IMT-2000 radio interfaces as defined in Recommendation ITU-R M.1457 are expected to evolve within the framework of ITU-R beyond those initially specified, to provide enhanced services and services beyond those envisaged in the initial implementation;
b) that ITU-R has envisaged that new elements of systems beyond IMT-2000 will be developed, which will closely interwork and be interoperable with currently operating IMT- 2000 and its future enhancements;
c) *that there is a need for appropriate naming to be developed in advance of WRC-07 for the future development of IMT-2000 and systems beyond IMT-2000, recognizing:*

a) the time necessary to develop and agree on the technical, operational, spectrum and regulatory issues associated with the continuing enhancement of mobile services;
b) that service functionalities in fixed, mobile and broadcasting networks are increasingly converging;
c) that, in the future, mobile systems are expected to adopt more spectrum-efficient techniques;
d) the needs of developing countries for the cost-effective implementation of advanced mobile communication technologies and the propagation characteristics of lower frequency bands that result in larger cells, *resolves*
1. to invite ITU-R to further study and develop Recommendations on technical and operational issues relating to the future development of IMT-2000 and systems beyond IMT-2000;
2 to invite ITU-R to complete studies on the spectrum requirements and the potential frequency ranges suitable for the future development of IMT-2000 and systems beyond IMT-2000, and in what time-frame such spectrum would be needed, taking into consideration the evolving market, including the growth in demand for IMT-2000 services, and the evolution of IMT-2000 and other mobile systems through advances in technology;
3 that the studies referred to in *resolves* 1 and 2 should take into consideration the particular needs of developing countries;
4 that the studies referred to in *resolves* 1 and 2 should include sharing and compatibility studies with services already allocated in potential spectrum for the future development of IMT-2000 and systems beyond IMT-2000;
5 that the spectrum requirements for the future development of IMT-2000 and systems beyond IMT-2000 should be considered by WRC-07, taking into account the results of the ITU-R studies referred to in *resolves* 2, *urges administrations* to participate actively in the studies by submitting contributions to ITU-R.

Table 8 - WRC 2000

2 500-2690 MHz Allocations

(Primary in All Capital Letters)

<table>
<tr><th colspan="3">ALLOCATION TO SERVICES[24]</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>2 500-2 520
FIXED
MOBILE except aeronautical mobile
MOBILE-SATELLITE (space-to-Earth)</td><td colspan="2">2 500-2 520
FIXED
FIXED-SATELLITE (space-to-Earth)
MOBILE except aeronautical mobile
MOBILE-SATELLITE (space-to-Earth)</td></tr>
<tr><td rowspan="2">2 520-2 655
FIXED
MOBILE except aeronautical mobile
BROADCASTING-SATELLITE</td><td rowspan="2">2 520-2 655
FIXED
FIXED-SATELLITE (space-to-Earth)
MOBILE except aeronautical mobile
BROADCASTING-SATELLITE</td><td>2 520-2 535
FIXED
FIXED-SATELLITE (space-to-Earth)
MOBILE except aeronautical mobile
BROADCASTING-SATELLITE</td></tr>
<tr><td>2 535-2 655
FIXED
MOBILE except aeronautical mobile
BROADCASTING-SATELLITE</td></tr>
<tr><td>2 655-2 670
FIXED
MOBILE except aeronautical mobile
BROADCASTING-SATELLITE
Earth exploration-satellite (passive)
Radio astronomy
Space research (passive)</td><td>2 655-2 670
FIXED
FIXED-SATELLITE (Earth-to-space); (space-to-Earth)
MOBILE except aeronautical mobile
BROADCASTING-SATELLITE
Earth exploration-satellite (passive)
Radio astronomy
Space research (passive)</td><td>2 655-2 670
FIXED
FIXED-SATELLITE (Earth-to-space)
MOBILE except aeronautical mobile
BROADCASTING-SATELLITE
Earth exploration-satellite (passive)
Radio astronomy
Space research (passive)</td></tr>
<tr><td>2 670-2 690
FIXED
MOBILE except aeronautical mobile
MOBILE-SATELLITE (Earth-to-space)
Earth exploration-satellite (passive)
Radio astronomy
Space research (passive)</td><td>2 670-2 690
FIXED
FIXED-SATELLITE (Earth-to-space); (space-to-Earth)
MOBILE except aeronautical mob.
MOBILE-SATELLITE (Earth-to-space)
Earth exploration-satellite (passive)
Radio astronomy
Space research (passive)</td><td>2 670-2 690
FIXED
FIXED-SATELLITE (Earth-to-space)
MOBILE except aeronautical mobile
MOBILE-SATELLITE (Earth-to-space)
Earth exploration-satellite (passive)
Radio astronomySpace research (passive)</td></tr>
</table>

[24] **Region 1** comprises Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia; **Region 2** covers the Americas, Greenland and some of the eastern Pacific Islands; **Region 3** contains most of non-former-Soviet-Union Asia, east of and including Iran, and most of Oceania.

Appendix B: Technology Overview - for the 2.6 GHz Band

This section presents the primary wireless technologies available for the 2.6 GHz band. It discusses 1G to 4G cellular migration, Third Generation Partnership Project (3GPP) technology evolution, details of High Speed Packet Access (HSPA) and its roadmap of enhancements, Long Term Evolution (LTE), and WiMAX evolution.

1G to 4G Migration

Table 9 summarizes the technology generations, including the type of radio used (analog, time division multiple access, code division multiple access, and orthogonal frequency division multiple access), and requirements.

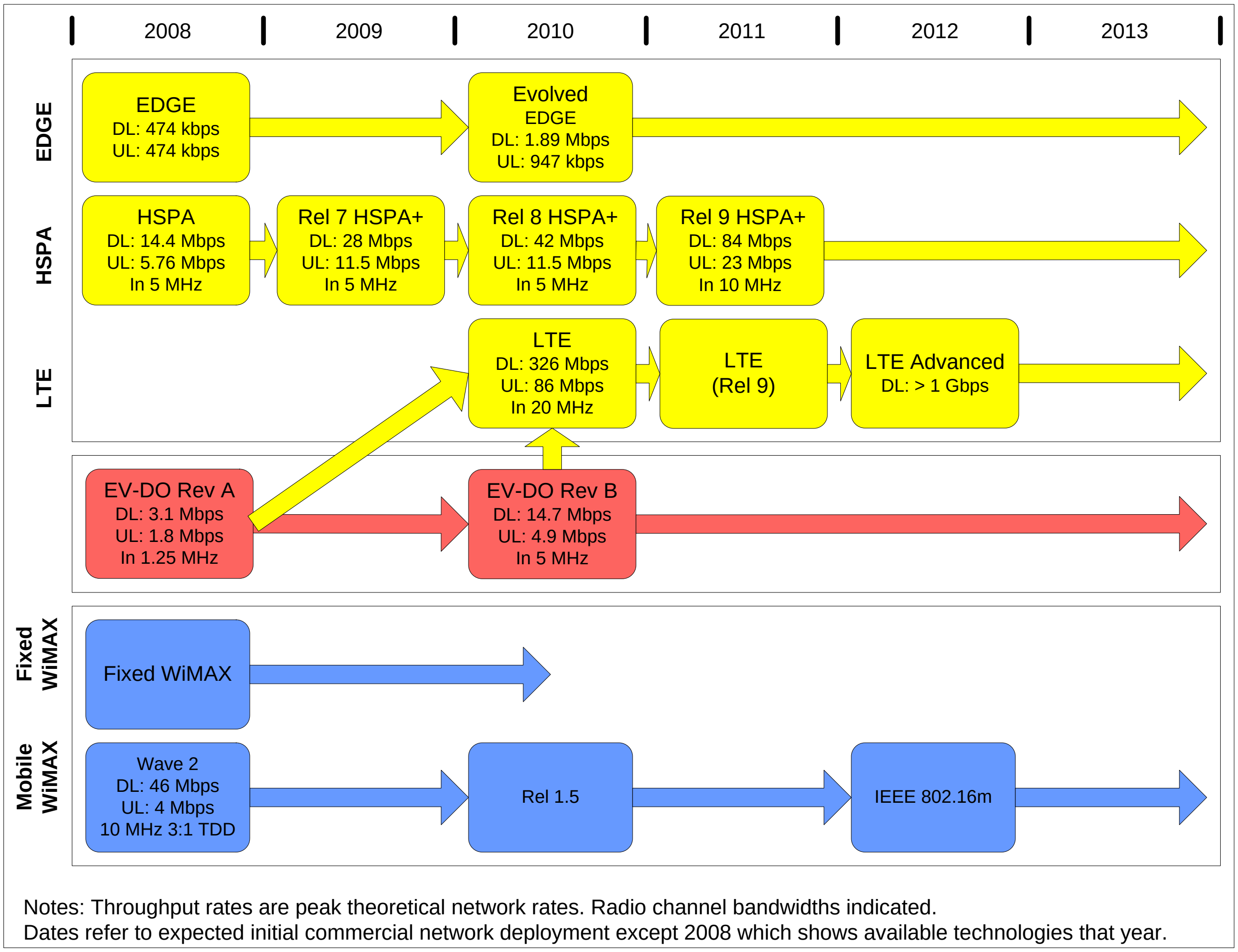
Table 9: Generations of Wireless Technology

Generation	Radio	Requirements	Comments
1G	Analog	No official requirements.	Deployed in the 1980s.
2G	Digital (TDMA and CDMA)	No official requirements.	Deployed in the 1990s. New services such as SMS and low-rate data. Increased voice capacity. Primary technologies include CDMA2000 1xRTT and GSM.
3G	Mostly CDMA. WiMAX and LTE are OFDMA.	ITU IMT-2000 requires 144 kbps mobile, 384 kbps pedestrian, 2 Mbps indoors	Primary technologies include CDMA2000 EV-DO and WCDMA/HSPA. WiMAX now an official 3G technology. LTE also a 3G technology.
4G	OFDMA	ITU's IMT-Advanced requirements include ability to operate in up to 40 MHz radio channels and very high spectral efficiency.	No technology meets requirements today. LTE Advanced and 802.16m are the leading candidates for IMT-Advanced selection.

Source: Rysavy Research.

There are two primary technology families that are the leading technology candidates for the 2.6 GHz band. These include the 3GPP family of technologies, show in yellow in Figure 5, and the WiMAX family of technologies, shown in blue.

Figure 5: GSM and WiMAX Family Technologies



Source: Rysavy Research.

3GPP Evolution

The 3GPP family of technologies constitutes an evolution of TDMA, CDMA, and OFDMA approaches. Even with significant growth in 3G technologies such as UMTS/HSPA, the majority of subscribers today still use TDMA-based GSM, which was initially deployed in the 1990s.

Improvements to GSM and EDGE continue to be made. Similarly, there are continual improvements in the 3G technologies, with significant emphasis on improving data performance and efficiency. High Speed Packet Access (HSPA) is undergoing a series of enhancements, resulting in projected peak theoretical throughput rates as high as 84 Mbps.

3GPP has also defined an OFDMA path, incorporated in LTE. LTE provides significant gains in performance and efficiency, with peak throughput rates as high as 326 Mbps and over 1 Gbps in planned approaches for LTE-Advanced. These are peak theoretical rates. Actual user throughputs will be lower. LTE trial networks are being launched in 2009 with initial service scheduled to become available in 2010.

Operators wishing to support mobile broadband services have the choice of deploying either HSPA or LTE, or a combination.

HSPA Evolution

HSPA+ is a significant technology development because it implements a considerable degree of innovation applied towards a CDMA approach.

Continued development of CDMA approaches has allowed CDMA to largely match OFDM performance, especially in narrower bandwidths such as 5 MHz. Some of the radio enhancements employed in HSPA to increase data throughput rates and spectral efficiency include:

- Higher order modulation (up to 64 quadrature amplitude modulation).
- Multiple Input Multiple Output (MIMO) antennas.[25]
- The option to run circuit switched voice over HSPA packet channels for increased voice capacity.
- A well defined roadmap for migration to VoIP, with the ability to simultaneously support circuit-switched and packet-switched voice users in the same radio channel.
- A one-tunnel architecture option that flattens the network (fewer infrastructure nodes) and thus reduces latency.
- Radio channel aggregation, including dual carrier (2 channels) then multi-carrier (possibly up to 4 channels speculated for a future release) for significantly higher throughputs.

The following table (Table 10) summarizes the throughput rates that HSPA can achieve on the downlink (DL) and the uplink (UL) based on various combinations of features. Operators can selectively deploy these features to address their specific deployment configurations and market demands.

It is important to note that these throughput values are theoretical maximums of the technology. Actual user rates depend on a variety of factors such as signal quality, network loading, and device capabilities. Typical user throughputs are thus generally lower than these peak rates. Nevertheless, peak data rates are useful in comparing different technologies, and in demonstrating the capabilities of the technology.

[25] Because of their shorter wavelengths, 2.6 GHz frequencies facilitate implementation of smart antenna technologies like MIMO in smaller devices such as handsets. This is true for both CDMA and OFDMA technologies.

Table 10: Peak Data Rates for HSPA Based on Different Configurations

Technology	DL Peak Data Rate (Mbps)	UL Peak Data Rate (Mbps)
Rel' 6 HSPA	14.4	5.76
Rel'7 HSPA+, DL 64 QAM, UL 16 QAM	21.1	11.5
Rel'7 HSPA+, DL 16 QAM, UL 16 QAM 2X2 MIMO	28.0	11.5
Rel'8 HSPA, DL 64 QAM, UL 16 QAM 2X2 MIMO	42.2	11.5
Rel'9 HSPA, DL 64 QAM, UL 16 QAM Dual Carrier	56.0	23
Rel'9 HSPA, DL 64 QAM, UL 16 QAM 2X2 MIMO, Dual Carrier	84.0	23

Source: Rysavy Research.

HSPA+ matches WiMAX Release 1.0 performance for both throughput rates and spectral efficiency. For example, WiMAX Release 1.0 has a peak theoretical rate of 46 Mbps in 10 MHz time division duplex, DL/UL ratio of 3. This rate is lower than some of the specified HSPA+ configurations. WiMAX Release 1.0 also has lower spectral efficiency than HSPA+ that employs 2X2 MIMO.[26]

Operators have begun deploying evolved HSPA features and HSPA+ launches include: Telstra (Australia), Mobilkom (Austria), CSL Limited (Hong Kong), Starhub (Singapore). There are many other networks in trials or planned.

LTE

3GPP LTE is the highest performing OFDMA system defined, with peak theoretical rates of 326 Mbps in a 20 MHz, 4X4 MIMO configuration. Throughputs as high as 246 Mbps have been measured in test networks.[27] Work on LTE began in 2004, and 3GPP Release 8, which specifies LTE, was completed in early 2009.

LTE is not just a radio technology. It operates within the Evolved Packet System (EPS), an overall architecture that includes the Evolved Packet Core (EPC) which handles all communications, including voice, in the IP domain. EPS is designed to support not only LTE access networks, but legacy GSM/3GSM access networks, as well as non-3GPP networks. With the integration of IP Multimedia Subsystem (IMS), EPS/LTE provides a flexible and capable platform for operators to deliver innovative mobile broadband services.
LTE features include:

- Operation in either FDD or TDD modes.

[26] Source: Rysavy Research white paper for 3G Americas, "EDGE, HSPA and LTE - Broadband Innovation," August, 2008. Spectral efficiency analysis based on consensus view of multiple operators and vendors.
[27] LTE/SAE Trial Initiative Latest Results from the LSTI, Feb 2009.

- The highest spectral efficiency of any available wireless technology, resulting in the lowest operating costs for operators.
- Extremely high voice capacity of 500 simultaneous users in a cell sector, using 10 MHz of spectrum.[28]
- A flat architecture with EPS that reduces infrastructure costs and improves application performance.
- Evolved quality-of-service (QoS) capability.
- A stepping stone to LTE Advanced, which will meet IMT-Advanced (4G) requirements.

Since LTE development began after WiMAX, engineers were able to implement enhancements that were either not available or not understood when WiMAX development occurred. Consequently, LTE is expected to outperform WiMAX Release 1.5 version which will become available in the same approximate time frame as LTE. Some specific technical reasons for LTE's superior performance include:

4. LTE uses 1 msec subframes whereas WiMAX uses 5 msec subframes. Shorter subframes reduce channel quality feedback delays and also result in shorter user data delays.
5. LTE uses incremental redundancy for error recovery whereas WiMAX uses Chase combining. Incremental redundancy achieves a given error rate at a lower signal-to-noise ratio (SNR) and hence is more efficient.
6. LTE uses a closed-loop system for MIMO whereas WiMAX in TDD mode does not. Though this is available in FDD mode, all currently planned WiMAX deployments are TDD.

Vendors have been able to demonstrate LTE capabilities in various test networks, e.g. Huawei for Telenor in Oslo, Motorola's involvement in TD-LTE trials with China Mobile, and Ericsson's and Alcatel-Lucent's trials with Vodafone.

WiMAX Evolution

WiMAX technology is based on the IEEE 802.16 standard, which was originally designed for telecom backhaul, and then later evolved to fixed, point-to-multipoint capability, and more recently to mobile capability. Table 11 summarizes the IEEE 802.16 standards.

Table 11: Summary of IEEE 802.16 Standards

IEEE Standard	Objective
IEEE 802.16	Telecom backhaul.
IEEE 802.16-2004	Fixed, point-to-multipoint.
IEEE 802.16e-2005	Mobility amendment. Used in WiMAX System Profile Release 1.0.
IEEE 802.16 Rev 2	Performance enhancements. Used in WiMAX System Profile Release 1.5.
IEEE 802.16m	Being designed to meet IMT-Advanced requirements.

Source: Rysavy Research.

[28] Source: 3GPP Multi-member analysis.

It is important to note that many WiMAX deployments globally are based on the IEEE 802.16-2004 standard, and it was only in late 2008 and 2009 that mobile WiMAX became commercially available.

Mobile WiMAX networks being deployed in 2009 are based on WiMAX System Profile Release 1.0. Release 1.5 provides performance enhancements and includes the following features:

- TDD and FDD support
- Higher VoIP capacity
- Backward compatibility with release 1.0
- 4 X 2 MIMO as an optional configuration

Release 1.5 could be available for deployment in a similar time frame as LTE. Since Release 1.5 was designed to be largely a software upgrade for Release 1.0 networks, not as many features could be incorporated as might otherwise have been possible. This is one of the reasons that Release 1.5 is not as efficient as LTE.

APPENDIX C: Regional and Country Examples of the 2.6 GHz Band

Country Auction Structures/Data

Singapore

Table 12 - WBA Spectrum Auction

Frequency	2.3GHz	2.6 GHz
Bandwidth for Auction, MHz	50	90
Total Number of Lots for Auction	10	15
Size of each Lot, MHz	5	6
Total Cap per Bidder (SingTel and StarHub)	4 lots[1]	
Total Cap per Bidder (other operators)	6 lots[1]	

Source: Infocomm Development Authority of Singapore, www.ida.gov.sg.
1. Six lots are considered sufficient for nationwide rollout of WBA in Singapore. A lower cap was applied to for SingTel and StarHub since they were thought to have enough existing infrastructure to need smaller amounts of bandwidth for WBA.

Table 13 - Winning Bidders in WBA Auction

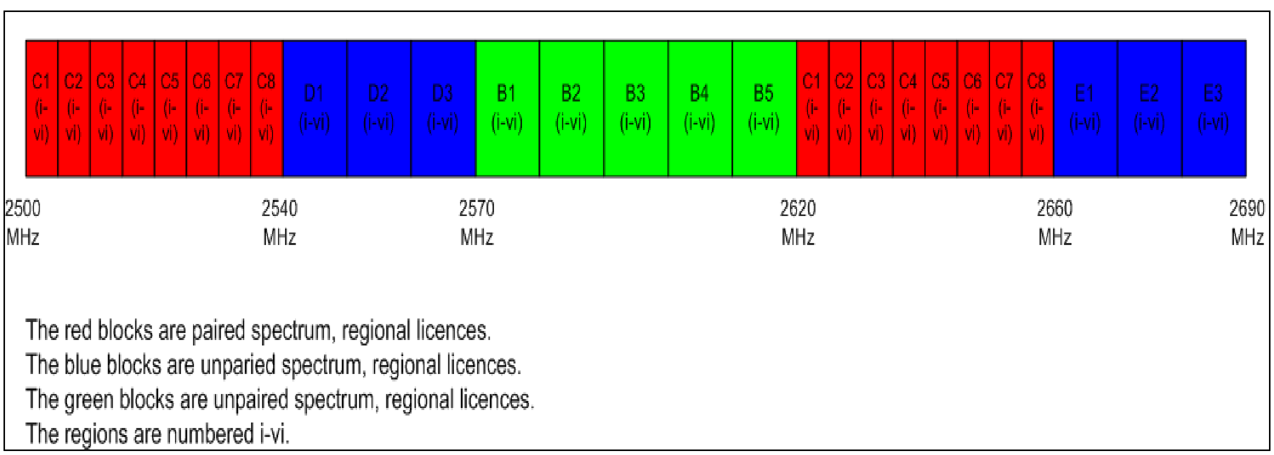
No	Operator	Spectrum Lots Awarded	Final Auction Price Paid (S$)	Price per MHz per POP[1] US$/Euros	
				US$	Euros
1	inter-touch Holdings (Singapore) Pte Ltd	7	215,200		
		8	269,000		
		9	269,000		
		10	269,000		
2	MobileOne Ltd	11	550,000	0.0125	0.0099
		12	550,000	0.0125	0.0099
		21	500,000	0.0114	0.0090
		22	500,000	0.0114	0.0090
3	Pacific Internet Corporation Pte Ltd	15	450,000	0.0103	0.0081
		16	450,000	0.0103	0.0081
		19	550,000	0.0125	0.0099
		20	550,000	0.0125	0.0099
		25	269,000	0.00613	0.00484

No	Operator	Spectrum Lots Awarded	Final Auction Price Paid (S$)	Price per MHz per POP[1] US$/Euros	
				US$	Euros
4	Qala Singapore Pte Ltd	1	215,200		
		2	269,000		
		3	215,200		
		4	215,200		
		5	215,200		
		6	269,000		
5	Singapore Telecom Mobile Pte Ltd	13	550,000	0.0125	0.0099
		14	500,000	0.0114	0.0090
		23	500,000	0.0114	0.0090
		24	500,000	0.0114	0.0090
6	StarHub Ltd	17	500,000	0.0114	0.0090
		18	500,000	0.0114	0.0090

Source: Infocomm Development Authority of Singapore, www.ida.gov.sg.

Norway

Table 14 - Norwegian 2.6 GHz Band Plan



Source: Norwegian Post and Telecommunications Authority, www.npt.no.

Table 15 - Winners of Norwegian 2.6 GHz Band Auction

Frequency band (Lots)		Block		Region					
Lower (MHz)	Upper (MHz)			1	2	3	4	5	6
2010	2025	A	Unpaired	Inquam Broadband GmbH					
2500 / 2620	2505 / 2625	C1	Paired	Hafslund Telekom AS	NetCom AS				
2505 / 2625	2510 / 2630	C2	Paired	NetCom AS					
2510 / 2630	2515 / 2635	C3	Paired	NetCom AS					
2515 / 2635	2520 / 2640	C4	Paired	NetCom AS					
2520 / 2640	2525 / 2645	C5	Paired	Telenor ASA					
2525 / 2645	2530 / 2650	C6	Paired	Telenor ASA					
2530 / 2650	2535 / 2655	C7	Paired	Telenor ASA					
2535 / 2655	2540 / 2660	C8	Paired	Telenor ASA					
2540	2550	D1	Unpaired	Telenor ASA					
2550	2560	D2	Unpaired	Telenor ASA					
2560	2570	D3	Unpaired	Hafslund Telekom AS	Hafslund Telekom AS	Arctic Wireless AS	Hafslund Telekom AS	Arctic Wireless AS	Arctic Wireless AS
2570	2580	B1	Unpaired	Craig Wireless Systems Ltd.					
2580	2590	B2	Unpaired	Craig Wireless Systems Ltd.					
2590	2600	B3	Unpaired	Craig Wireless Systems Ltd.					
2600	2610	B4	Unpaired	Craig Wireless Systems Ltd.					
2610	2620	B5	Unpaired	Craig Wireless Systems Ltd.					
2660	2670	E1	Unpaired	Telenor ASA					
2670	2680	E2	Unpaired	Telenor ASA					
2680	2690	E3	Unpaired	Hafslund Telekom AS	Not assigned	Not assigned	NetCom AS	Not assigned	NetCom AS

Source: Norwegian Post and Telecommunications Authority, www.npt.no.
Note: NetCom AS is a subsidiary of the Swedish/Finnish incumbent operator TeliaSonera

Finland

Finland is a small country with well established mobile operators and slow market growth. For the 2.6 GHz auction, there were no new entrants vying for the FDD spectrum, which is used by incumbent mobile operators. Also, there was enough spectrum to distribute among the three main mobile operators (DNA, Elisa and TeliaSonera), which already possess ample quantities of spectrum in the 900 and 1800 MHz bands and the 3G 2.1 GHz spectrum. The operators can deploy broadband wireless systems in all bands, if desired and necessary. It is expected that LTE will be introduced into the 1800 MHz band at up to 2x15-20 MHz over the next five years, even in densely populated areas. The availability of 1800 MHz reduces operators' reliance on 2.6 GHz for launching LTE in urban areas and none of the operators were in favor of the auction format. Previously, Finland attributed spectrum via beauty contests. Thus, competition was not driving prices upward for the FDD spectrum.

However, the unpaired TDD spectrum was a different situation. TDD spectrum typically sells for much less than FDD (e.g. Sweden where 2.6 GHz FDD sold for five times as much as TDD), yet in the Finnish auction, competition for the TDD block led to prices nearly twice as much as those paid for the FDD blocks. There were competing bids for the single 50 MHz TDD block, which is not large enough to accommodate two broadband wireless operators efficiently since it must absorb two 5 MHz guard bands to avoid interference with adjacent FDD frequencies, plus an additional guard band if two TDD operators were to be accommodated. Hence, deploying two 20 MHz TDD networks would not be feasible. The TDD spectrum was acquired by the Finnish Association of local telephone operators, which accounted for approximately one fifth of fixed telephone and one eighth of broadband connections as of year-end 2008.

Finally, one particular feature of the auction rules also helped to keep prices low. If a bidder moved from one lot to another and then returned to the first lot, it could restart bidding at the reserve price, so long as no other participant had made a bid on the original lot. Participants used this rule to strategically keep prices low. In the 2008 Swedish auction, any bidder leaving a lot and then returning to it had to increase its offer.

Therefore, the results of the 2.6 GHz auction in Finland are not necessarily indicative of the demand and, hence, prices for 2.6 GHz frequencies that will prevail in many other countries whose competitive conditions and current spectrum holdings as well as demographics are likely very different from those in Finland.

Hong Kong

Table 16 - Outcome of the Hong Kong 2.6 GHz Band Auction

Provisional Successful Bidder	Radio Spectrum Bid	SUF Payable (HK$M)
Genius Brand Limited	30 MHz (2500-2515 MHz paired with 2620-2635 MHz)	518.0
CSL Limited	30 MHz (2540-2555 MHz paired with 2660-2675 MHz)	523.0
China Mobile Hong Kong Company Limited	30 MHz (2555-2570 MHz paired with 2675-2690 MHz)	494.7
Total	**90 MHz**	**1535.7**

Source: Office of the Telecommunications Authority Hong Kong, www.ofta.gov.hk.

Global LTE Launch Plans

Table 17 – Anticipated LTE Launches

#	Country	Operator	Expected Launch (year)	Expected Launch (quarter)	#	Country	Operator	Expected Launch (year)	Expected Launch (quarter)
1	USA	CenturyTel (700)	2010	2010	61	Netherlands	Vodafone Libertel	2012	Q4 2012
2	USA	Cox Communications (7/21)	2010	2010	62	Paraguay	America Movil Paraguay	2012	Q4 2012
3	USA	Verizon Wireless (7/21)	2010	Q1 2010	63	Puerto Rico	America Movil	2012	Q4 2012
4	China	China Mobile	2010	Q2 2010	64	Sweden	H13G (2600)	2012	Q4 2012
5	UAE	Etisalat	2010	Q2 2010	65	UK	Vodafone	2012	Q4 2012
6	Bahrain	Zain	2010	Q3 2010	66	Uruguay	AM Wireless Uruguay	2012	Q4 2012
7	Saudi Arabia	Zain	2010	Q3 2010	67	Uruguay	ANCEL	2012	Q4 2012
8	Canada	Rogers Wireless	2010	Q4 2010	68	Uruguay	Telefónica Móviles del Urug	2012	Q4 2012
9	Italy	Telecom Italia	2010	Q4 2010	69	USA	T-Mobile USA	2012	Q4 2012
10	Japan	NTT DoCoMo (2100)	2010	Q4 2010	70	Australia	Hutchison 3G	2013	Q1 2013
11	South Korea	KT (KTF)	2010	Q4 2010	71	Australia	Optus	2013	Q1 2013
12	South Korea	SK Telecom	2010	Q4 2010	72	Australia	Vodafone	2013	Q1 2013
13	South Korea	LG Telecom	2010	Q4 2010	73	Brunei	DSTCom	2013	Q2 2013
14	Sweden	Tele2	2010	Q4 2010	74	Egypt	ECMS	2013	Q3 2013
15	Sweden	Telenor Sweden	2010	Q4 2010	75	Brazil	Sercomtel	2013	Q4 2013
16	USA	Metro PCS	2010	Q4 2010	76	Cambodia	Cadcomms	2013	Q4 2013
17	Canada	Bell Wireless	2011	2011	77	Cambodia	Cambodia GSM	2013	Q4 2013
18	Canada	Telus Mobility	2011	2011	78	Cambodia	Cambodia Shinawatra	2013	Q4 2013
19	Japan	eAccess	2011	2011	79	Colombia	Colombia Movil	2013	Q4 2013
20	Japan	KDDI	2011	2011	80	Colombia	Comunicaciones Celulares	2013	Q4 2013
21	Japan	Softbank Mobile	2011	2011	81	Colombia	Telefonica Moviles Colombi	2013	Q4 2013
22	Kuwait	Zain	2011	Q2 2011	82	Ecuador	Conecel	2013	Q4 2013
23	Austria	Mobilcom Austria (2600)	2011	Q4 2011	83	Ecuador	Otecel	2013	Q4 2013
24	Austria	Hutchison 3G	2011	Q4 2011	84	Hong Kong	Hong Kong CSL	2013	Q4 2013
25	Belgium	Mobistar (Orange) 2600	2011	Q4 2011	85	Hong Kong	Hutchison	2013	Q4 2013
26	France	Orange France	2011	Q4 2011	86	Hong Kong	PCCW Mobile	2013	Q4 2013
27	Germany	T-Mobile	2011	Q4 2011	87	Hong Kong	SmarTone-Vodafone	2013	Q4 2013
28	Germany	Vodafone D2	2011	Q4 2011	88	Indonesia	Excelcomindo	2013	Q4 2013
29	Norway	Netcom (2600)	2011	Q4 2011	89	Indonesia	Indosat	2013	Q4 2013
30	Norway	Telenor (2600)	2011	Q4 2011	90	Indonesia	Telkomsel	2013	Q4 2013
31	Singapore	StarHub	2011	Q4 2011	91	Malaysia	DiGi	2013	Q4 2013
32	South Africa	MTN	2011	Q4 2011	92	Malaysia	Maxis Communications	2013	Q4 2013
33	South Africa	Vodacom	2011	Q4 2011	93	Malaysia	Telekom Malaysia	2013	Q4 2013
34	Sweden	Teliasonera (2600)	2011	Q4 2011	94	Paraguay	Núcleo	2013	Q4 2013
35	UK	Orange	2011	Q4 2011	95	Paraguay	Telecel	2013	Q4 2013
36	USA	AT&T Mobility (7/21)	2011	Q4 2011	96	Peru	America Movil Peru	2013	Q4 2013
37	Egypt	Vodafone Egypt	2012	Q1 2012	97	Peru	Telefonica Móviles	2013	Q4 2013
38	Singapore	SingTel Mobile	2012	Q1 2012	98	Philippines	Smart Communications	2013	Q4 2013
39	Australia	Telstra	2012	Q2 2012	99	Puerto Rico	AT&T Mobility	2013	Q4 2013
40	China	China Telecom	2012	Q2 2012	100	Senegal	Sonatel-Mobiles	2013	Q4 2013
41	Egypt	Etisalat Misr	2012	Q2 2012	101	Sri Lanka	Dialog Telekom	2013	Q4 2013
42	New Zealand	Telecom New Zealand	2012	Q2 2012	102	Taiwan	Chunghwa Telecom	2013	Q4 2013
43	New Zealand	Vodafone New Zealand	2012	Q2 2012	103	Taiwan	FarEasTone	2013	Q4 2013
44	Singapore	MobileOne	2012	Q2 2012	104	Taiwan	Taiwan Mobile Company	2013	Q4 2013
45	Argentina	CTI Holdings	2012	Q4 2012	105	Taiwan	VIBO	2013	Q4 2013
46	Argentina	Telecom Personal	2012	Q4 2012	106	USA	Leap Wireless	2013	Q4 2013
47	Argentina	Telefónica Móviles Argentin	2012	Q4 2012	107	USA	US Cellular	2013	Q4 2013
48	Brazil	Claro Telecom	2012	Q4 2012	108	Venezuela	Corporación Digitel	2013	Q4 2013
49	Brazil	Telemar PCS (Oi)	2012	Q4 2012	109	Venezuela	Movilnet	2013	Q4 2013
50	Brazil	Telefonica Moviles	2012	Q4 2012	110	Venezuela	Telcel	2013	Q4 2013
51	Brazil	TIM Brasil	2012	Q4 2012	111	Pakistan	Telenor	2014	Q1 2014
52	Brazil	Vivo	2012	Q4 2012	112	Vietnam	Viettel	2014	Q2 2014
53	Brunei	B-mobile Communications	2012	Q4 2012	113	Pakistan	PMCL	2014	Q4 2014
54	Chile	Claro	2012	Q4 2012	114	Thailand	AIS	2014	Q4 2014
55	Chile	Entel PCS Telecomunicacio	2012	Q4 2012	115	Thailand	DTAC	2014	Q4 2014
56	Chile	Telefónica Móviles Chile	2012	Q4 2012	116	Vietnam	MobiFone	2014	Q4 2014
57	India	BSNL	2012	Q4 2012	117	Vietnam	VinaPhone	2014	Q4 2014
58	Mexico	America Movil/Radiomóvil	2012	Q4 2012	118	Canada - Quebec	Videotron	2015	Q4 2015
59	Mexico	Telefónica Móviles Mexico	2012	Q4 2012	119	Canada-Saskatchewar	SaskTel	N/A	N/A
60	Namibia	Powercom	2012	Q4 2012	120	Philippines	Globe Telecom	N/A	N/A

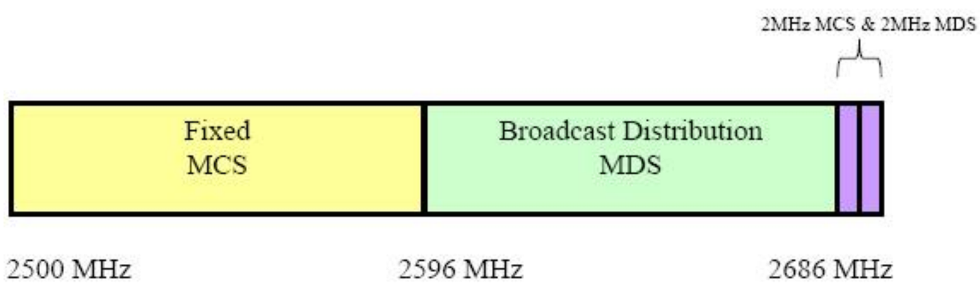
Sources: 3G Americas, October 2009,
http://www.3gamericas.org/documents/LTE%20Global%20Deployments%20Status%20October%202009%20.pdf .

Canada

Similar to the United States a few years earlier, Canada embarked on the process of transitioning the 2.6 GHz band from current licenses and BRS licensees (Broadband Radio Service), with a target date for the transition of March 2011. In addition to a technical requirement to avoid cross border interference, Canada's natural inclination is to follow the lead of its southern neighbor given population centers close to the United States' border. However, the October 2009 report referenced herein clearly shows strong support from incumbent operators for ITU Option 1. Prior history is discussed below.

In March 2009, Industry Canada launched a Consultation on the Transition to BRS in the band 2500-2690MHz and comments were received in mid-June 2009. The current band plan is shown in Figure 6 below:

Figure 6: Current 2.6 GHz Band Plan in Canada



The consultation covered many issues raised by the transition, from the fees for BRS licenses fees to their geographic structure. With respect to the BRS band plan, several respondents recommended that the future 2.6 GHz band plan in Canada should follow either the United States or the ITU approach, most likely ITU Option 1, and not seek to find some other alternative. Ericsson Canada firmly recommended adoption of ITU Option 1, while Intel is in favor of the United States band plan, making the claim among others:

"We note that in the United States band plan, incumbents have the flexibility to deploy Time Division Duplex (TDD) or Frequency Division Duplex (FDD) anywhere in the band. Utilization of this band plan could facilitate roaming within North America."

However, Intel's statement has little justification and describes an outcome that is less likely to be realized than if ITU Option 1 is adopted. Ease and availability of roaming would be hindered rather than enabled by the problems of coordination and inefficient use of spectrum. Such problems could arise if various incumbents choose to deploy very different configurations of paired and unpaired spectrum in different regions of the continent within either Canada and the United States, or both. Further, roaming arrangements, which depend on both business and technical procedures and agreements, are much more developed between operators that deploy 3GPP technologies (e.g. LTE) than for any other technology.

The dominance of spectrum holdings in the 2.6 GHz band by one operator in the United States arose as a result of a series of very specific initiatives and contingent decisions. These decisions were not taken in the context of a coherent and objective assessment of how best to exploit the band for the benefit of customers and the overall economy. Canada now has the opportunity to undertake such an assessment and reach its own decisions for the 2.6 GHz band.

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Scott Fox
Chairman & CEO
Global View Partners
San Diego, CA USA

www.GlobalViewPartners.com

