Spectrum for Mobile Broadband in the Americas: Policy Issues for Growth and Competition

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January 2011

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Executive Summary

A Looming Spectrum Shortage

Operators, public policy makers and regulators in the Americas and across the globe will confront a daunting challenge during the next decade. The development of mobile broadband services will be severely inhibited unless substantial amounts of additional spectrum – several hundreds of MHz - are allocated for the deployment of new mobile broadband networks.

While a looming spectrum shortage is a global challenge, it is particularly acute in Latin American countries. In this region current spectrum allocations and assignments for mobile services are significantly smaller than in Western Europe or the United States (U.S.). Furthermore, mobile broadband access will have to play a relatively larger role in the overall broadband picture in Latin America than in these other regions which have more highly developed fixed access networks. One consequence of a shortage of spectrum for the delivery of mobile broadband services will be corresponding shortfalls in meeting the ambitious targets for economic and social development that have been enunciated in various national broadband plans and international forums. These targets depend upon achieving widespread affordable access to high quality broadband services for residents, businesses and institutions.

Impact of Spectrum Assignments on Techno-Economic Efficiency and Cost Minimization

In order to ensure the techno-economic[1] efficiency of the mobile broadband networks and services that are deployed, spectrum has to be allocated and assigned wisely. Decisions with respect to the characteristics of spectrum assignments have a significant influence upon the costs and capabilities of the mobile broadband networks that operators can deploy. They therefore also affect the total costs of broadband services, which in addition to the radio access network (RAN) include the costs of mobile devices, other network elements - such as backhaul, core networks, operating and support systems - as well as service providers' sales and marketing, financing and other expenses. Awards of spectrum should take account of the following characteristics of wireless technology and lessons from competitive spectrum assignments in the Americas and elsewhere:

- The finite amount of spectrum that is available for mobile broadband services in the most attractive frequency range up to about 3 GHz will only support a small number (typically three to four) of efficient mobile operators in a market. This dynamic is an inevitable consequence of the combination of the dependence of network costs and capacity on the amount of bandwidth ("spectrum depth") to which a network has access, and the large investments needed to deploy national networks. A minimum market share and amount of spectrum are needed for a facilities-based mobile operator to build a long-term viable business[2].
- The costs of deploying nationwide broadband networks are minimized when operators have access to adequate amounts of bandwidth distributed across frequencies both below and above 1 GHz, and channel widths that are substantially greater than those employed in previous generations of mobile technology. For example, ideal channels for LTE are 2x15 or 2x20 MHz in paired (FDD) spectrum and 20 MHz in unpaired (TDD) mode, compared to the 5 MHz blocks or less offered in previous spectrum awards for 2G and 3G deployments.

[1] The greatest capacity and capability at the lowest costs, supporting prices that are affordable to the greatest number of potential users

[2] An overview of the issues, costs and benefits associated with different numbers of mobile operators in a country can be found at "Mobile licences – how many to grant?" http://www.sunriseconsultants.com/mobilelicences.html

Conditions of Eligibility of Access to New Spectrum

Regulators face critical choices in setting conditions of eligibility of access to new spectrum for incumbents and potential new entrants, and to existing mobile spectrum being refarmed for broadband systems. They have to balance a desire to ensure effective competition between facilities-based operators, which is used to justify policies to encourage the entry of additional competitors, against the techno-economic reality that only a limited number of efficient operators can be supported. In practice new spectrum allocations and assignments in the Americas over the past four years have been designed to achieve very diverse, country-specific policy objectives through the introduction of conditions for awarding spectrum that target, not always successfully, very different outcomes for potential new entrants. These conditions also affect the ability of existing operators to acquire additional spectrum they need to deploy new and expanded broadband networks. Experiences show that:

- The prices paid for spectrum and success in assigning spectrum to operators for the efficient development of mobile services are very sensitive to the rules introduced by regulators and others (e.g. Competition Authorities) to influence the outcomes of spectrum assignments, including especially the conditions of eligibility of access to spectrum.
- Spectrum prices have varied enormously (by orders of magnitude) even for similar spectrum offered in markets at comparable stages of development at almost the same time. High spectrum prices can be counterproductive by eroding operators' ability to finance subsequent network deployments, and/or by discouraging competent operators from even bidding, leaving valuable spectrum unused.

Sources and Timing of New Spectrum for Mobile Broadband

The principal sources of additional spectrum that can be utilized for mobile broadband networks in the Americas are at different stages of availability, and confront different obstacles or sources of delays to be overcome before they can be assigned to mobile operators. These frequencies include primarily:

- The AWS (1.7/2.1 GHz) band, that has already been assigned in the United States, Canada, Chile, and Mexico, is not encumbered by non-mobile uses, and for which equipment and devices are already widely available;
- The 2.5 GHz (2500-2690 MHz) band, the largest amount of new spectrum available for mobile networks below 3 GHz, whose use for mobile services requires refarming and remapping, for which there is growing momentum behind the adoption of the ITU Option 1 frequency arrangement (2x70 MHz paired and 50 MHz unpaired) to achieve the widest possible harmonization of this band within the region and globally;
- The "Digital Dividend" (700 MHz) spectrum, the schedule of whose availability for mobile networks is linked to refarming and remapping of frequencies in the context of the transition from analog to digital broadcasting, which so far has only been completed in the United States. In several countries in Latin America there are initiatives underway (e.g. Mexico) to accelerate the availability of these frequencies for mobile broadband earlier than was foreseen originally, which was towards or at the end of the second decade of this century. In some countries it is possible to take advantage of the circumstance that the band is relatively vacant.

- "Refarmed" (and/or unused) spectrum in the 850 and 1900 MHz bands which has already occurred on a significant scale in several countries in the Americas, typically for initial deployments of broadband systems in a country (EV-DO and WCDMA- based).

However, regulatory and legal procedures and political interventions mean that it can take many years to assign new spectrum even after the need in face of a looming spectrum shortage has been clearly identified. This challenge has been intensified as a result of the broader diversity of the influences and interests, broadcasting and media as well as telecommunications, involved in broadband compared to voice-dominated narrowband mobile networks. In most countries the unencumbered AWS band offers the earliest opportunities for making additional frequencies available for mobile services, as has already occurred in Chile and Mexico. The 2.5 GHz is expected to be the next available additional band, as agreements are reached on the complete or partial migration of existing uses of these frequencies for multipoint video distribution. The schedules for making "digital dividend" spectrum available for mobile networks will depend upon the schedule for the implementation of the transition to digital broadcasting. Recently pressure has been growing and initiatives pursued, e.g. in Colombia and Mexico, to make progress towards this transition more rapidly than was foreseen earlier, in recognition of the special value of this band for achieving nationwide mobile broadband coverage economically.

Growing Pressure for Multiband Spectrum Planning

Significant pressure has recently developed in Europe to plan future spectrum allocations and the conditions for future spectrum assignments on a multiband, rather than a band-by-band basis. This pressure is driven by recognition of significant differences in the technical and economic implications of available frequency bands and disparities between the current spectrum holdings (by quantity and distribution by band) of competing operators. This pressure will be particularly intense where these disparities are substantial and/or there are very large differences in the spectrum fees (by one or more orders of magnitude) that competing operators have to pay. It may be argued that these disparities can lead to undesirable market distortion effects and are inconsistent with competition policy.

Choice of Broadband Wireless Technology

The costs and capabilities of mobile broadband services to users are respectively minimized and maximized when they can take advantage of the economies of scale of equipment and devices developed for large markets and for standards that are widely adopted on a regional or even global basis. These factors favor harmonization of frequencies and band plans across countries wherever possible, and deployment of WCDMA-based (HSPA/HSPA+) and OFDMA-based LTE systems. The very long term (2025) road map for mobile broadband technology has become much clearer over the past four years. Eventually, over a 15 to 20 year period mobile broadband networks are likely to converge gradually towards one broadband wireless technology, LTE.

Matching Network Capacity to Mobile Broadband Demand

Forecasts of growth in mobile data traffic vary widely from an increase of 10 to 12 times over five years up to 50 times or even more[3]. But the combined effect of exploiting all potential current and potential frequencies and increased spectral efficiency alone will at most enable increases in network capacity of around ten to twelve times over the next decade. Hence the combination of new spectrum and new broadband wireless technologies alone will likely be insufficient to avoid

[3] See for example, Cisco Visual Networking Index, Forecast and Methodology, 2009-2014 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360_ns827_Networking_Solutions_White_Paper.html

congestion and hence declines in the overall quality of mobile broadband services in the areas of highest traffic volumes per km^2 as demand grows.

Conclusions and Recommendations

Conclusions arising from analyses of these issues and findings are both country- and band-specific as well as in some instances generally applicable:

- **Minimize Delays in Spectrum Assignments:** In order to minimize inevitable delays in making new spectrum available for mobile broadband services, all key stakeholders in the public sector (e.g. the Sector Regulator, Ministry/Policy Maker, Competition Authority) should actively coordinate their initiatives and policy recommendations to define as early as possible an agreed set of enduring principles and goals as well as conditions and procedures for new spectrum allocations and assignments. The aim should be to limit the scope and plausibility of potential objections to, and hence delays in spectrum allocations and assignments arising from divergent or conflicting policies and initiatives within the public sector itself. Awarding frequencies in the AWS band, which is not encumbered by other uses as are the 2.5 GHz and 700 MHz bands, should be targeted as a short term priority where this has either not been, or only partly carried out.
    - **Encourage Competition in Mobile Markets:** In order to ensure healthy and vigorous competition for the benefit of users in a mobile market that will only support a small number of efficient facilities-based operators, regulators and policy makers should evaluate pursuing or extending one or several selected measures customized to their national circumstances to prevent or inhibit anti-competitive behavior[4] and facilitate competition. These measures may include for example: (a) Obligations on operators involving: (i) Interconnection, provision of wholesale services, infrastructure sharing, and consumer protection, as well as (ii) Spectrum licenses such as coverage targets over time (“use it or lose it”), and (b) Application of antitrust legislation.
    - **Exploit Opportunities for Global Economies of Scale and Harmonization:** ITU-R M.1036-3 Option 1 frequency arrangement - 2x70 MHz FDD, with 120 MHz duplex separation and 50 MHz TDD at the center - should be adopted wherever possible for the 2.5 GHz band to enable users to benefit from the economies of scale of equipment and devices developed for this band plan, and the platform it will provide for international roaming with a single device.
    - **Accelerate Availability and Pursue Regional Harmonization of Digital Dividend Spectrum:** The allocation process of 700 MHz spectrum to mobile services should advance in parallel with the transition to digital television process, depending on the extent of its current occupancy in each country by analog TV channels, so as to maximize the timeliness and amount of new spectrum that is made available for mobile broadband networks. This spectrum is not on a path to achieve comparable harmonization at the global level as the 2.5 GHz band, but may nevertheless become harmonized across many Latin American countries if they adopt the channelization plan proposed for Asia[5] for reasons of economies of scale.

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[4] Assessment of the appropriateness of these and other measures lies beyond the scope of this paper. They are mentioned to indicate that spectrum policy and strategy are only one, albeit a key element of overall policy for the mobile sector. They should be coordinated with other initiatives to achieve goals of public policy to foster healthy development of, and robust competition in mobile markets.

[5] "Harmonized Frequency Arrangements for the Band 698-806 MHz", APT/AWF/REP-14, available at http://www.apt.int/AWF-RECREP

- **Coordinate Spectrum Planning on a Multiband Basis:** The amounts and distributions of spectrum by band have a significant impact on the costs and capabilities of mobile broadband networks. Hence operators and regulators in the Americas should ensure coordination of spectrum planning and optimization across multiple available bands, both existing and new, taking account of their individual circumstances and goals.
- **Combine Spectrum Initiatives with Complementary Measures to Mitigate Congestion:** Even a maximum combination of potentially available additional spectrum and increased spectral efficiency will be inadequate to handle traffic if the more aggressive demand forecasts are realized. Hence operators should plan to have to implement a variety of network- related and other measures to meet traffic demands and mitigate congestion problems[6], such as: (a) Off- loading of mobile traffic onto the fixed access network via Wi-Fi and femtocell connections; (b) Application of web and content optimization techniques to reduce traffic volumes; and (c) Management of subscriber usage patterns via new pricing models and acceptably non-discriminatory traffic management techniques.

[6] Assessment of use of these tools and techniques by operators also lies beyond the scope of this paper. They are mentioned to indicate that spectrum policy and strategy are only one, but a key element in operators' business planning, which must be coordinated with other initiatives. Traffic offloading is the only approach that can cope long term with two or more orders of magnitude increases in mobile data traffic (see Martyn Roetter, "The Spectrum is not Enough," August, 2010, http://www.bmi-t.co.za/?q=content/spectrum-not-enough)

Spectrum for Mobile Broadband in the Americas: Policy Issues for Growth and Competition

1. Introduction

This paper examines four important, related aspects of spectrum allocations and assignments for mobile communications, emphasizing mobile broadband networks and services. It focuses on findings and conclusions that are particularly relevant to countries in the Americas (ITU Region 2). Some of these findings are similar to those that apply in other regions of the world, while others are specific to, or at least heavily influenced by circumstances characteristic of the Americas or of individual countries in this region. The four critical aspects of spectrum policy covered are:

1. ***Total amount of spectrum allocated*[7].** Projections of future mobile broadband traffic (CITEL Recommendation CCPII/Rec 70 – XXII-02) indicate that by 2020 in the Americas total additional bandwidth of 721 or 1161 MHz will be needed in low demand and high demand areas respectively.
2. ***Structure of the spectrum allocated*[8].** Spectrum structure - e.g. channel widths and the use of paired and/or unpaired and contiguous and non-contiguous blocks of frequencies - has a significant impact on the spectral efficiency of broadband systems, and hence on the costs and capabilities of mobile services. For example, the costs of LTE networks are significantly lower if they are deployed in wide channel widths such as 2x15 or 2x20 MHz (paired) or 20 MHz (unpaired).
3. ***Distribution of the spectrum assigned to operators across multiple frequency bands.*** The frequency dependence of signal propagation and the amount of bandwidth to which an operator has access significantly influence network economics and capability. Operators with no access to frequencies below 1 GHz and/or with relatively small amounts of bandwidth have a significant economic and operational handicap compared to competitors who do, since the former have to deploy networks with a significantly larger number of base stations to achieve the same capacity and coverage.
4. ***Conditions of eligibility and prices paid for spectrum assignments.*** Spectrum costs can be significant for operators and hence consumers. Their levels are very sensitive to the conditions of eligibility of access for existing operators and potential new entrants to spectrum, and may hinder the goal of welfare maximization. Huge differences (factors of 10 or even 100 or more) in spectrum prices can result from very specific market circumstances and auction rules. These huge differences cannot be reasonably attributed to other causes, since in some cases they involve the same frequencies in countries with very similar economic environments awarded at almost the same time.

Spectrum assignments have to be made in the face of conflicting pressures to ensure that:

[7] Thomas W. Hazlett and Roberto E. Muñoz, "Spectrum Allocation in Latin America: An economic analysis", Information Economics and Policy, (21), Issue 4, November 2009, http://econpapers.repec.org/article/eeeiepoli/v_3a21_3ay_3a2009_3ai_3a4_3ap_3a261-278.htm

[8] Thomas W. Hazlett and Roberto E. Muñoz, "What Really Matters in Spectrum Allocation Design," April 2010, http://businessinnovation.berkeley.edu/Mobile_Impact/Hazlett-Munoz_Spectrum_Matters.pdf

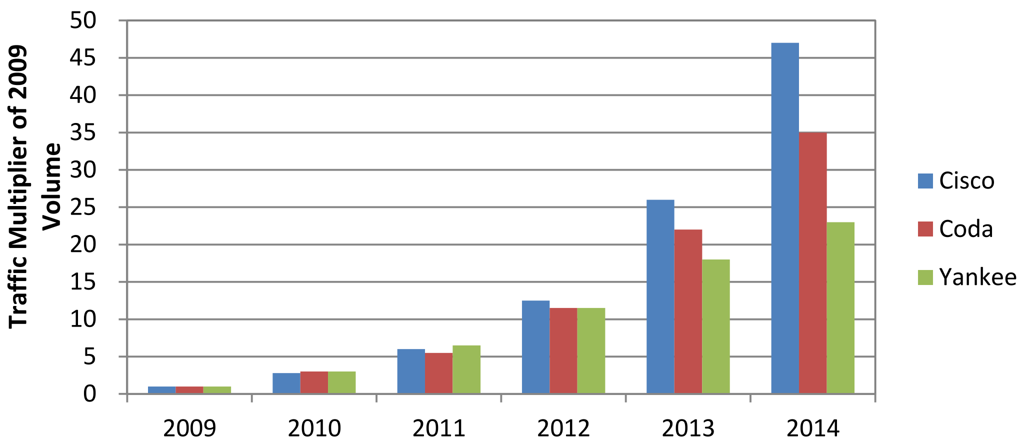
- Each facilities-based operator has access to sufficient bandwidth from a limited inventory of this scarce resource under conditions that give it a chance of competing efficiently and effectively, while
- The competitive and innovative dynamics of mobile broadband markets are maintained or enhanced despite the limited number of operators for whom this condition can be satisfied.

The situations, experiences and plans of a range of countries in the Americas regarding allocations and assignments of spectrum for mobile broadband networks are analyzed, with selected examples from other regions. The intent of these analyses is to provide insights into which policies and initiatives are most promising for the purpose of stimulating a healthy development of mobile broadband services. On the other side of the coin, the results of the analyses indicate where caution should be exercised in pursuing courses of action which may have unintended negative consequences. Examples are presented of specific policy questions that have emerged or are likely to emerge in the process of making new spectrum available for mobile broadband networks.

2. Spectrum Requirements and Consequences of a Spectrum Shortage

Current trends in mobile broadband data usage point to the inevitable exhaustion of available spectrum in the Americas in the relatively near term, before the end of the second decade of this century. Forecasting is notoriously uncertain and projections of traffic volumes vary widely (Figure 1). Forecasts that are even more aggressive than Cisco's shown in this Figure have also been made for future global mobile data traffic, up to 100 times over five years[9], while at the other extreme Analysys Mason[10] has presented more conservative estimates of its own, with growth of just under 12 times in mobile data traffic in Latin America from 2010 to 2015 (i.e. 16 petabytes to 191 petabytes per month). The same Analysys Mason report predicts that by 2015 Latin America, with at that time a total population of 640 million, will include 300 million smartphones, 500 million voice-centric phones, 38 million computer-based mobile broadband devices and 4 million wireless access devices of other types.

Figure 1: Forecasts of Mobile Broadband Traffic for the United States



Source: Cisco Systems, Coda Research, Yankee Group

[9] Analysys Mason, "The message from MWC 2010", http://www.analysysmason.com/About-Us/News/Insight/The-message-from-MWC-2010

[10] Analysys Mason, http://www.analysysmason.com/About-Us/News/Press-coverage/Wireless-network-traffic-estimated-to-rise-at-86-CAGR-from-2010-15/?journey=582,55

Thus there are many diverse indications that *at least an order of magnitude increase in mobile data traffic* is likely over the next five years, building on the volume generated by today's heaviest users of mobile broadband services and the growing number of mobile subscribers who are being attracted to smartphones and other broadband devices and video- and image-intensive applications and services. Even in the United States, which already has much more spectrum assigned to mobile services than Latin American countries as of mid-2010 (Table 1)[11] the FCC has stated that it needs and intends to make an additional 500 MHz of spectrum available for broadband in the next 10 years, with 300 MHz to be added within 5 years[12]. The maximum amount of spectrum that will be needed is determined by peak traffic volumes (and hence capacity requirements in terms of $Mbps/km^2$) in the most economically and demographically important (dense urban) areas, such as New York City, and major metropolitan areas in Latin America such as Mexico City and São Paulo, where the number of and separation between base stations is capacity- and not coverage-limited[13]. Of course if new spectrum is not assigned then mobile data traffic will not reach even the most conservative forecast levels, because demand will be suppressed. The consequence will be substantial shortfalls in both direct and indirect value creation, and in reaching the targets established in national broadband plans[14].

Table 1: Spectrum Assigned to Mobile Operators (Q3 2010)

Country	U.S.	Argentina	Brazil	Chile	Colombia	Mexico	Peru	Venezuela
Total MHz Assigned	547	170	350	260	190	210	146	124

Source: GSMA

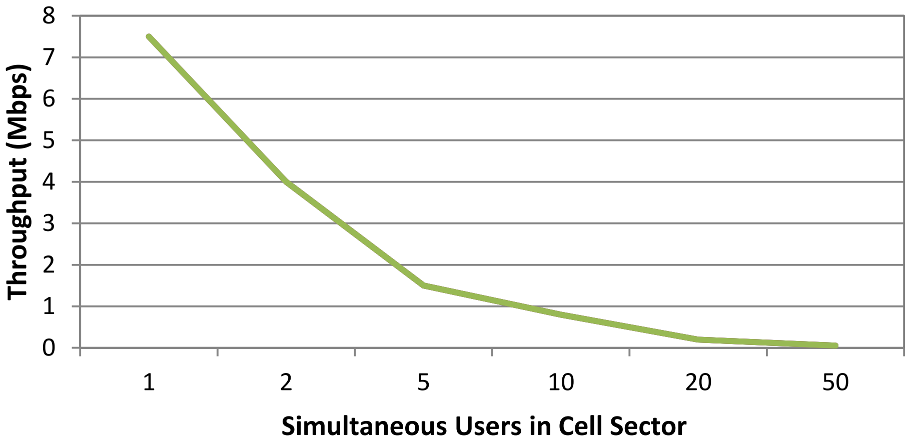
[11] Source: GSMA presentations of Sebastian Cabello, MFR Consulting. Note: Argentina used to have 170 MHz available until Telefonica Movistar completed the return of spectrum holdings in excess of the 50 MHz cap that resulted from the acquisition of Movicom Bell South.

[12] FCC: "Connecting America - The National Broadband Plan", March, 2010, http://download.broadband.gov/plan/national-broadband-plan.pdf

[13] As the FCC pointed out in its paper "Mobile Broadband: The benefits of Additional Spectrum" (http://www.fcc.gov/Daily_Releases/Daily_Business/2010/db1021/DOC-302324A1.pdf) in rural, coverage-limited areas a significantly smaller amount of spectrum than 547 MHz (the 170 MHz in the 850 and 1900 MHz bands which were the first frequencies allocated to commercial mobile services and the ones in heaviest overall use) is adequate to handle current traffic levels and those expected in these areas in the US for at least several more years.

[14] LECG, "3G mobile networks in emerging markets: The importance of timely investment and adoption," report prepared for the GSM Association, January, 2009, http://www.gsmworld.com/documents/Report_GSMA_LECG_Feb09.pdf; Roberto Pinto Martins, Secretary of Telecommunications, Ministry of Communications (Brazil), " TIC y Telecomunicaciones: para el uso masivo de los servicios", presented at ACIEM Telecom 2010, Bogota, Colombia, July 29, 2010.

Figure 2: Throughput (Mbps) per User as a Function of the Number of Active Users in a Cell Sector



Source: Rysavy Research[15]

A major consequence of insufficient spectrum is that as the number of simultaneous users in a cell increases the average throughput they experience will decrease to unacceptably low levels, i.e. well below broadband speeds. Figure 2 shows an example of throughput falling to below 1 Mbps when the number of active users increases from 5 to 10 in a cell with HSPA deployed in 20 MHz of spectrum. Currently in the United States each cell site serves on average about 1,000 mobile customers, and up to three times this amount in the densest areas. Hence the number of customers per sector in a three sector cell site deployment can range from 300 to 1,000. Even a small percentage of this number, between 1 to 3%, can thus effectively consume all available capacity.

Additional spectrum can be found in varying amounts and with different timing depending on the country, including both currently unassigned frequencies in existing bands, such as 1900 MHz or 850 MHz, and spectrum in three new key bands. Some countries in the Americas have already begun to assign spectrum in these new bands to operators. In descending order of the timing of their availability for mobile networks these three key bands are:

- AWS band (1.7/2.1 GHz) in which 90 MHz of paired spectrum is available in a configuration harmonized throughout the Americas, and for which significant networks and devices are already in service, including HSPA and most recently the first LTE deployment in the U.S.;
- 2.5 GHz band (usually 2500-2690 MHz) in which up to 190 MHz of spectrum can be found once existing holders of this spectrum are migrated to other bands and/or allowed to convert their licenses at least for part of their spectrum to mobile services. There is now significant momentum towards widespread harmonization of the configuration of this band in the Americas (and elsewhere) with 140 MHz of paired and 50 MHz of unpaired spectrum. LTE networks in paired spectrum are in commercial service in Scandinavia, although LTE handsets have yet to be commercialized, only dongles, as are WiMAX networks in unpaired spectrum. The first LTE network in unpaired spectrum is anticipated in Poland for 2011.
- "Digital dividend" spectrum, or 700 MHz in the Americas, in which approximately just over 100 MHz of spectrum can be made available when current holders of these frequencies (TV broadcasters) vacate them in the transition to digital over-the -air broadcasting. The current level of occupancy by TV broadcasters and the schedules when this band will be freed for

[15] Rysavy Research, , "Spectrum Shortfall Consequences", April 21, 2010, http://files.ctia.org/pdf/filings/100421_Rysavy_Spectrum_Shortfall_Filing.pdf

mobile use vary widely from one country to another. The future configuration of this band in much of Latin America may be aligned with what is adopted in Asia rather than in the U.S., the first country to complete the digital transition. The Asian plan should permit the award of licenses with wide channel widths, e.g. 2x15 MHz, allowing more efficient and economic deployments of LTE than in the narrower channels inherent in the U.S. band plan (see Section 3.1 below).

In some countries other frequency bands may also come into play to varying degrees depending on their current uses and whether their occupants can be migrated. An example is the 2.3 GHz band for which there are significant markets in Asia, and a handful of networks deployed in the U.S., South America, and the Caribbean.

Table 2 presents some approximate estimates of the concentrations of mobile broadband users in urban areas that may generate the highest mobile broadband traffic densities. If or when a sizable minority, let alone a majority, of operators' mobile customers become serious users of mobile broadband services, the capacity of their networks to handle peak broadband traffic in the densest areas becomes very sensitive to the amount of spectrum they hold and the number of the cell sites they deploy. This number is inversely proportional to cell sizes and directly dependent on the level of capital investments operators can afford. Furthermore, in these capacity-limited conditions congestion will arise. Not only will throughput rates decrease, but packet latency (delay) will increase, packets may be dropped, and transport layer protocols such as TCP and indeed applications may time out. In a worst case, a vicious spiral may develop with excessive data retransmission and poor application performance, so that users may find the service to be increasingly unattractive and even unusable for their purposes.

Table 2: Scenarios of High Density Mobile Broadband Subscribers

City	Range of Number of Subscribers/Km^2 per Operator[1]	Range of Number of Broadband Subscribers per picocell[2] – assumes 10% penetration of all mobile	Range of Number of Broadband Subscribers per picocell[2] – assumes 40% penetration of all mobile	Maximum Number of Broadband Subscribers per MHz per picocell with 40% penetration — Amount of broadband spectrum per operator, MHz		
				10 MHz	30 MHz	100 MHz
London (U.K.)	1250-1750	13-18	50-70	7	2.33	0.7
Hong Kong	1250-3200	13-32	50-130	13	4.33	1.3
Mumbai (India)	3000-7500	30-75	120-300	30	10	3
Mexico City	210-3700	2-37	8-150	15	5	1.5

Notes: 1. Approximate estimates based on subscriber numbers from regulators and operators at end-2009, converted to estimates for largest and smallest market shares in areas within the respective cities; since total mobile penetration is already or close to, at, or above 100% in all these cities, the absolute numbers of subscriptions may not increase substantially over the next decade. 2. Assumes a picocell covering 1/10th to 1/8th km^2

Source: Regulators and Operators web sites, MFRConsulting

The figures shown in Table 2 demonstrate the value of additional spectrum by showing how many subscribers have to be supported per MHz of bandwidth. This number can be improved, i.e. reduced, by shrinking cell sizes so there are fewer subscribers per cell. If for example only 10 MHz is available for a broadband network then cells covering about 1/30th km^2 are required to achieve the same number of broadband subscribers per MHz as in the scenario with 30 MHz of assigned spectrum. Cells of this size would not only entail many more cell sites and hence much higher investments than the picocell example shown, but also cell site separations of around 100 meters. But at separations this small, it becomes very hard to plan for contiguous network coverage[16]. As cells become smaller individual buildings and streets have a major effect on the shape of the cell boundary. Furthermore the precise location of base stations becomes very important, and there is a higher risk or probability that only one location will be effective, which however may not be accessible. For reference it may be noted that today cell site separations in major urban areas in Germany, where mobile penetration is well over 100%, lie between 300-350 meters.

3. Structure of Spectrum Assignments for Efficiency

Key characteristics of spectrum used for broadband services and their subsequent assignments to individual operators include the:

- **Band plan**, namely whether and how spectrum is offered in pre-determined paired and/or unpaired blocks, as well as the widths and locations of these blocks (Figure 3 illustrates alternatives considered for the 2.5 GHz band).
- The **amounts and structure** (paired or unpaired) of the contiguous spectrum that are included in individual licenses
- The **geographic structures** of individual spectrum licenses (national, within zones or regions of various sizes, or with mixtures of national and regional licenses).

Decisions with respect to these characteristics have a significant influence upon the costs and capabilities of the mobile broadband networks that operators can deploy. They therefore also affect the total costs of broadband services, which in addition to the radio access network (RAN) include the costs of mobile devices, other network elements - such as backhaul, core networks, operating and support systems - as well as service providers' sales and marketing, financing and other expenses.

The practices and choices made with respect to band and license structures in the Americas and elsewhere vary widely, for example:

- For the most part, Canada and the United States do not award national licenses, opting for licenses that cover areas of diverse sizes and geographic and demographic characteristics. Operators tend to be prepared to pay more (sometimes much more) on a per MHz/POP basis for licenses in areas of high revenue/km^2 potential, although they are also prepared to bid for licenses elsewhere so they can deliver service in less attractive areas and hence guarantee very wide coverage to their most lucrative peripatetic customers.

- In its mid-2010 AWS spectrum auction Mexico offered a mix of national and regional (9 regions) licenses, with the national licenses being for 2x15 MHz, while regional licenses were based on 2x 5 MHz blocks. In its concurrent auction of unused PCS (1900 MHz) frequencies Mexico only offered regional licenses (no 1900 MHz frequencies were available in one region) in blocks of 2x5 MHz, whereas Canada's AWS auction included licenses with 2x5 MHz and 2x10 MHz blocks.

- Colombia and Chile respectively awarded national licenses of 2x25 MHz at 2.5 GHz (one only) and 2x15 MHz in the AWS band (three in all). In both cases incumbent operators were excluded from bidding for these licenses by spectrum caps.

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[16] Plum Consulting, "An Assessment of Spectrum Management Policy in India," a final report to the GSMA, December, 2008, http://www.plumconsulting.co.uk/pdfs/GSMA%20spectrum%20management%20policy%20in%20India.pdf

Other conditions of licenses also vary widely along dimensions such as length and coverage obligations. The United States awards licenses for a term of 10 years. So does Canada, albeit with strong presumptions of their renewal, however with annual fees that can be revised. In contrast Mexico awards 20 year licenses, including annual spectrum fees (in addition to the prices paid at auctions) on a per MHz basis (varying by band and region). The net present values of these annual fees can greatly exceed or at least be comparable to winning auction bids, depending on the sizes of the latter. Significant coverage obligations for license winners are common in recent spectrum auctions in Latin America, e.g. the 2.5 GHz winner in Colombia has to cover all municipalities with populations of over 500,000 within 14 months and 80% of those with populations of from 250,000 to 500,000 within 20 months. However in the United States and Canada coverage obligations have been formulated much less ambitiously. For example as a condition of combining their 2.5 GHz holdings Sprint/Nextel/Clearwire only had to offer services using this spectrum to at least 15 million Americans by end-2010, and an additional 15 million (i.e. 30 million in all, fewer than 10% of the U.S. population) by end-2012. In Canada's AWS auction coverage amounts were specified as indicative targets for entrants with the incentive of extending their rights to sharing and roaming with incumbents if they are met, but not as obligations.

The huge impact of the conditions under which spectrum is awarded on the prices paid by operators for bandwidth (and hence the costs they will seek to recover from their customers) can be seen in Table 3. There are *orders of magnitude* differences in these prices, even between similar spectrum awarded in countries at comparable levels of economic development within a few months or even weeks of each other.

Table 3: Examples of Prices Recently Paid for Spectrum Awards

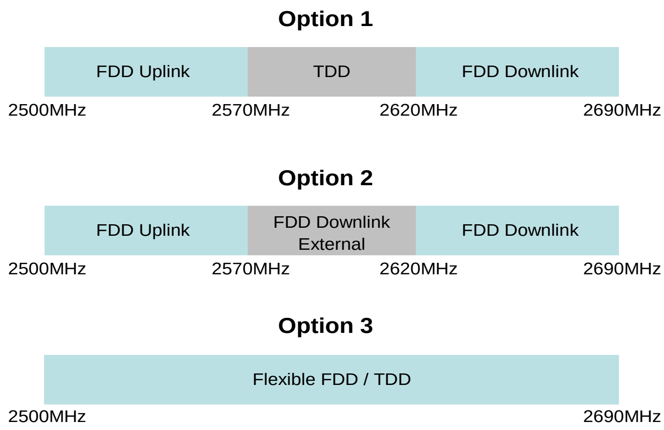
Country	Frequency band	Date of award	Price per MHz/pop, $
Brazil	2.1 GHz	12/2007	0.159
Chile	1.7/2.1 GHz	09/2009	0.0113
Colombia	2.5 GHz	06/2010	0.0188
Peru	2.5 GHz	08/2009	0.0058 (unpaired)
Mexico	1.7/2.1 GHz	07/2010	0.176
U.S.	1.7/2.1 GHz	09/2008	0.54
Netherlands	2.5 GHz	04/2010	0.00177
Denmark	2.5 GHz	05/2010	0.153**
Finland	2.5 GHz	11/2009	0.00465
Germany	2.5 GHz	05/2010	0.0292
Sweden	2.5 GHz	05/2008	0.247
India	2.1 GHz	05/2010	0.300

*Source: Regulators' websites and MFRConsulting calculations, based on exchange rates at times of awards; all prices are national averages for paired spectrum except where noted. Notes: ** mix of paired and unpaired*

The choice of band plan by a country has implications for the economies of scale in equipment and devices and the roaming possibilities that mobile users based in the country will enjoy, which are maximized if the same plan is followed in many countries. Latin America has typically benefited from the economies of scale, i.e. low costs, of network equipment and mobile devices developed and deployed earlier for the same frequencies in large and wealthy markets elsewhere, primarily the U.S. and Europe. This benefit will also be available in the era of mobile broadband, for example with respect to AWS frequencies already in wide use in the U.S., and 2.5 GHz frequencies in Europe (first in Scandinavia). Also Asian markets, as well as the U.S., may prove to be valuable proving grounds for wireless systems and devices for eventual deployment in the 700 MHz or digital dividend spectrum in Latin America.

In order to gain maximum benefit from these economies of scale and scope, countries in the Americas should adopt standardized band plans wherever and whenever possible, for instance ITU Option 1 (Figure 3) for the 2.5 GHz band (ITU-R recommendation M.1036-3)[17].

Figure 3: ITU Recommendation for the 2.5 GHz Band (ITU-R M.1036-3)



The AWS band plan and the availability of equipment and devices are already clearly established for the Americas, while eventual band plans for the digital dividend are likely to be influenced by decisions to be taken in Asia. Asia is not expected to adopt the 700 MHz band plan defined in the United States, which reflects conditions that are very specific to that country. Latin American countries may benefit from adopting a 700 MHz band plan that is the result of efforts at regional harmonization of this band in Asia, to exploit the large economies of scale achievable in that vast region's most populous markets.

Maximum harmonization of the 2.5 GHz band plan throughout the Americas will not only enable mobile users to benefit from economies of scale in the equipment and devices that are deployed, but will also provide a network platform for convenient roaming with a single device throughput the region and even with other world regions. Although the United States currently has a 2.5 GHz band plan that is not compatible with ITU Option 1, other countries in the Americas are clearly leaning towards it (Canada[18]) or have made the decision to adopt it (Chile[19], Brazil[20]). Colombia held an auction in 2010 to assign up to 60 MHz of 2.5 GHz spectrum in which bidders were free to choose whether they wanted paired or unpaired spectrum. However, the outcome of the auction, which included two bidders, was the award of one 2x25 MHz license to a new entrant (UNE-EPM), thereby making it possible in accordance with the announced intention of the Ministry of Communications to structure the band to conform to ITU Option 1 when all frequencies within the 2.5 GHz band are assigned.

[17] See the following report for a thorough discussion of the options available and reasons why Option 1 (2x70MHz FDD on the sides with 120MHz duplex separation and 50 MHz TDD at the center) is preferable over the others for the 2.5GHz band: Global View Partners , **" The 2.6 GHz Spectrum Band: Unique Opportunity to Realize Global Mobile Broadband",** report prepared for the GSMA, December, 2009, http://gsmworld.com/documents/GVP_-_GSMA_2_6_GHz_Report_-_Final_9Dec09.pdf

[18] Industry Canada, "Decisions on the Transition to Broadband Radio Service (BRS) in the Band 2500-2690 MHz) and Consultation on Changes Related to the Band Plan", DGSO-001-10, June, 2010, http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09882.html

[19] Chile: Subtel Resolutions 479/05 and 733/07

[20]For Brazil's decision in August, 2010 see: http://www.gsmworld.com/newsroom/press-releases/2010/5355.htm

In the U.S., the imperatives of business and technology are encouraging the primary holder of spectrum with some 120-150 MHz in many major market areas in this band, Clearwire, to modify its original decision to deploy only TDD WiMAX systems. Clearwire has announced that it will launch trials of both FDD and TDD LTE systems in Arizona before the end of 2010. In Clearwire's network LTE may coexist with WiMAX in this band and also provide a long term migration path from WiMAX if the road map of this latter technology is abandoned. Hence while it may not have originally conformed to ITU Option 1 the operational shape of the 2.5 GHz band in the U.S. may well move closer to this structure over the next three to five years. Clearwire is one of the operators that asked the 3GPP (3^{rd} Generation Partnership Project) standards body to start work on specifications (a request accepted by 3GPP in March, 2010) to define TDD LTE for deployment in the United States in the 2.5 GHz band.

3.1 Impact of Channel Widths and Developments in Broadband Wireless Technology

Channel widths become more and more significant as users demand services that must be supported by higher data rates. LTE is fully expected to become eventually the most widespread in mobile broadband networks worldwide, even though it has only recently begun to enter commercial service. LTE equipment and devices are rapidly becoming available for all significant frequencies for mobile broadband in the Americas, in both FDD and TDD modes that are being designed for maximum commonality and interoperability between them, and for deployment in a wide range of channel widths. FDD LTE networks have already entered commercial service in the 2.5 GHz band in Sweden and Norway. In addition FDD LTE systems will enter commercial service before the end of 2010 with Verizon Wireless in the 700 MHz band in the United States. Initially LTE service at 700 MHz and 2.5 GHz is being offered via data cards and dongles, with LTE smartphones or handsets anticipated in 2011.

Also noteworthy is that FDD LTE equipment and even the first LTE smartphone (Samsung SCH-R900) for the AWS band are coming to market in the United States, and as of November, 2010 had already entered service in the Tier 2 operator Metro PCS's spectrum in this band. Development of TDD LTE has also been proceeding very rapidly, and if requested it will be available for commercial deployment in 2.5 GHz unpaired spectrum awarded in future assignments, as an alternative to WiMAX. The development of TDD LTE, which has featured trials and demonstrations at 2.5 GHz among other bands is being backed by a powerful group of the most prominent wireless vendors (e.g. Ericsson, Alcatel-Lucent, Nokia Siemens Networks, Huawei, ZTE), responding to the lure of the large Chinese market which is committed to TDD as well as FDD systems. TDD LTE's first large scale commercial deployment seems likely to occur in the 2.3 GHz spectrum in India awarded in 2010.

Hence operators, regulators and policy makers in the Americas should be able to count on the availability of LTE equipment and devices for deployment and use in all significant new bands (AWS, 2.5 GHz and 700 MHz) for mobile broadband services in this region (ITU Region 2) in the near future. Nevertheless, although ultimately LTE will become ubiquitous it is anticipated that it will co-exist with earlier technologies for many years. Indeed for this very reason LTE is designed to be as compatible as possible with HSPA/HSPA+ (WCDMA-based) networks which have been deployed at a rapid rate over the past few years, and will continue to expand further on a large scale. HSPA/HSPA+ is a well-established and still evolving mobile broadband technology throughout the Americas for 850 and 1900 MHz and AWS frequencies, and will remain the most widely deployed broadband wireless system until well after 2015. Dual-mode LTE/EV-DO devices are also becoming available to support and protect the assets of CDMA2000 operators (e.g. Verizon Wireless in the U.S.) in the Americas who adopt LTE as their next generation wireless technology. LTE itself has its own long term road map including next generations of the technology that will meet IMT-Advanced (or true 4G) specifications[21], taking its capacity beyond what can be achieved with HSPA/HSPA+.

Since LTE is going to play a ubiquitous role in future mobile broadband networks, a factor to consider in allocating spectrum for mobile broadband is that wider channel blocks (e.g., 2x15 or 2x20 MHz) are required to enable OFDMA-based systems to achieve maximum techno-economic efficiency i.e. deliver most capacity at lowest cost. This factor is playing a consideration in the ways in which some blocks for spectrum licenses have already been constructed or are being evaluated, such as the 2x15 MHz blocks in the AWS auctions in Chile and for national AWS licenses in Mexico, as well as the minimum bid size requirement of 30 MHz in the 2.5 GHz auction in Colombia. Furthermore, of the licenses awarded so far in Europe at 2.5 GHz a significant proportion are for 2x20 MHz paired or 25 or 50 MHz unpaired (this last being the entire center band according to ITU Option 1).

These licenses reflect the reality that in the emerging wireless broadband era, there will be a strong relationship between the costs of network deployments and the widths of the channels in which they are deployed, as illustrated in Table 4.

Table 4: Costs of LTE Service as a Function of Channel Width

Minimum Monthly Cost of FDD LTE Service in Selected Major Metro Areas in South America				
Spectrum Allocation	2x20 MHz	2x15 MHz	2x10 MHz	2x5 MHz
Relative Cost	1	1.3	2	4

Source: Wayne A. Leighton, "Measuring the effects of Spectrum Aggregation Limits: Three Case Studies from Latin America", October, 2009, http://ssrn.com/abstract=1494371

The costs reported in this Table are based on a model which estimates the costs of building a new broadband mobile network (LTE) with increasingly large amounts of spectrum. The model does not include other costs of an operator that are not directly related to building and maintaining the network, such as marketing and some employee expenses. The investments needed to deploy a broadband wireless network to serve estimated numbers of wireless data users in these markets are calculated for different amounts of spectrum, and then the monthly ARPU necessary for the operator to break even after 8 years is determined for each spectrum assignment. As larger amounts of spectrum are assigned, that then allow an operator to serve more customers from a given cell site, network equipment investments and hence cost-based prices to customers are correspondingly lower.

5. Distribution of Spectrum by Operator

4.1 Impact of Spectrum on Mobile Broadband Capacity, Costs, and Competition

Two aspects of the distribution of total assigned spectrum to individual operators are particularly relevant to the:

(a) Capacity and costs of the broadband services that their customers can enjoy,

[21] Report ITU-R M.2134, http//www.itu.int/publ/R-REP-M.2134-2008/en

(b) Competitiveness of each operator, and
(c) Overall competitive intensity of the mobile market.

These two key aspects of spectrum holdings or bandwidth are the: (i) Total amount to which an operator has access, and (ii) Distribution by frequency band. Both aspects have a significant influence on the capacity and costs of an operator's networks and thus of the services which it can deliver, and therefore on the overall costs and capabilities of mobile broadband services on offer in a country.

As discussed below, more bandwidth is better and a diverse spectrum portfolio is economically and operationally advantageous compared to one which includes only high frequencies (near or above 2 GHz) or only low frequencies (below 1 GHz) since almost all networks, except in city states, have to cover very demographically and geographically diverse regions. As a consequence if spectrum licensed to mobile services is fragmented among a large number of operators then none of them may have enough bandwidth to operate efficiently. Also if there are significant disparities in which one or two operators hold much more bandwidth than others, or have a spectrum portfolio that is diverse in terms of low (below 1 GHz) and high frequencies whereas their competitors are confined to high frequencies, then the latter will be at an economic and operational disadvantage in competing with the former.

4.2 Benefits of Larger Spectrum Blocks

Increases in the spectrum to which an operator has access for its network deployments can increase its traffic carrying capability per MHz (as well as in total), and hence reduce its costs per bit transmitted in several ways, for example:

- The trunking efficiency of each cell site increases, enabling higher utilization for a given grade of service
- Inter-cell distances to provide a given desired capacity (expressed in terms of Mbps/km^2) can be greater, which mitigates reductions in cell capacity that may arise due to the need to avoid interference between cells using the same frequency (the importance of this advantage varies with frequency i.e. propagation characteristics)
- Broadband wireless systems can be deployed in wide channel bandwidths (as compared to 5 MHz blocks) provided licenses are structured and offered accordingly to maximize their spectral efficiency (see Table 4 above).

Operators facing a need to increase the capacity of their networks have two main alternatives in addition to deploying new technologies. They can add still unused additional frequencies from their inventory to their network deployments, and/or further divide their existing cell sites (or add underlays, e.g. picocells within micro- and macro-cell structures). The costs of adding more frequencies to existing cell sites, if available, are lower than the costs of adding new cell sites. The former may only involve the installation of additional electronics into existing base stations, while the latter requires finding and paying for new sites and for associated civil as well as radio engineering, and perhaps for entirely new backhaul links as well. More sites also incur more ongoing monitoring and maintenance expenses.

In the broadband context the greatest sources of new bandwidth for network deployments in the Americas over the next decade will be found in the AWS (a total of 90 MHz) and 2.5 GHz bands (a total of 190 MHz)[22]. "Digital dividend" spectrum will be much less abundant than 2.5 GHz frequencies, although in principle its bandwidth may be comparable to that available in the AWS band. However, the challenges of clearing and assigning this spectrum for mobile services are especially complex, given the direct involvement of powerful incumbent broadcasting as well as telecommunications interests and the need to accommodate large installed bases of analog TV sets. Significant costs are associated with the digital transition both for broadcasters and to provide digital-to-analog converters for these TV sets, which may amount to between $35-80 per converter[23]. These costs either have to be borne in full by broadcasters or consumers themselves, or they may be mitigated with the help of full or partial subsidies from public funds. Broadcasters of course benefit after the digital transition is completed by being able to accommodate more channels (or a higher quality audio/video signal) within a given bandwidth. The economic and competitive implications of the digital transition are significant with the potential of affecting many diverse and influential organizations, and thus the transition is politically charged and usually requires a deliberative and lengthy process to address concerns regarding this transition.

Therefore in Latin America as elsewhere it may take a number of years before all the issues involved in refarming and remapping 700 MHz spectrum are resolved, so that the spectrum can be assigned and used for mobile broadband. The difficulty of allocating 700 MHz spectrum to mobile services varies by country depending on how many channels in the 698-806 MHz band are actually assigned to over-the-air analog TV broadcasts. Mexico is an example of a relatively favorable environment in this regard, in which assigning significant amounts of 700 MHz spectrum to mobile operators can be relatively independent of the timetable for the full transition to DTT. In many of its nine Regions most of this spectrum is not occupied by TV broadcasters, which is also the situation in Chile and Argentina. It is encouraging from the perspective of the mobile sector that Mexico has now decided to initiate the transition to DTT in 2011 and complete it by the end of 2015, whereas previously there was no target date for ASO (analog switch off), and the DTT transition had a completion date of 2021[24]. Obstacles or objections to more rapid DTT transitions can be overcome or mitigated with the help of subsidies to TV users and to broadcasters for the costs they incur respectively in buying digital-capable TV sets or digital-to-analog decoders and acquiring new transmitting equipment. These subsidies may be funded by a Government appropriation (such as for decoder vouchers for households in the United States) and/or by initiatives such as transferring a portion of the revenues generated by auctions of 700 MHz frequencies to broadcasters, as Mexico plans to do.

Table 5: Spectrum Holdings of U.S. Mobile Operators

Operator Average (Top 100 markets)	850 MHz	1900 MHz	AWS	Digital Dividend (700 MHz)	2.5 GHz	TOTAL MHz
Verizon Wireless	25	21	13	32	0	91
AT&T	25	34	12	20	0	91
Sprint/Nextel	14 (SMR)*	36	0	0	0	50
T-Mobile	0	25	26	0	0	51
Cable Operators	0	0	19	0**	0	19
Clearwire	0	0	0	0	150	150

*Notes: *Specialized Mobile Radio; **A few cable operators (notably Cox, with licenses covering 7% of the U.S. population) did win some blocks of spectrum in the 700 MHz auction*
Source: Yankee Group, MFRConsulting

[22] Global View Partners : ibid., December, 2009, and **"Mobile broadband in the Americas: Momentum Building in the AWS Band",** May, 2009, http://www.gsmworld.com/documents/Momentum_Building_in_the_AWS_Band_Report%281%29.pdf, reports prepared for the GSMA

[23] Martyn Roetter, "The Transition to Digital Terrestrial TV Broadcasting," July 2010, http://www.bmi-t.co.za/?q=content/transition-digital-terrestrial-tv-broadcasting

[24] President Calderon decree of 2 September 2010, see: http://www.telesemana.com/analisis/detalle.php?id=3391

Nevertheless, any relatively spectrum-poor operator seeking substantial additional spectrum, or the pursuit of a policy goal of facilitating a new competitor's access to significant amounts of bandwidth, will generally be primarily dependent in the first place on securing spectrum assignments in one or the other, or both, of the AWS and 2.5 GHz bands. These two higher frequency bands have already become and in many other cases will become available earlier than 700 MHz spectrum, especially the AWS band, which is not occupied by broadcasters or other non-mobile services. They can be exploited to mitigate existing operators' spectrum constraints and/or to introduce new facilities-based operators if that is deemed to be desirable. As examples, T-Mobile in the United States reached its goal of acquiring enough bandwidth to deploy HSPA/HSPA+ networks by acquiring frequencies in the AWS band auction in 2006 (Table 5), while new entrants were specifically favored to and did win spectrum in the AWS bands in Chile (2009) and Mexico (2010) (Table 6), as well as in the 2.5 GHz band in Colombia (2010). Two entrants in Chile and one in Colombia have respectively won spectrum of 60 and 30 MHz (in blocks of 2x15 MHz) in the AWS band, and 50 MHz (in a block of 2x25 MHz) at 2.5 GHz, while an entrant in Mexico won a national AWS license of 30 MHz (2x15 MHz). In Chile, Colombia and Mexico the spectrum offered was structured to ensure that winning entrants were bound to acquire large amounts of bandwidth. However in Canada AWS spectrum was offered in such a way that while a winning entrant could acquire up to 40 MHz in a license area (as Videotron did in Montreal), it might also have to be content with only 10 (2x5) MHz, as was indeed the outcome in several major urban areas. Longer term if these new entrants are to become viable competitors with national coverage at economical costs they will also need access to lower frequencies (either their own, or through roaming or MVNO arrangements under reasonable commercial terms) for the reasons discussed in section 4.3 below. It is relatively expensive to cover rural or less densely populated areas at the higher frequencies on which they are launching their service.

Table 6: Spectrum Holdings of Mexican Mobile Operators Pre- and Post- 2010 PCS and AWS Auctions

Region	R1	R2	R3	R4	R5	R6	R7	R8	R9	National Average
Telcel (America Movil)										
Pre-auction (850 +PCS)	48.4	48.4	53.4	53.4	53.4	48.4	48.4	48.4	53.4	50.6
850 only	*20*	*20*	*25*	*15*	*25*	*10*	*20*	*20*	*15*	*18.9*
Post- PCS auction	48.4	48.4	53.4	53.4	53.4	48.4	48.4	48.4	53.4	50.6
Post-auctions PCS+AWS	78.4	68.4	73.4	73.4	78.4	68.4	68.4	78.4	73.4	73.9
Telefonica (Movistar)										
Pre-auction (850 +PCS)	50	50	50	51.9	30	30	30	30	30	39.1
850 only	*20*	*20*	*20*	*20*	*0*	*0*	*0*	*0*	*0*	*8.9*
Post- PCS auction	60	60	70	61.9	50	50	50	30	60	54.7
Post-auctions PCS+AWS	60	70	80	71.9	50	60	60	30	70	61.3
Iusacell										
Pre-auction (850 +PCS)	31.6	31.6	31.6	31.6	51.6	56.6	51.6	51.6	56.6	43.8
850 only	*0*	*0*	*0*	*0*	*20*	*25*	*20*	*20*	*25*	*12.2*
Post- PCS auction	51.6	51.6	41.6	41.6	61.6	66.6	61.6	51.6	56.6	53.8
Post-auctions PCS+AWS	51.6	51.6	41.6	41.6	61.6	66.6	61.6	51.6	56.6	53.8
Nextel										
Pre-auction (800 SMR)	9.3	18.4	17.4	14.7	21.4	19.2	21.5	21.5	20	18.2
Post- PCS auction	9.3	18.4	17.4	24.7	21.4	19.2	21.5	21.5	20	19.3
Post-auctions PCS+AWS	39.3	48.4	47.4	54.7	51.4	49.2	51.5	51.5	50	52.6

Source: Cofetel, MFRConsulting

The outcomes for operators' spectrum holdings awarded according to procedures and rules adopted in assigning 2.5 GHz frequencies will have major consequences for the future of mobile broadband competition and markets. Table 7 shows the current situation (mid-2010) for operators' spectrum holdings in Canada, excluding the large amounts of spectrum in the 2.5 GHz band that a joint venture (Inukshuk) of the two largest mobile incumbents (Rogers Communications and Bell Mobility) will hold automatically after the migration of this band to mobile services (BRS) in 2011, before the auction of the remaining 2.5 GHz frequencies.

Table 7: Canadian Operators' Spectrum Holdings in Major Cities Pre- and Post-2008 AWS Auction

City/Population (millions)	Rogers**		Bell**		Telus		Wind (new entrant)	Videotron (new entrant)
	Pre-auction*	Post-auction	Pre-auction*	Post-auction	Pre-auction*	Post-auction	Post-auction	Post-auction
Toronto/5.113	75	95	55	75	50	60	20	10
Montreal/3.636	85	105	45	55	50	70	0	40
Vancouver/2.117	85	105	40	50	55	75	10	0
Ottawa-Gatineau/1.131	85	105	45	55	50	70	0	20
Calgary/1.079	85	105	40	50	55	75	10	0
Edmonton/1.035	85	105	40	50	55	75	10	0

Notes: *Includes 850, 1900 MHz and SMR – only Rogers and Bell have 850 MHz spectrum, while Telus has 10 MHz of SMR bandwidth. ** Excludes 2.5 GHz spectrum holdings of Inukshuk, a joint venture between Rogers and Bell
Source: Lemay-Yates Associates, MFRConsulting

Operators who conclude that they have inadequate spectrum to compete effectively against others who hold more bandwidth and/or to address the growing demands of their current and targeted customers efficiently are strongly motivated to seek to acquire additional frequencies. The ability of spectrum constrained operators to grow their business to a sustainable size is likely to be severely inhibited if they lack sufficient bandwidth to offer broadband services comparable to those of competitors with much larger bandwidth holdings. This handicap can nullify any other competitive strength they may have or develop with respect to the key success factors of a mobile business. Telefonica was in exactly this situation in the key Region 9 (Mexico City and surrounding areas) prior to the PCS frequencies it won in the recent auction in Mexico, as was T-Mobile in the U.S. before it could double its bandwidth holdings in the AWS auction.

4.3 Value of a Diverse Spectrum Portfolio

The main relevant properties of different frequency bands that affect the costs and capabilities of radio access networks are:

(1) Propagation range;
(2) In-building penetration; and
(3) Capacity, i.e. bandwidth available in the band.

One consequence of variations in these properties is that the spectrum holdings that enable the most economical deployments of mobile networks across a range of topological and demographic environments, from dense urban to rural, include a mix of low (below 1 GHz) and higher frequencies (between about 2-3 GHz). The lower frequencies have a longer propagation range that is suited to deployment with the fewest base stations (lowest costs) in low density areas, whereas the higher frequencies with shorter ranges and higher capacities (notably the 2.5 GHz band which has a total of 190 MHz available) are most effective in high density areas which require closely packed cells, and have to handle the greatest density of traffic in terms of Mbps/km^2.

The number of base stations in a RAN (Radio Access Network) is the most important variable which affects its costs, both capital investment (capex) and operating expenses (opex). Table 8 illustrates that the number of base stations required is significantly lower in less dense user environments for deployment of a broadband network at frequencies below 1 GHz compared to one at higher frequencies, enabling substantial savings to be achieved. In an actual example of a mobile broadband deployment Optus in Australia[25] has reported that its mobile broadband network covering a range of urban, suburban, and rural environments which used a combination of 900 and 2100 MHz frequencies required capex of under A$500 million, in contrast to an investment that would have exceeded A$800 million if the network had been confined to 2100 MHz frequencies.

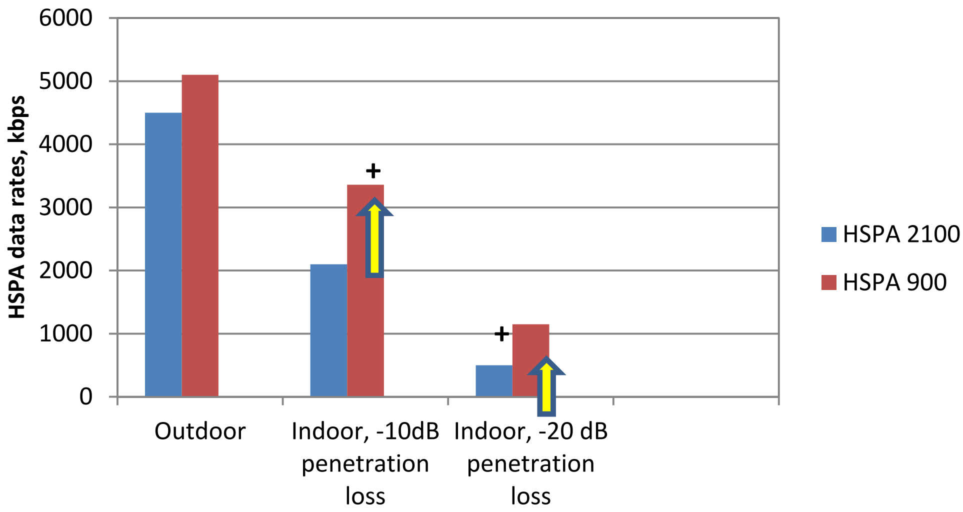
Table 8: Impact of Frequency on Base Station Densities

Area covered by a Base Station, km^2	3G 900 MHz	3G 1800 MHz	3G 2100 MHz
Suburban	59	37	27
Remote/rural	125	77	56

Source: Adapted from Ofcom for the U.K.

In addition, Figure 4 shows that low frequencies are more effective in providing in-building coverage than higher ones. The value of superior in-building penetration lies in the observation that a high proportion (40-80%)[26] of usage of mobile networks arises in fixed or nomadic contexts when users are indoors. A low frequency network can provide better indoor performance, which is one of the key criteria - coverage where you are - on which mobile customers select their preferred service provider.

Figure 4: Frequency Dependence of In-building Penetration



Source: Nokia Siemens Networks [27]

[25] "UMTS900 - A Case Study Optus," June 2009, http://www.gsacom.com/downloads/pdf/GSA_Optus_UMTS900_June_2009.php4

[26] Estimates range as high as 80% (ibid., Analysys Mason, "The message from MWC 2010"; and Instat, http://www.instat.com/mp/09/IN0904558CWW_Mktg_Pkt.pdf)

[27] Nokia Siemens Networks, "WCDMA Frequency Refarming", http://w3.nokiasiemensnetworks.com/NR/rdonlyres/822AB956-2775-41BB-AEE3-9A67C895316C/9126/WCDMA_Frequency_Refarming___White_Paper.pdf

Therefore operators who currently have no access to frequencies below 1 GHz have strong competitive and economic incentives to seek to acquire them, either from the 850 or 900 MHz bands if any is still or will be made available, and/or from digital dividend UHF spectrum as this is allocated to mobile services. They can use these frequencies to cover rural and less dense areas more economically than at higher frequencies and to provide additional capacity in other areas where superior in-building penetration is especially desirable.

Typically one or two of the original cellular operators in a country are the only ones who have 850 or 900 MHz licenses. Hence operators in the position of lacking access to frequencies below 1 GHz today often include incumbents as well as new entrants, which is the situation in the Americas. Tables 5,6, and 7 (above) and Table 9 (below) show that entrants in several countries in the Americas, including Chile (VTR, Nextel), Colombia (UNE-EPM), Canada (Wind, Videotron), and Mexico (Nextel), as well as some incumbents (e.g. T-Mobile (U.S.) and Entel PCS (Chile)) do not hold any spectrum below 1 GHz - nor does Claro (America Movil) in Uruguay - while in Mexico Telefonica (Movistar) and Iusacell do not have nationwide coverage of their 850 MHz frequencies in contrast to the market leader Telcel (America Movil).

Table 9: Spectrum Holdings of Operators in Chile and Colombia

Operator	850 MHz	1900 MHz	AWS	2.5 GHz	700 MHz	TOTAL, MHz
Chile						
Telefonica (Movistar)	25	30	0	N/A	N/A	55
Entel PCS	0	60	0	N/A	N/A	60
America Movil (Claro)	25	30	0	N/A	N/A	55
Nextel Chile	0	0	60	N/A	N/A	60
VTR	0	0	30	N/A	N/A	30
Colombia						
America Movil (Comcel)	25	25	N/A	0	N/A	50
Telefonica (Movistar)	25	15	N/A	0	N/A	40
Tigo (Millicom)	0	50	N/A	0	N/A	50
UNE-EPM	0	0	N/A	50	N/A	50

Source: Regulators' web sites, operators, MFRConsulting

Among other considerations related to conditions of eligibility of access to additional spectrum, regulators are faced with the choice of deciding whether they want to introduce rules for awarding spectrum below 1 GHz that favor those operators who are for now confined to higher bands, or allow all bidders to contend for these low frequencies on an equal footing. So far this choice has come to the fore most visibly in Europe, with mixed attitudes, while in the United States no limits were placed on the two major occupants of 850 MHz spectrum who were free to bid for digital dividend (700 MHz spectrum) in the 2008 auction.

For example, the Spanish Ministry of Industry, Tourism and Commerce presented proposals earlier in 2010 for conditions on future auctions of spectrum for public consultation which included: (a) Requirements on current holders of 900 MHz spectrum to return some of this spectrum to be auctioned if they wish to refarm it for mobile broadband, and (b) A combined spectrum cap of 2x20 MHz to be applied to frequencies below 1 GHz (900 MHz and digital dividend). It also proposed to establish a combined spectrum cap of 2x 55 MHz for paired spectrum in the bands of 1800 and 2100 MHz and 2.5 GHz.

In contrast, Germany imposed looser restrictions on spectrum holdings below 1 GHz in its recent auction of digital dividend spectrum, in which the two incumbents who held the largest amounts of 900 MHz frequencies (Vodafone and T-Mobile (Deutsche Telekom), both with 2x12.4 MHz at 900 MHz) were limited to acquiring 20 MHz each out of the 60 MHz on offer in the 800 MHz band (792-821 and 832-862 MHz). This restriction ensured that 20 MHz would be available for the other two incumbents, who each hold 2x 5 MHz at 900 MHz Auction of these frequencies was combined with auctions of unassigned frequencies in the 1800 MHz and 2.1 GHz (3G) bands as well as of the new 2.5 GHz band, following ITU Option 1. The result of the German auction was that one of the operators with only 10 MHz below 1 GHz (the third largest operator E-Plus owned by the Dutch incumbent KPN) was unable to acquire any digital dividend frequencies, which were won by the other non-900 MHz operator (Telefonica's O2) as well as by T-Mobile and Vodafone. E-Plus did bid for 800 MHz spectrum but withdrew when in its judgment the bids rose too high, preferring to secure frequencies in higher bands at substantially lower prices. Unlike the higher frequencies, coverage obligations in rural areas are associated with the 800 MHz licenses. In the auction of digital dividend spectrum in the United States, that included no restrictions on spectrum holdings and no coverage obligations, by far the largest amounts of the bandwidth on offer were acquired by the two biggest incumbents, perpetuating the situation in which (excluding SMR spectrum which Sprint/Nextel holds) they are the only two nationwide operators with networks in spectrum below 1 GHz (Table 5 above).

6. Conditions of Eligibility and Prices for Spectrum Assignments

5.1 Time Required to Make New Spectrum Available for Mobile Use

The process of making spectrum available for use by mobile networks has historically been a lengthy one (Table 10), since it affects many powerful commercial and financial interests and can get bogged down in time-consuming legal, regulatory and political procedures. Furthermore the scope and complexity of the considerations which regulators and policy makers must take into account in reaching decisions and formulating conditions for spectrum allocations for mobile broadband networks have expanded compared to the more sharply focused era of narrowband, voice-dominated mobile communications. The important role of broadband (fixed as well as mobile) as a factor in the social and economic development and global competitiveness of a country has become widely acknowledged, and is a subject of vigorous controversy and debate at national and international levels. Furthermore issues of new spectrum allocation and assignment for mobile broadband, especially in the 2.5 GHz and digital dividend spectrum, now necessarily implicate major influential broadcasting and media as well as telecommunications interests.

Table 10: Time Required for Spectrum to become available for Mobile Services in the U.S.

Band	Initial Step	Available for Use	Approximate Time Required, years
Cellular (850 MHz) – Advanced Mobile Phone System (AMPS)	1970	1981	11
PCS (1900 MHz)	1989	1995	6
2.5 GHz	1996	2006	10
Digital Dividend (700 MHz)	1996	2009	13
AWS-1 (1.7/2.1 GHz)	2000	2006	6

Source: Ibid. FCC (March 2010)

In order to minimize delays in making spectrum available, all key participants in the public sector (e.g. Sector Regulator, Ministry/Policy Maker, Competition Authority) should actively coordinate their initiatives and policy recommendations to define as early as possible an agreed and enduring set of principles and goals as well as conditions and procedures for new spectrum allocations and assignments. The aim should be at least to reduce the scope and plausibility of potential objections to, and hence delays in spectrum allocations and assignments that can exploit divergent or conflicting policies and initiatives within the public sector itself.

5.2 Goals and Consequences of Conditions for Spectrum Assignments

Recent assignments of spectrum in the Americas have been pursued with a variety of country-specific policy objectives in mind. For example in Chile and Colombia (Table 11) the processes to assign AWS and 2.5 GHz spectrum respectively were designed exclusively to permit new entrants. In the Canadian AWS auction and the concurrent auctions of 1900 MHz and AWS spectrum in Mexico (Table 12) the goals included both guaranteeing openings for new entrants and enabling incumbents to acquire more frequencies for broadband deployments. In Mexico one incumbent, Telefonica's Movistar (the second largest operator), was as noted unable to deploy broadband in the country's capital without the new spectrum which it acquired at 1900 MHz (Table 6). In the AWS and 700 MHz auctions in the U.S. no substantial advantages were offered to potential new entrants, with the result that the two largest operators were able to consolidate their spectrum advantage, although the fourth largest operator T-Mobile did succeed in acquiring enough AWS spectrum to launch a broadband network (Table 5 above). Like Telefonica in Mexico City, T-Mobile did not possess enough spectrum (but in its lack of spectrum was nationwide) to deploy broadband systems in the U.S. prior to this acquisition of AWS frequencies.

Table 11: Examples of Recent Spectrum Assignments for Mobile Services in South America

Country	Frequency Band; Date	License Conditions	Eligibility of Incumbents	Prices, $ per MHz/POP (natl. average except as noted)		Outcomes & Comments
				Unnormalized	Normalized[1]	
Brazil	2.1 GHz; 12/2007	Auction of regional licenses	Yes	0.159	0.977	Only incumbents won; potential entrant Nextel outbid; backhaul coverage obligations subsequently imposed on winners[28]
Chile	AWS; 09/2009	90 MHz in 3 national licenses; 1st round to qualify technically, then financial bids	No 60 MHz spectrum cap	0.0113	0.0573	Two bidders: Nextel won two blocks of 2x15 MHz and VTR one block, paying about 40% of Nextel's price
Colombia	2.5 GHz; 06/2010	Auction of 60 MHz maximum, minimum bid for 30 MHz,	No, 60 MHz spectrum	0.0188	0.164	2 Bidders; UNE-EPM won paired 2x25 MHz block; ITU Option 1

[28] The coverage obligation is that 50% of the cities already covered in 2008 by mobile systems (2G and 2.5G) with more than 200,000 inhabitants should be also covered by 3G in the first 3 years (by end- 2011); 40% should be covered in the first 4 years (2012); and 60% in the first 5 years (2013). Another obligation establishes that 50% of the cities that had no mobile service in 2008 should be covered by some mobile service (2G, 2.5G or 3G) in the first year, and all of them in the first 2 years (by end 2010). All cities below 30,000 inhabitants should be covered with 3G technology by 2016. Other obligations for cities with between 30,000 and 200,000 inhabitants were also established by Anatel...

		paired or unpaired as requested; coverage obligations	cap			band outcome likely
Peru	2.5 GHz; 08/2009	24/22 MHz unpaired at top of band; pre-qualification round; coverage obligations	No, 60 MHz spectrum cap	0.0058	0.0614	One prequalified bidder, Russia-based Yota, has deployed WiMAX – 2 attempts to auction 25 MHz at 1.9 GHz have attracted no bids

1. Normalized to the U.S. GDP/capita here and in the following Tables 12-14.

Source: Regulators' websites, MFRConsulting

In Brazil's 3G auction in the 2.1 GHz band there were also no special provisions for new entrants, with the result that Nextel's Brazilian operation (unlike its Mexican company) did not acquire any spectrum but was outbid by the incumbents. In September, 2010 Anatel announced conditions for award of the remaining 20 MHz (Band H) at 2.1 GHz. This spectrum will be awarded as 2x10 MHz to an entrant if an eligible bid is presented, for example by Nextel. If no entrant presents an eligible bid, then the frequencies will be thrown open to bids from incumbents in two blocks of 2x5 MHz. Unallocated spectrum in the 800 and 900 MHz and the 1.8 and 1.9 GHz bands will be auctioned at the same time. The spectrum will be awarded in a total of 165 lots, with coverage obligations will similar to those imposed for the earlier awards of 2.1 GHz spectrum. These obligations include 100% coverage of municipalities with populations of over 100,000 and 50% of those with populations between 30,000 to 100,000 within 5 years, and 15% of municipalities under 30,000 within seven years.

Table 12: Examples of Recent Spectrum Assignments for Mobile Services in North America

Country	Frequency Band; Date	License Conditions	Eligibility of Incumbents	Prices, $ per MHz/POP (natl. average except as noted)		Outcome & Comment
				Unnormalized	**Normalized**	
Mexico	AWS; 07/2010	Two national (2x15 MHz) plus three 2x5 MHz licenses in all 9 regions (90 MHz total); total costs of spectrum include large annual fees over 20 years plus auction prices	Partial, limits by region based on spectrum caps of 80 MHz – ineligible for national AWS licenses	*National:* 0.176 for single block (auction 0.00432) and 0.293 (auction 0.121) for sum of all regional blocks; *Region 9:* 0.637 (auction 0.361)	*National:* 0.882(one block); *Region 9:* 1.60[1]	Entrant Nextel won national AWS license; market leader Telcel won large amounts of regional licenses; no bidder for 2nd national AWS license
	1.9 GHz; 07/2010	Three 2x 5 MHz licenses in all Regions except 8; same annual fees in total spectrum costs as AWS	Partial, limits by region based on spectrum caps of 80 MHz	*Region 9:* 0.569 (auction 0.263)	*Region 9:* 1.42	#2 operator Telefonica won large amounts of spectrum it needed to deploy broadband in crucial Region 9
U. S.	AWS; 09/2006	Auction of 90 MHz (p) in regional licenses	Yes	0.54	0.54	2 largest incumbents biggest winners; #4 operator T-Mobile won spectrum it

						needed to deploy broadband
	700 MHz; 10/2007	Purchase of Aloha by AT&T (spectrum trade)	N/A	1.07	1.07	Sale of spectrum acquired in earlier 700 MHz auction
	700 MHz; 03/2008	Auction of regional licenses in blocks of non-IMT standard sizes	Yes	1.23	1.23	2 largest incumbents biggest winners; public safety block not awarded (reserve price not met)
Canada	AWS; 07/2008	Auction of 90 MHz (p) in 10 year regional licenses; 40 MHz set aside for entrants	Partial, for 50 MHz of open blocks; subject to roaming and sharing obligations with entrants	1.54 (open block prices higher by $0.39+)	1.79	Incumbents acquired most spectrum; no new national entrant[2]; some entrants began service at end 2009 and in 2010

Source: Regulators' websites, MFRConsulting

5.2.1 Causes and Implications of Huge Variations in Spectrum Costs

The prices paid for spectrum across the world vary enormously by several orders of magnitude as can be seen from the Tables 11 and 12 above and Tables 13 and 14 below. These variations are even larger when they are normalized in relation to a country's GDP per capita, to account for the relative wealth of an economy as an approximate measure of its revenue potential, which is one of the factors considered in valuing spectrum. Furthermore these prices vary widely even between spectrum in the same band allocated at almost the same time in different countries at very similar stages of economic and mobile market development. The price paid for 2.5 GHz spectrum in Denmark in 2010 was about 85 times higher than that in the auction held in the Netherlands only a few weeks earlier. Moreover spectrum prices vary widely not only by region within a country when licenses are offered on a regional basis, but also for national licenses at the same frequencies offered at the same time and won by different bidders (e.g. Denmark and Chile, in Table 13 and 11 respectively).

Table 13: Examples of Recent Spectrum Assignments for Mobile Services in Europe

Country	Frequency Band; Date	License Conditions	Eligibility of Incumbents	Prices, $ per MHz/POP (natl. average except as noted)		Outcome & Comment
				Unnormalized	Normalized[1]	
Germany	800 MHz; 05/2010	Auction of 60 MHz, paired; coverage obligations for rural areas	Two major 900 MHz incumbents restricted to 20 MHz each	0.92	1.08	Multiband auction of national licenses; bids only from the 4 incumbents who all acquired spectrum, but one did not win any 800 MHz frequencies and
	1800 MHz; 05/2010	Auction of 50 MHz paired	Yes	0.0331	0.0388	
	2.1 GHz; 05/2010	Auction of 39.6 MHz paired, 19.2 MHz	Yes	0.140 (p); 0.00946 (unp)	0.164 (p); 0.0111 (unp)	

		unpaired				today has only very limited spectrum below 1 GHz (2x5MHz)
	2.5 GHz; 05/2010	Auction of 190 MHz, ITU Option 1	Yes	0.0292 (p); 0.0275 (unp)	0.0342 (p); 0.0321 (unp)	
Netherlands	2.5 GHz; 04/2010	Auction of 190 MHz, some flexibility for bidders regarding unpaired spectrum	Restricted to maximum of 2x25 MHz each	0.00177	0.00172	5 bidders (2 entrants and all incumbents) all won FDD, but no bids for TDD spectrum; prices very low; incumbents reached caps
Denmark	2.5 GHz; 05/2010	Auction of 190 MHz, ITU Option 1	Yes	0.153 (average of paired and unpaired)	0.126	All 4 incumbents won spectrum, 3 both TDD and FDD, 1 FDD only; 1 winner paid 3% of others' prices
Finland	2.5 GHz; 11/2009	190 MHz, ITU Option 1	Yes	0.00465 (p);0.00821 (unp)	0.00474 (p); 0.00837 (unp)	3 incumbents all won FDD spectrum; entrant won 50 MHz TDD block
Norway	2.5 GHz; 11/2007	Auction of 190 MHz, more unpaired spectrum (110 MHz) than in ITU Option 1; regional licenses	Yes	0.0400 (p);0.0508 (unp)	0.023 (p); 0.0394 (unp) – but still no TDD WiMAX deployment	Both incumbents won FDD, and 1 also TDD spectrum which could be combined into FDD; entrant Craig won most TDD spectrum; FDD LTE service has been launched
Sweden	2.5 GHz; 05/2008	Auction of 190 MHz, ITU Option 1	Yes	0.247 (p); 0.0568 (unp)	0.258 (p); 0.0594 (unp) – but still no TDD WiMAX deployment	All 5 bidders won spectrum - Intel Capital (TDD) and 4 incumbents (FDD); FDD LTE-based service has been launched

Source: Regulators' websites, MFRConsulting

These enormous variations severely limit and justify extreme caution in using international benchmarking to justify or base an expectation of a pricing outcome. They are the result of large differences in the drivers of spectrum valuation and prices as a function of local, national, and individual operators' competitive circumstances and regulations, as well as the specific conditions applied by regulators to individual competitive assignments of spectrum.

For example, conditions which affect the number and identities of eligible bidders for spectrum have a profound effect upon spectrum prices, which was one of the reasons behind the very different pricing outcomes of the Danish and Dutch 2.5 GHz auctions. Unsurprisingly, if major incumbents are excluded from bidding for some or all frequencies in a band then the prices paid for these frequencies will be lower (e.g. set-aside blocks in the AWS auction in Canada, whose prices were some $0.30 per MHz/POP lower than the open blocks[29]).

Table 14: Examples of Recent Spectrum Assignments for Mobile Services in Asia

Country	Frequency Band; Date	License Conditions	Eligibility of Incumbents	Prices, $ per MHz/POP		Outcome & Comment
				Unnormalized	Normalized	
India	2.1 GHz; 05/2010	Auction of paired, 2x5MHz licenses in 22 circles	Yes; earlier set-asides for state-owned BSNL, MTNL (at same price as auction winners)	0.30 (national average) 3.88 (Delhi circle)	14.61 (national average)	No operator won licenses nationwide; revenues from 2 auctions comparable to 5 years cumulative mobile investments
	2.3 GHz; 06/2010	Auction of unpaired 20MHz licenses in 22 circles	Yes; earlier set-asides for state-owned BSNL, MTNL (at same prices as auction winners)	0.11 (national average) 1.34 (Delhi circle)	5.36 (national average)	Only 1 operator (entrant) acquired national coverage; mix of TDD-LTE & WiMAX deployments expected
Hong Kong	2.5 GHz; 01/2009	90 MHz (p) in 3 licenses	Yes	0.32	0.50	3 of 5 bidders each won 30 MHz (2x15)
Singapore	2.5 GHz; 05/2005	90 MHz specifically for WiMAX in 6 MHz blocks	Yes	0.011 (unp)	0.015 (unp)	No WiMAX services have been launched; regulator considering a new auction; winners have conducted LTE trials

Source: Regulators' websites, MFRConsulting

If there are fewer eligible bidders for the number of licenses that are offered, then the prices will be lower still (e.g. Chile (Table 11) or the recent 2.5 GHz auction in the Netherlands (Table 13)), and there may even be no eligible bidders for some blocks (e.g. the second national AWS license in Mexico, or the unpaired 2.5 GHz frequencies in the Netherlands (see Tables 12 and 13 for more details)). In Peru, which has imposed a spectrum cap of 60 MHz since 2005, there have been two failures, most recently in January, 2010, to attract any new bidders for 25 MHz on offer in the 1900 MHz (PCS) band. Outcomes in which no spectrum is awarded are worst cases if the primary goal in assigning spectrum is to support the deployment of mobile broadband networks. If no assignment is made, no new networks are deployed nor do existing networks obtain additional capacity. In contrast to situations that fail to attract any bidders, auctions of new spectrum such as AWS may in some cases attract strong competition and result in relatively high prices when these assignments offer opportunities for well-backed incumbent operators to expand their spectrum holdings and better position themselves to offer mobile broadband services.

[29] Christian Michael Dippon, NERA Economic Consulting, "Regulatory Policy Goals and Spectrum Auction Design - Lessons from The Canadian AWS Auction", July, 2009, http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/dgrb-001-09-NERA-replyComments.pdf/$FILE/dgrb-001-09-NERA-replyComments.pdf; Anqi Fu, "Design and Competitive Analysis of the AWS Spectrum Auctions; Thesis presented to the Department of Economics, University of Maryland, May, 2009, http://econ-server.umd.edu/~vegh/courses/Econ396-397/Papers/anqi.pdf

Canada presents a striking example of a potential future policy issue regarding spectrum prices. Prices on a per MHz/POP basis for spectrum in the same band have typically exhibited significant and understandable variations, such as 40% or even 60%, across geographies within a country or even within the same geography, as shown in Tables 11-14. In Canada spectrum fees for 2.5 GHz licenses converted from MCS will for now continue at their current level of CAD$1.30 per MHz per 1000 households per year. The NPVs (net present values) of these fees over the 10 year license term applicable in Canada using annual discount rates of 7% and 10%, and assuming an average of 2.5 people per household, amount respectively to CAD$0.00365 and CAD$0.0031932 per MHz/POP. In contrast winning AWS auction bids in 2008 lay between CAD$1.67-1.91 for the open blocks, and reached a high of CAD$1.35 for the set-aside blocks, in other words some 400 to 600 times greater than the current MCS/BRS spectrum costs. The auction of 2.5 GHz frequencies that are not retained by current band incumbents may result in prices that are comparable to, or perhaps significantly lower, but probably not by an order of magnitude, than the AWS spectrum prices. In light of this possible outcome or scenario two related policy questions will likely arise in Industry Canada's planned public consultation about future BRS fees:

- Will operators who are not incumbents in the 2.5 GHz band be discouraged from bidding for the frequencies offered via an auction, if they perceive that their costs for deploying 2.5 GHz networks will have to include much higher spectrum costs than those of the incumbents, and

- Will the fees set for incumbency in 2.5 GHz spectrum create large arbitrage opportunities for selling all or part of this spectrum at prices well below the likely levels of an auction? Or will continuation of these fees at a very low level as just calculated have a marked influence on the dynamics of the auction process, by offering potentially substantially less expensive alternatives to otherwise highly motivated bidders?

There is little hard evidence to enable precise quantification of the absolute levels, expressed in terms of $ per MHz/POP or some other metric, at which the costs of spectrum for an operator become unreasonably burdensome in different national markets. The experiences of the European 3G auctions at the beginning of the century, which led to spectrum prices of a few $ per MHz/POP, and subsequent substantial billion dollar write-offs, are not necessarily relevant in today's circumstances. At that time about a decade ago the world was far from ripe, technologically and otherwise, for genuinely mobile broadband services, which is not the case today. Nevertheless the Indian example from 3G (2.1 GHz) and 2.3 GHz auctions in mid-2010 is sobering (Table 14). These two auctions raised a combined amount of about $23 billion. Significantly, a strong strain in thinking about spectrum auctions in India, driven by the Finance Ministry, has been to use spectrum assignments as a means to raise revenues for the public Treasury, notably to help cover deficits in the national budget[30]. Pursuit of a goal to generate revenues for the public Treasury from spectrum auctions can lead to very high prices that siphon financial resources away from operators, whereas these resources might arguably be better applied to investment in more and better networks. The total sums generated in the Indian auctions are very comparable in size to the actual total investments made in existing 2G networks and to the amounts of new mobile investments anticipated in India over the next five years, which are both about $25 billion. For comparison in 2009 total investments by mobile operators in Latin America amounted to about $11.2 billion, a level that is expected to increase over the next few years.

[30] For example Business Standard India, " Spectrum auction revenues may help reduce deficit to 4.5%," June 11,2010, http://www.business-standard.com/india/news/spectrum-auction-revenues-may-help-reduce-deficit-to-44/97675/on

Chile offers an example which stands in striking contrast to the philosophy of the Indian Finance Ministry. In Chile spectrum is assigned not with the motive of maximizing revenues for the State. It is awarded in light of assessments of the investments, technologies and other aspects of the business plans of the bidders for the spectrum[31], and the contributions their proposed wireless networks will make as a crucial element in the country's efforts to close its gap with the most advanced countries.

A very different scenario than India is also found in Peru (Table 11) regarding the ratio of network investment to spectrum price in the 2.5 GHz TDD WiMAX[32] network deployment of the Russia-based operator Yota. The spectrum Yota is exploiting (24 or 22 MHz of unpaired spectrum in different parts of the national territory) was acquired for $3.9 million, while its total projected investment over 5 years is about $100 million, i.e. over 25 times greater than the spectrum price just quoted. At the opposite extreme Jordan has provided an example of how demands for high spectrum prices can discourage potential bidders from seeking spectrum. In this country no bids were forthcoming by the deadline of late June, 2010 for the 2.5 GHz frequencies on offer, while only one 3G license in the 2.1GHz band could be awarded in 2009 after a difficult tender process that included an initial spectrum price of about $1.17 per MHz/pop, or $14.8 per MHz/pop when normalized to per capita GDP. Jordan joins India as a very high end outlier in this aspect of spectrum pricing[33].

As a general guideline, spectrum prices should be regarded as too high if their financial impact on operators leads to delays and limitations in the desirable coverage of their network deployments, and significant upward cost and pricing pressures on mobile services. If the prices paid or the fees levied for spectrum for mobile services are too high in comparison to the investments needed to deploy mobile networks, and the income which can reasonably be anticipated from mobile services at affordable prices, then the revenues derived from spectrum charges are counterproductive. They will reduce the financial capacity of operators to invest in networks and associated assets, and may raise the total costs of service to the point where they become unaffordable for significant segments of the potential market. The resulting total shortfall or loss in the value generated by mobile networks, both directly and indirectly, may then far exceed the revenues received from the spectrum charges[34].

Since spectrum is a scarce public resource, public policy in some countries may be based on a combination of trying to ensure that the spectrum is acquired by operators that perceive and are able to generate the greatest value from its exploitation, while also providing a reasonable financial return for the public from granting rights to use this resource to build a profitable business. Whatever public policy objectives for spectrum usage are established, the purposes of spectrum allocations and the fees associated with spectrum licenses as well as the goals linked to spectrum assignments should be clearly defined with respect both to competition and techno-economic efficiency. All efficient and potentially efficient operators will need substantial amounts of spectrum to handle demands for broadband traffic. At one extreme it makes no sense to restrict access to new spectrum so severely that the prices paid fall to the lowest levels of the examples shown in Tables 11-14 (below 0.2 cents per MHz/POP). It makes equally little sense to pursue revenue-maximizing

[31] Statement by the then Subsecretary for Telecommunications in "Hoy en Telecomunicaciones", Mexico, August 11, 2010

[32] In its home base of Russia, where Yota operates the second largest WiMAX network (after Clearwire) with over 500,000 subscribers as of mid-2010, it has now started to deploy LTE networks as well, which is another indication of the growing momentum behind this broadband technology

[33] In addition annual payments of about $3.5 million are required for the 15 year duration of the 3G license in Jordan, which increases the cost per MHz/pop by about 75%, assuming a discount rate of 10%.

[34] Ibid., LECG, February, 2009; ibid., Christian Michael Dippon, NERA Economic Consulting, (July 2009); Costas Couroubetis and Richard Weber, "Pricing Communications Networks: Economics, Technology and Modeling," John Wiley and Sons, 2003, p.324

tactics for spectrum awards that will impede necessary and value-creating investments in mobile broadband networks.

The nature of the potential spectrum pricing issue for 2.5 GHz frequencies in Canada discussed above is an illustration of the often very country- and band- specific policy issues which are encountered in allocating and assigning spectrum for mobile broadband. Another example of a very specific condition for a spectrum award is Anatel's condition for the auction of the remaining Band H frequencies at 2.1 GHz in Brazil. As noted, these frequencies will be reserved for a new entrant, but only if there is an eligible bid for the entire 2x10 MHz block. If there is no such bid incumbents will be allowed to bid for Band H in two 2x5 MHz blocks. Some conditions and rules that regulators may wish to introduce are contingent on specific national configurations of legacy spectrum holdings, as well as existing market positions of operators that have arisen to a large extent as a result of decisions taken before attention to broadband became a central factor in the mobile sector. At the same time, as shown in the preceding Sections 1 through 3 of this paper, the complete set of drivers that influence spectrum policy and operators' spectrum strategies also includes several powerful supply- and demand-side factors that are common to all countries, notably: (i) Global developments in mobile wireless broadband technology; (ii) Technical and economic implications of different frequency bands and channel widths utilized in broadband networks; and (iii) Very large and rapid rises in mobile broadband traffic that are developing as combinations of reasonable broadband speeds and affordable prices, and attractive or even exciting mobile devices and applications become available.

7. Conclusions

The prospects of a spectrum shortage in the Americas, especially Latin America, during the coming decade are too large to ignore. Absent substantial new spectrum it will be difficult if not impossible to meet rapidly increasing demands for mobile broadband services that are affordable, widely accessible, of high quality, and can generate widespread economic and social value,. Furthermore only operators with access to significant amounts of spectrum (more than they typically have today) across multiple bands are likely to be in positions to compete credibly to win enough customers and revenues in mobile markets to sustain profitable business models. Conclusions for policies and actions by regulators and public policy authorities and/or by operators themselves follow directly from these findings. They take account of the technical and economic realities of wireless communication and global technology investments, as well as political, legal, and regulatory time scales, and reflect the following priorities:

- **Minimize Delays in Spectrum Assignments:** In order to minimize inevitable delays in making new spectrum available for mobile broadband services, all key stakeholders in the public sector (e.g. Sector Regulator, Ministry/Policy Maker, Competition Authority) should actively coordinate their initiatives and policy recommendations to define as early as possible an agreed set of enduring principles and goals as well as conditions and procedures for new spectrum allocations and assignments. The aim should be to limit the scope and plausibility of potential objections to, and hence delays in spectrum allocations and assignments arising from the exploitation of divergent or conflicting policies and initiatives within the public sector itself. Awarding frequencies in the AWS band, which is not encumbered by other uses as are the 2.5 GHz and 700 MHz bands, should be targeted as a short term priority where this has either not been, or only partly carried out.
- **Encourage Competition in Mobile Markets:** A mobile market can only support a small number of efficient facilities-based operators. Hence regulators and policy makers should

not rely on limiting bandwidth holdings of operators to the point where they cannot be efficient in meeting customers' demands, and/or an economically unviable number of operators can enter the market. Rather they should evaluate pursuing or continuing one or several other selected measures customized to their national circumstances to prevent or inhibit anti-competitive behavior[35] and facilitate competition, for example: (a) Obligations on operators involving: (i) Interconnection, provision of wholesale services, infrastructure sharing, and consumer protection, as well as (ii) Spectrum licenses such as coverage targets over time ("use it or lose it"), and (b) Application of antitrust legislation.

- **Exploit Opportunities for Global Economies of Scale and Harmonization:** ITU-R M.1036-3 Option 1 band plan (2x70MHz FDD on the sides with 120MHz duplex separation and 50 MHz TDD at the center) should be adopted wherever possible for the 2.5 GHz band to enable users to benefit from the economies of scale of equipment and devices developed for this band plan, and the platform it provides for international roaming with a single device

- **Accelerate Availability and Pursue Regional Harmonization of Digital Dividend Spectrum:** The allocation process of 700 MHz spectrum to mobile services should advance in parallel with the transition to digital television process, depending on the extent of its current occupancy in each country by analog TV channels, so as to maximize the timeliness and amount of new spectrum that is made available for mobile broadband networks. This spectrum is not on a path to achieve comparable harmonization at the global level as the 2.5 GHz band, but may nevertheless become harmonized across many Latin American countries if they adopt the channelization plan proposed for Asia[36] for reasons of economies of scale.

- **Coordinate Spectrum Planning on a Multiband Basis:** The amounts and distributions of spectrum by band have a significant impact on the costs and capabilities of mobile broadband networks. Hence operators and regulators in the Americas should coordinate spectrum planning and optimization across multiple available bands, both existing and new, taking account of their individual circumstances and goals.

- **Combine Spectrum Initiatives with Complementary Measures to Mitigate Congestion**: Even a maximum combination of potentially available additional spectrum and increased spectral efficiency will be inadequate to handle traffic if the more aggressive demand forecasts are realized. Hence operators should plan to have to implement a variety of network- related and other measures to meet traffic demands and mitigate congestion problems[37], such as: (a) Off- loading of mobile traffic onto the fixed access network via Wi-Fi and femtocell connections; (b) Application of web and content optimization techniques to reduce traffic volumes; and (c) Management of subscriber usage patterns via new pricing models and acceptably non-discriminatory traffic management techniques.

[35] Assessment of the appropriateness of these and other measures lies beyond the scope of this paper. They should be coordinated with other initiatives to achieve goals of public policy to foster healthy development of, and robust competition in mobile markets

[36] "Harmonized Frequency Arrangements for the Band 698-806 MHz", APT/AWF/REP-14, available at http://www.apt.int/AWF-RECREP

[37] Assessment of use of these tools and techniques by operators also lies beyond the scope of this paper. They are mentioned to indicate that spectrum policy and strategy are only one, but a key element in operators' business planning, which must be coordinated with other initiatives. Traffic offloading is the only approach that can cope long term with two or more orders of magnitude increases in mobile data traffic (see ibid., Martyn Roetter, (August, 2010))

Glossary

2G, 3G: Second Generation, Third Generation (referring to wireless technologies)
Anatel (Brazil): Telecommunications regulator (Agência Nacional de Telecomunicações)
ASO: Analog Switch Off
AWS: Advanced Wireless Services
BRS: Broadband Radio Service
CDMA: Code Division Multiple Access
CITEL: Comisión Interamericana de Telecomunicaciones - Inter-American Telecommunication Commission
Cofetel (Mexico): Telecommunications regulator (Comisión Federal de Telecomunicaciones)
DTT: Digital Terrestrial Television
EV-DO: Evolution Data Optimized, a CDMA-based mobile data technology
FCC: Federal Communications Commission (U.S.)
FDD: Frequency Division Duplex
GSM: Global System for Mobile Communications
HSPA: High Speed Packet Access
IMT: International Mobile Telecommunications – the ITU's concept for global broadband multimedia international mobile telecommunication systems
ITU: International Telecommunication Union
LTE: Long Term Evolution
Mbps: Megabits per second
MCS: Multipoint Communication Service
OFDMA: Orthogonal Frequency Division Multiple Access
PCS: Personal Communications Service
RAN: Radio Access Network
TCP: Transmission Control Protocol (with IP (Internet Protocol) the main protocol of the Internet)
UHF: Ultra High Frequency
UMTS: Universal Mobile Telecommunications Service
WCDMA: Wideband CDMA
WiMAX: Worldwide Interoperability for Microwave Access
WRC: World Radiocommunication Conference