Exploring the Value and Economic Valuation of Spectrum

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Work in progress, for discussion purposes

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1 Introduction

For the past two decades, the management of electromagnetic spectrum has been undergoing a substantial evolution. Indeed, the rise of different theories about the nature of spectrum and its use – and by extension, how spectrum should be regulated – may be the most significant since governments began managing spectrum resources roughly a century ago.

Increasingly, both industry and governments are viewing spectrum in economic terms, as an input to the production of telecommunications services. It is not hard to see why. Over the past 20 years, the world has seen the birth and adolescence of a rapidly growing commercial mobile service industry. The importance of this industry in the development of societies and economies and its consequential financial weight have brought increasing pressure on governments and regulators to make increasingly large portions of spectrum available to the mobile industry to meet its spectacular growth.

This leads policy-makers to the same underlying question about spectrum: how much is it worth? In other words, how should one *value* spectrum? This is a much more complex question than most policy-makers and economists have yet acknowledged.

In purely financial terms, one can establish the value of a discrete block of spectrum by putting it up for sale and seeing how much anyone is willing to pay to use it. This is the broad principle behind auctions and, by extension, secondary markets – including spectrum trading, leasing and even resale by downstream service providers. But the building blocks of spectrum value are as much political and socio-economic as they are purely financial. A government's approach to spectrum regulation, its market structure and its investment regulations can influence the perceived value of a spectrum license. Add to that the demographics, physical geography and political history of the country, and you begin to get a picture of valuation that is highly situational and variable.

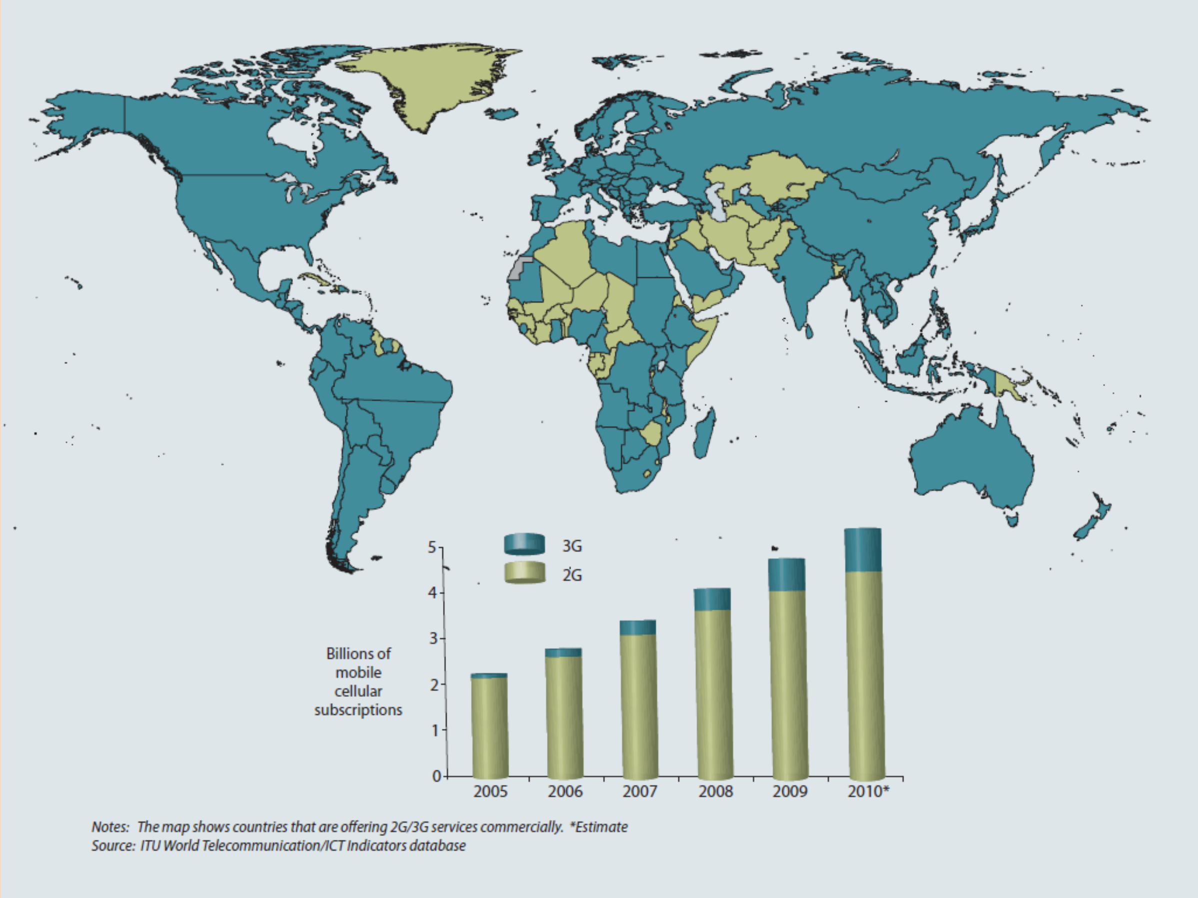
This paper explores the current economic philosophies and public policy debates over spectrum valuation – particularly in light of the overwhelming demand for new spectrum resources for broadband wireless access (BWA) services. It reviews the growing body of thought about valuation, as well as the variables and factors that may change based on situation and location. It also reviews how this process has begun playing out across the world as governments seek to make spectrum available for wireless Internet access. The goal of this paper is to provide some insight into how spectrum value may be assessed in different situations.

The stakes have never been higher, considering the increased bandwidth demand for the delivery of mobile broadband and the consequent scarcity of the spectrum resource. Also, the challenges posed by the emergence of market choices (based on national and regional spectrum allocation decisions as well as choices of technology standards) further increases the spectrum valuation complexity. On this point, the need for spectrum harmonization plays an important role; as any potential cross-border interference or adjacent band interference can negatively impact on the economic value of spectrum.

2 The Exploding Demand for Spectrum

The expanding growth of BWA technologies worldwide is increasing the need for regulators to find, if not a definitive answer on spectrum valuation, at least viable estimates. By the end of 2010, there were 5.3 billion mobile cellular subscriptions globally, including 870 million active mobile broadband subscriptions.[1]

Figure 2.1: The Scope and Scale of 3G Services



Increased traffic on wireless networks increases the demand for the spectrum on which these new communications superhighways run. As both developed and developing countries move from 2G to 3G networks, and ultimately to 4G, a historic convergence is taking hold: Mobile communications and the Internet are migrating toward the same platforms. As a result, advanced wireless networks are becoming a more significant portion of many national economies, increasing the need to assess the value of spectrum on which this infrastructure runs.

This increased demand for spectrum creates an economic challenge for regulators: how to balance spectrum demand and supply. Increasingly, regulators are relying on purely economic models, letting market forces play a larger role in spectrum management to address these supply and demand issues.[2] Technology advances, meanwhile, are driving more demand, and regulators are striving to realize the full economic potential of spectrum, and to keep pace with market changes.[3]

2.1 Market-Based Approaches

The basic spectrum management models – *command-and-control*, *property rights* and *commons* – have existed for essentially all of the past two decades of policy change in spectrum management.

In many instances, regulators continue to apply a command-and-control approach to spectrum assignment. This is especially true with regard to government usage of spectrum, or for licensing of spectrum used for maritime and aeronautical services or for professional fixed or mobile usage. Even beyond such uses, however, some governments retain a belief that regulators are best suited to determine which operators should be granted licenses, and in some cases there may be insufficient demand for spectrum to warrant competitive bidding.

Even so, the advent of broadband services is increasingly putting pressure on traditional spectrum assignment processes, leading more governments to overhaul their licensing approaches. Recent policy innovations combine flexible regulations with something akin to private property rights in defining spectrum rights of use, by giving operators the freedom to:

- Transfer control of spectrum licenses (often – but not always – with government or regulator approval);
- Determine how the spectrum will be used (subject to technical requirements); and
- Profit from use, leasing or resale of the resource.[4]

The term of *flexible rights of use* is often used to describe this approach.[5]

The antithesis of this model is *spectrum commons*, for which there is no licensing or granting of exclusivity to any operator. This model is captured in license-free or unlicensed services, which may be given particular spectrum bands to use as their "commons." As a result of spectrum congestion, unlicensed operation is also authorized in frequency bands shared with other services (e.g. 5 GHz), hence not used as *commons*.

Interestingly, governments have generally been cautious in determining which approach to use. The result, across the world, is a combination of spectrum management regimes that incorporate:

- Legacy command-and-control regimes for government services,
- Auctions and bidding for many commercial (e.g., cellular mobile) licenses, and
- unlicensed uses for low-power devices (e.g. WiFi).

Table 2.1 – Applications of the Three Spectrum Distribution Models

Model	Typical Users	Typical Uses
Command and Control	• Government agencies – Military – Public safety – Resource managers – Transport operators • Broadcasters • Professional users • Earth station operators	• Radars • Aeronautical and maritime • Tactical radios • Remote sensing • Terrestrial Television broadcasting • Professional mobile radio • Point-to-point links • Satellite telecommunications
Property Rights (Flexible Rights of Use)	• Commercial terrestrial wireless operators • Satellite operators	• 2G and 3G mobile services • Satellite broadcasting and telecommunications • WiMax or fixed wireless
Commons	• Internet hotspot providers • Individuals	• WiFi (WLANs) • Other Low-power devices (key fobs, garage openers)

Coexistence of these different schemes of managing spectrum complicates the task of determining how to attach value to spectrum. In particular, since only the commercial mobile licenses are "sold" (through auctions or through being subject to license fees), there is no standard way to apply market value to other blocks of spectrum.

2.2 BWA Demand Is Driving Monetization

To address the explosion of real and perceived demand for spectrum capacity to accommodate broadband services, the property right/flexible rights of use model presents several advantages:

- The need to make large blocks of spectrum available to the market is seen as urgent and time-sensitive;
- Command-and-control allocation procedures are often time-consuming, less efficient and less effective at making spectrum resources available;
- Adopting market mechanisms is seen as a better way to ensure that spectrum rights are assigned to those most able to use them efficiently and effectively; and
- Governments can obtain revenues from auctioning (in one form or another) spectrum rights.

In reality, however, deciding to auction spectrum, or to authorize a tender process, is not a simple process. Market value for spectrum can fluctuate tremendously, and key decisions about timing, auction processes, regulatory rules, bidding thresholds and market structure can mean the difference between very low bids and irrational overbidding.

At the core of designing a proper market-based assignment process is learning how to value spectrum in economic terms. Section 3 of this paper discusses the basic methodologies for economic valuation of spectrum. It also explores the various intrinsic and extrinsic properties of spectrum that cause variations in value. Section 4 then surveys what some developing markets have done in exploring pricing as part of spectrum assignment practices. Finally, the paper offers a checklist for regulators to approach spectrum pricing and value in this light.

3 Economic Valuation of Spectrum

Before examining how to value spectrum, it is first useful to consider *why* spectrum is given a value. In other words, why is spectrum valuation relevant to what regulators do? We have already noted that the demand for BWA services increasingly leads to consideration of spectrum access from an economic angle, but what specific occasions arise for using valuation methods? The most common uses can be summarized in the following three points:

- *Spectrum assignment* – Valuation is often instrumental in determining threshold or reserve prices in spectrum auctions or tender processes, and bidders can be expected to estimate spectrum value in designing their bidding strategies;
- *Spectrum trading* – Secondary markets involve both suppliers and customers, and both seek to determine valuation in order to arrive at an optimal price point for their businesses; and
- *Spectrum fees* – Regulators need to estimate spectrum value in order to set recurring fees (or even up-front fees) that go beyond their regulatory costs (i.e., fees set based on *administered incentive pricing* or AIP) (See box 3.1).

Box 3.1 AIP: A Proxy for Market-Set Prices

The model for spectrum pricing known as *administered incentive pricing* (AIP), is based on the economic rationale that market-based signals will generate economic responses that will lead to more efficient and productive use of spectrum resources.

In practice, *opportunity cost* calculations (See Section 3.1) and spectrum management policies are used to derive market-oriented fees, even for spectrum bands that have never been auctioned. The fees may represent discounts from true market-oriented amounts, based on policy goals or to avoid "fee shock" for users in lucrative bands below 3 GHz. The fees are then imposed as economic costs upon the users of the spectrum input. If the users find that the fee costs cannot be justified economically, they can release the spectrum. The intended result is more productivity gained from the finite spectrum resource.

In its broadest sense, administered pricing has been employed in numerous countries, wherever governments have opted not to conduct auctions but rather to set up-front or recurring fees based on calculations – or often simply estimates – of what the operators would consent to pay. Contemporary AIP, however, seeks to marry auction avoidance with market-oriented fees that are based on sound economic principles. Not all governments, however, have been willing to impose AIP on all services – particularly the command-and-control public service operations that they themselves operate.

It is important to note that there is no single value that applies for all three situations. For example, the economic and competitive factors involved in securing initial spectrum, through an auction or tender, may not be replicated when that same spectrum (or a portion of it), is offered for sale or lease in a secondary market. For one thing, a secondary trade will need to reflect the spectrum holder's incentive to generate a profit, as opposed to simply warehousing the spectrum for further expansion of its own service. There will also be transactional costs stemming from bilateral negotiations and capital costs – all of which may differ from those involved in the original bid.

Moreover, competitive interests and strategies often weigh in during such negotiations. The spectrum holder must determine whether the value of leasing the spectrum outweighs the potential negative effects from facing competition engendered by the new market entrant to which it leases the spectrum. On the other side of the transaction, the value proposition for the potential new market entrant may be no greater than at the time of original bidding (and is often less appealing, since the original license winners have early-mover advantages). So there may be some built-in economic reasons for the spectrum holder to seek a higher lease rate, even while the secondary market bidder is seeking a lower one. This complicates the chances of reaching a mutually optimal secondary trading price.[6]

In the case of spectrum fees, meanwhile, valuation may only be a starting point in determining the ultimate level of the actual fees. Policy rationales may call for discounting fees below the determined value, or for phasing in the valuation-based fee, in order to avoid a financial shock or government rent-taking effect on the licensee.

The overall theme, then, is that valuation is highly situational. It varies over time, from market to market, and from transaction to transaction. There is no simple recipe for determining the absolute economic value of spectrum. Quite simply, different users will value a particular band differently, at different times. But even if the economic valuation of spectrum depends on numerous variables, certain basic valuation assumptions can be used. These will be explored in the following section.

3.1 Opportunity Cost

In the work done more than a decade ago to prepare the way for AIP in the United Kingdom, the key concept that emerged was what economists call *opportunity cost.* Essentially, the opportunity cost is the amount that a potential buyer (or bidder) would have to confront before he or she would give up and go someplace else to get what he or she needed.

In terms of spectrum, opportunity cost is relevant because of the array of both costs and benefits associated with spectrum's role as an input to commercial services. In the case of assignment or secondary trading, bidders are acting rationally up until they reach their opportunity cost – *the cost of the most economically rational alternative*. In practical terms, if it becomes cheaper or more profitable to pursue spectrum in another band, or to utilize a landline substitute – or simply to sit out the opportunity and invest later – the rational actor will stop bidding and choose the more economical alternative. In theory, the last remaining bidder, after all others have dropped out, will be the one best prepared to make the optimal use of that particular spectrum.

Opportunity cost assessments generally reflect the estimated price markets would place on spectrum at auction. This entails taking into account different circumstances, such as congestion levels that vary from band to band (lower prices generally apply to less congested bands). The U.K.'s 2002 Spectrum Management Review stated that users should face continuing incentives towards more productive use of spectrum, and such incentives should "be financial and based on *opportunity cost* of spectrum use. In this way, spectrum would be costed as any other input into the production process." Thus, market players could make informed judgments about their use of spectrum and available alternatives.[7]

The U.K.'s AIP methodology was developed by consulting firm Smith-NERA, which examined the marginal value of spectrum to the user. This takes into consideration the amount of congestion in a given band and attempts to set fees at "market-clearing" rates that balance spectrum supply and demand.[8] Ofcom has said that one way to evaluate the marginal value to the user is on the basis of the "additional costs of the least-cost practicable alternative" – another way of stating opportunity cost. For example, for a user of a point-to-point fixed service band, the most cost-effective alternative to using the band would be either deploying more spectrally efficient systems or relocating to higher frequencies. The relative costs of these alternatives reflect the *marginal value*.[9]

Therefore, most valuation models involve a calculation of marginal costs associated with network infrastructure, including equipment and construction costs, as well as cost of capital or labour. Some of these costs can be known or at least well estimated, through benchmarking and survey of existing equipment markets. This is particularly helpful if the spectrum being valued is harmonized across multiple markets (or even worldwide), leading to predictable economies of scale and scope in manufacturing. It is also clear that such cost calculations are made on a forward-looking, incremental basis, because the analysis must capture ongoing costs, not a theoretical start from a baseline of zero.

3.1.1 Balancing Costs and Revenues

In the real world, a decision to bid on spectrum is not only based on costs, but also on a projection of future revenues, after analyzing the efficiency and capability of the technology and the marketability of the resulting applications that the spectrum will support. Again, measurements of potential revenues can be forecast with some reliability, through benchmarking similar services, or benchmarking identical services in other markets. More focused research can be done through marketing studies and demand surveys of discrete markets.

All of this can be captured in the concept of *net present value* (NPV), which balances the net costs against the net cash inflows over time. From the point of view of a potential operator choosing whether or not to invest in a particular BWA market (for example), this can translate into a calculation of the total net value of a project. This allows an assessment of whether positive outputs (i.e., revenues) will exceed input costs over time. A calculation of the cost of obtaining access to spectrum resources can be included as a factor in determining net project value for a wireless network project – and whether the cost for the spectrum input is justified.[10]

Generally, bidders are looking to see the cost of any discrete spectrum opportunity priced as an expression of the *price per megahertz,* representing a baseline per-unit price a bidder might pay at auction. Another figure often cited is *price per megahertz pop* – the price per megahertz divided by the number of potential customers.

3.1.2 Benchmarking

Meanwhile, in combination with direct valuation estimates, it may be possible to compare the results of different assignment transactions (notably auctions) across different economies. In a 2008 report for the Australian Communications and Media Authority (ACMA), however, Plum Consulting observed that use of market benchmarks to make opportunity cost estimates remained difficult. Plum noted that "there are relatively few comparators and national markets and the timing of spectrum releases differ[s] considerably. Furthermore, in the one case where there has been considerable market information, namely auctions of spectrum for 3G mobile services, the volatility in market values meant that prices based on the early values were a very unreliable indicator of opportunity cost at a later date."[11]

ACMA cited three categories of market data that can be used as benchmarks to develop opportunity cost assessments, including:

(1) **Spectrum market transactions** or a "market comparables" approach (e.g., past auction results from the same or similar bands or trades in the secondary markets).

(2) **Values of companies** that own spectrum (e.g., market valuations of firms that hold spectrum rights are a reflection of the value of the spectrum, plus additional assets).

(3) **Capacity sales** of spectrum-utilizing services (e.g., data on the sale price of capacity for services that rely on spectrum as an input).[12]

One must be careful, however, in drawing universal conclusions, through benchmarking, about a process (valuation) that, as stated before, varies so widely over time, geography and type of service.

In a 2009 research project for Ofcom, for example, consultants considered how to derive a "service-neutral" model of spectrum value.[13] They encountered difficulty in doing so with any specificity, however, because the value would rely to a large extent on the network infrastructure utilized (on the cost side) and the traits of the particular market (on the revenue side). They then isolated and developed markets for four types of services: cellular mobile, fixed point-to-point, "single-site mobile" (private radio or "private business radio" used to connect employees within a company campus or job site) and broadcasting.

In looking at both potential costs and revenues, there are numerous factors that cannot be ignored. These can be divided into two categories, for purposes of this survey:

- Intrinsic factors – These are factors that pertain to the spectrum itself and cannot be changed by any particular government:
  - Factors stemming from laws of physics, or
  - As a result of worldwide trends (e.g. harmonization), or
  - International obligations (e.g. frequency allocations, bi-lateral or multi-lateral frequency coordination agreements)
- Extrinsic factors – These are factors that apply differently in each country, whether because of physical or demographic characteristics, historical, cultural or legal heritage or more pertinently, as a result of national government policies and regulations.

These factors are so numerous, and more importantly, so crucial to a real-world valuation of spectrum, that they will be considered in two separate sub-sections.

3.2 Intrinsic Factors

When considering the value of a certain band of spectrum, regulators can start with a baseline of factors that are unique to that particular set of frequencies. The most basic factor is the propagation characteristics of the band. Depending upon the potential usage, some spectrum may be better suited than others. In general, spectrum ranging from about 400 MHz up to 6 GHz will have higher value than bands at higher frequencies, because it enables greater throughput per megahertz at lower infrastructure cost.

This is because the service area covered by a base station is proportionate to the square of the frequency. For example, the minimum provision of service over a low population density region will require twice the number of base stations at 1 GHz than at 700 MHz, 8 times more at 2 GHz and 14 times more at 2.6 GHz, and the cost of deploying a mobile network in such a region will rise in proportion. This explains why the frequencies around 700 MHz are known as “golden frequencies”, and why these frequencies are increasingly in demand for BWA services (and were already widely used for 2G mobile services). This may also explain why the auctions recently held at 2.6 GHz have been “disappointing” for treasuries.

Moreover, BWA services are not the only ones for which excellent propagation conditions are preferable. Other types of systems, including radionavigation (GPS, radars) and terrestrial broadcasting, also require frequencies in this range, greatly increasing the competition for what has become a critically contested resource.

The number of potential uses for any given spectrum band also increases the perceived value of that spectrum. The advent of application that benefit from good propagation characteristics and can increase average revenue per user (ARPU) – as long as sufficient bandwidth is available to run them – underlines the intrinsic value of that spectrum.

Similarly, regulators are dealing with a globalized pattern of allocation. . In the case of mobile broadband, as was the case for 2G and 3G, worldwide or regional harmonization of spectrum brings economies of scale in manufacturing equipment that may be used anywhere in the world, which is also a requirement for international roaming. Harmonization also facilitates the conclusion of cross-border agreements, which are necessary in border areas.

The result is a trend towards harmonizing spectrum bands across multiple countries, both within the same region (e.g., Europe) and globally. Although this process is not intrinsic in the same way propagation is, harmonization is certainly a factor that comes to bear beyond the control or even influence of any single country’s regulatory authority. In effect, harmonization becomes an intrinsic value of the spectrum, apart from any factors unique to a single country.

Similarly, the constraints arising from international (bilateral or multilateral) agreements affect very significantly the value of a particular part of the spectrum. Spectrum internationally allocated to radars, satellite radionavigation, Earth observation or broadcasting, may not be practically available for mobile services (for example), either because the interference from neighboring countries would be unsustainable in border areas or because the interference from the mobile service would be unacceptable by other countries. This cross-border coordination dilemma can be particularly acute in regions where national boundaries are frequent and close together (i.e., Europe or Central America). But it may be an issue even among larger countries – in fact, wherever international borders exist.

These three factors – propagation, multiplicity of uses and applications, and harmonization/international constraints – are so powerful in combination that they largely drive decisions about spectrum allocations in most countries. They are directly related to the profile of cost and potential revenue that a prospective operator (or bidder) can expect from any particular spectrum band. Thus, they are an essential building block in estimations of valuation. Frequently, governments looking to maximize revenues from spectrum are induced to harmonize spectrum bands with international practice by allocating the same bands as their major trading partners or neighboring economies.

3.3 Extrinsic Factors

The intrinsic factors identified in the previous section explain why certain bands are allocated and brought to market by governments seeking to maximize spectrum value. They do not, however, ensure that potential bidders or market entrants will consider each national market a worthwhile investment. There are, in fact, numerous factors, beyond the characteristics of the spectrum bands themselves, which determine value in the spectrum marketplace. These can be divided roughly into three types of extrinsic factors:

- Physical characteristics of the market,
- Socio-economic and political characteristics of the market, and
- Policy and regulatory governance of the market.

The former category includes all of the factors – physical geography and topography – that increase network costs and potentially reduce or limit revenues. The second category takes in the elements of the social, economic and political topography that will determine the likelihood of a high return on the spectrum investment. The third category includes all of the telecommunications-specific (and spectrum management-specific) policies and regulations that apply to a potential spectrum valuation.

To reiterate, the exercise of attempting to set an economic value on spectrum is inherently situational; therefore, the factors that make up each national market will, along with the characteristics of the band itself, largely determine what value can be attached to any given band. Ultimately, valuation will be determined, and will fluctuate, based on actual transactions over time in each discrete marketplace. All attempts to arrive at valuation through costing or other administrative methods are essentially estimates.

Table 3.1 – Factors in Assessing Spectrum Value

Type of Factor	Factor
Intrinsic	• Propagation characteristics • Sharing capacity • Profusion of uses • Global and regional harmonization • International constraints
Extrinsic: Physical factors	• Geography • Climate
Extrinsic: Socioeconomic factors	• Demographics • Population density • Income distribution • Economic growth rate • Political stability • Absence of corruption • Rule of law
Extrinsic: Policy and Regulation	• Favorable investment and customs laws • Independent regulatory agency • Competition policy • Infrastructure sharing • Rules of protection of the public against electromagnetic waves • Open access rules • Technology neutrality • Limitation of and protection against interference • Coverage obligations • Spectrum caps • Auction rules and bidding credits/set-asides • Transparency • Licensing framework • Dispute-resolution mechanisms

Source: The author

3.3.1 Physical Market Factors

Geographical and topographical variations and barriers can impact the value of spectrum. Licenses that cover rural, suburban or highly congested urban areas can factor into the value that potential bidders place on the spectrum. In addition, these considerations should be coupled with technical factors such as the availability of robust electrical power supplies and physical limitations or barriers in the ability to install network infrastructure. Climate and weather can be a factor in calculating maintenance costs. Finally, remote or land-locked countries – for example, mountainous island nations – may be considerably less attractive to international bidders, absent significant man-made incentives to overcome the problems of their physical geographies.

These physical factors can raise the costs of network construction and maintenance, even for wireless networks (although wireless networks often gain a clear advantage over wireline facilities in such environments). This can be an acute factor, particularly in small and developing countries, where there is strong downward pressure on consumer telecommunication service rates.

In this context, the coverage obligations to be included in the licenses may considerably affect the value of the associated spectrum as seen from the potential licensee. The value for the society, however, given the objective of reducing the digital divide, may increase when strengthening these obligations.

3.3.2 Socio-Economic Market Factors

In determining whether – and how much – to bid for available spectrum, investors may look at the profile of a country's population, in all aspects. This includes population density and distribution – and whether that density coincides with physical geography that can be served cost-effectively. It may also include demographic factors, such as age distribution, income distribution and level of income. At the very least, this information will help inform marketing strategies if and when the spectrum rights are won. Markets with high potential for development, high population density and few geographic barriers are likely to be considered good candidates for investment, even if income levels may be low. The marketing strategy might include network build-out in metro areas, with pre-paid services that feature voice and SMS as a way to generate initial revenues.

3.3.3 Policy and Regulatory Environments

The broader policy and regulatory environment can impact spectrum valuation. If the bidder is uncertain as to whether regulatory obligations may change, he or she may discount the spectrum to a certain degree. This uncertainty may include a basic assessment of business and trade laws in the country. Any laws or rules that inhibit or put too high a price on investment, importation of equipment or repatriation of profits could negatively influence the potential for bidding on a spectrum opportunity. Conversely, a regulatory environment that provides a certain, flexible and stable environment for investment will likely attract more bidders and higher bids.

The possibility of unanticipated, post-auction regulatory fees or roaming requirements could also act to reduce a bidder's valuation. An example of the uncertainty of such post-auction obligations are potential changes in how fees are set. Consider a recommendation, in 2010, by the Telecommunications Regulatory Authority of India (TRAI) and the Department of Telecommunications (DOT) that the government impose higher spectrum usage fees on CDMA and GSM operators. Fees were to be assessed based on the number of megahertz the operator had under its control.[14] Other regulatory factors could include:

- **Open Access**: An open access requirement obliges a licensee to provide access to non-affiliated providers' devices or applications on its network. In the U.S., the FCC established open access obligations for one block of spectrum in the 700 MHz band, of which 60 MHz was auctioned in 2008. Some experts estimated that the winning bidder obtained a 40% discount for the spectrum due to the open access requirement.[15]
- **Technology-Neutrality:** Another policy consideration that could impact valuation is imposing a requirement to use a specific technology. Such a mandate could be designed to facilitate roaming or to advance the development of a certain technology, such as GSM in Europe in the 1990s.

One example of a specific technology mandate is the 2009 action by the Chinese government to assign 3G licenses to its three main operators. The government mandated the use of the Chinese home-grown wireless 3G technology, TD-SCDMA, by one of the licensees, China Mobile.[16] TD-SCDMA is heavily backed by the government, which has high hopes for its development as a home-grown technology and future export source.

In El Salvador, on the other hand, a major focus has been on regulatory flexibility for spectrum management. Concessions for the use of spectrum span 20 years and can be subdivided by frequency, geography or time dimensions – without regulatory approval. Rights holders may select whichever technologies they deem most useful or efficient.[17]

- **Coverage Obligations:** Many countries have identified the reduction of the digital divide as an essential policy consideration, particularly in relation to providing broadband service to sparsely populated areas. The corresponding obligations to cover such areas should be clarified from the outset in the licenses in order to permit future licensees to adequately assess the impact of this obligation on their expected investments and revenues. This cost-benefit analysis will affect their perception of the value of the associated spectrum.

- **Spectrum protection obligations:** another important valuation element of spectrum is the level of interference protection that future licensees will be offered/required to offer to/from the services authorized in:

  – In adjacent frequency bands within the same country

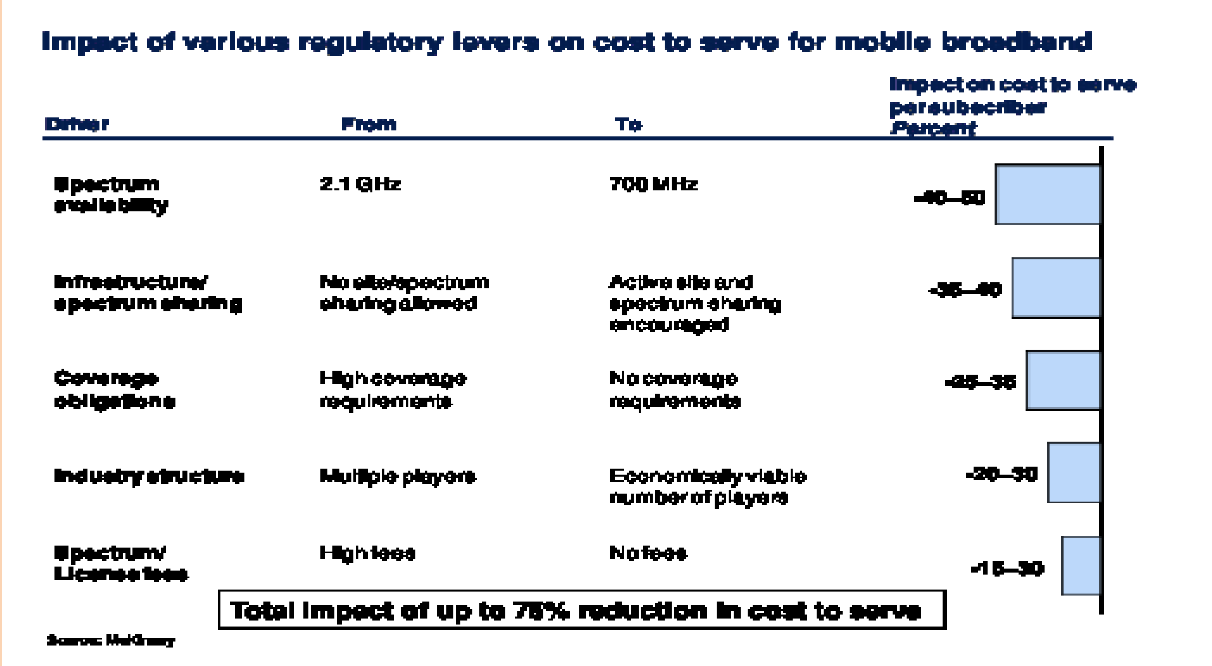
  – In the same frequency band within the same country

  – In the same frequency band in adjacent countries

  For example, in the bands made available as part of the digital dividend (700 MHz and 800 MHz), where coexistence with broadcasting is critical, the corresponding requirements may have important consequences and should be clarified from the outset by the regulator. This clarification may take time, since it may involve negotiations with the broadcasting sector and with neighboring countries.

  Also, when there may be legacy issues which delay the availability of the band until incumbent services in the band in the same country or other countries have been phased out. This issue is currently creating uncertainty in several countries of Eastern Europe in relation to the availability of the “digital dividend” band, as a result of the need to phase out aeronautical radionavigation systems. One way of clarifying this issue domestically is for the regulator/government to fund the relocation of government systems currently in use in the band.

- **Rules of protection of the public against electromagnetic fields**: the growing concern of populations around the world in relation to the potential consequences of the proliferation of base stations has led to increasingly constraining legislations and regulations to ensure protection of the public against electromagnetic fields. This further constrains the development of networks in higher frequency bands, where new base station sites will therefore become increasingly difficult. This also reduces the possibility of new entrants.



www.gsmworld.com/newsletter/newsflash/G20_Aide_Memoire.pdf

Certainly, the presence of an independent regulatory agency, with open and transparent processes and rules (particularly transparent auction rules), will inspire trust and greater commitment to any given market.

The remainder of this section looks at several aspects of regulatory policy that have a direct bearing upon spectrum values.

3.3.3.1 Competition Policy

The market structure in a country is one of the most fundamental characteristics that potential investors consider. New entrants may be reluctant to invest strongly in a market they view as being either saturated or completely dominated by existing incumbents. Regulators strive to strike a balance between opening up the market to new entrants, thus promoting competition, and allowing "too many" competitors, which they fear will simply promote industry consolidation and further entrench the incumbents.

This equation is complicated by the fact that for incumbents, spectrum has a value beyond its ability to be used for services in a given area: locking up spectrum forecloses competition. Incumbents will view the value of procuring spectrum both as an input to their services *and* as a way to keep frequencies out of the hands of a competitor.[18] Known as a *private value,* this potential agenda to preclude competition also can be deemed "foreclosure value" – as distinct from "use value." The value to the operator does not necessarily equate to value for the consumer.

Seeking to regulate the structure of a market is an ongoing task – not just a simple matter of delineating how many national licenses should be provided and then letting nature take its course. For example, when regulators engage in "refarming" existing allocations from 2G to 3G, they must assess how to treat incumbents so that there will be continuity of service, even while taking an opportunity to allow new market entry, as well as assessing the cost of reallocating incumbents. Incumbent GSM and Public Cellular Mobile operators in Hong Kong, China, were given the first right of refusal when their licenses expired in 2005/2006.In New Zealand, replacement 3G licenses were offered, on a case-by-case basis, to existing commercial operators. Those rights were offered five years prior to expiration of the operators' original 2G licenses, based on a price-setting formula.

Beyond the number and dominance of competing operators, competition policy consists of a realm of regulations and policies that act to check market power and promote the viability of new services and business plans. Spectrum management policies can be included in this cause, along with interconnection and pricing rules.

3.3.3.2 Spectrum Caps

In an effort to preclude spectrum hoarding, some governments have imposed caps on the size of individual operators' spectrum holdings. As the costs of building out more advanced wireless networks increase, however, operators argue that imposing ceilings on spectrum aggregation can curb innovation and investment. A common theme among such arguments is that other policy measures can achieve the same end, such as a case-by-case review of spectrum holdings rather than a one-size-fits-all cap.

A review of the many efforts to begin allocating 3G spectrum (see Section 4, below), indicates that spectrum caps are common around the world. In Latin American countries, for example, regulators have applied spectrum caps since 1998, and caps remain a regulatory tool of choice to address competition concerns.[19] Countries in the region with caps include: Argentina (50 MHz); Brazil (80 MHz); Chile (60 MHz); Colombia (40 MHz); Mexico (35 GHz); and Peru (60 MHz).[20] In 2009, the Chilean regulator SUBTEL announced plans to auction 3G licenses at 1700/2100 MHz in three blocks of 30 MHz. Because of a court ruling in support of a 60 MHz spectrum cap, incumbents could vie for spectrum in the auction but would have to dispose of some current spectrum assets if they won.[21]

The industry association 3G Americas has contended the caps in Latin America can present obstacles to advanced network investments, calling them "antiquated" in an era when mobile voice is being replaced by 3G data rates. As advanced wireless technologies such as LTE require larger amounts of bandwidth for data-intensive applications, a key question for regulators is how spectrum aggregation limits can be adjusted in the era of 3G and 4G technologies.

Indeed, in the Netherlands, spectrum caps were questioned after 2.6 GHz auction results that yielded somewhat low revenues in 2010. The Dutch government had implemented spectrum caps on incumbents based on their existing holdings of other spectrum. Under these rules, new entrants were restricted to 40 MHz, while incumbents also were subject to rationing (Vodafone could obtain up to 20 MHz and T-Mobile could win only 10 MHz).[22]

3.3.3.3 Incentives and Set-Asides for New Entrants

To encourage participation, some countries may provide bidding discounts or may set aside licenses for new entrants – sometimes including small businesses or ethnic minorities. Such efforts to provide incentives for new entrants in spectrum assignments have played an increasingly important role in auction policy, for example. The challenge is how to provide feasible, realistic incentives to draw in new players, while ensuring that those entrants are well-capitalized and technologically astute enough to provide meaningful competition to incumbents. Countries have addressed this balancing act in several ways:

- **Brazil**: When Brazilian regulator Agencia Nacional de Telecomunicacoes (Anatel) auctioned 4 licenses of 2.1 GHz spectrum in 2004, a swathe of spectrum was set aside for a new entrant.[23]Six years later, that spectrum was included in an auction of spectrum scheduled for late 2010. Brazil's four current wireless network operators were not allowed to bid on that spectrum unless no new potential bidders came forward. These rules prompted a lawsuit by a trade association, Sinditelebrasil, arguing that the country already had adequate wireless competition.[24]
- **Singapore**: A 2007 consultation by the Info-Communications Development Authority (IDA) addressed how to reallocate 2G spectrum at 900 MHz and 1800 MHz.[25] Spectrum had been assigned at 900 MHz to the GSM operators SingTel Mobile Pte Ltd (STM) and MobileOne Ltd (M1) and at 1800 MHz to STM, M1 and StarHub Mobile. The licenses were assigned, respectively, for seven- and six-year periods, which expired on 30 September 2008. Upon the expiration of these rights, these bands were freed for reallocation to advanced wireless services, as the original

operators did not have residual rights to continue using the spectrum for 3G. Incumbents were allowed to compete alongside new entrants for the right to continue using the spectrum.[26]

- **France:** In 2010, one remaining block (2x5 MHz) of 3G spectrum in the 2.1 GHz band was reserved for a new entrant in an auction process, together with an opportunity to gain access to the 900 MHz spectrum (2x5 MHz). It resulted in a fourth operator launching a commercial service at the end of 2011 and boosting competition in the mobile market.

3.3.3.4 Roaming Mandates

Mandating roaming requirements for mobile operators can be used to increase consumers' access to coverage areas that their own operator would not otherwise serve. As advanced wireless data networks are built out at different rates, however, the question of how roaming works in larger national markets becomes more complicated. This is even more true for international roaming, where travel across national borders is frequent and increasing. International roaming rates may have to be handled on a regional basis among governments. Otherwise, roaming rates can create the negative outcome of "bill shock" for end-users who travel frequently.

Box 3.2 Beyond "Euro-Tariffs": Europe's Response to High Roaming Rates

The European Union has taken a strong role in addressing the issue of high international roaming rates among its member states. The EU views roaming within the context of its Digital Agenda for Europe, which includes "key performance targets" for attaining a "Digital Single Market." Among those targets is a situation in which the difference between international roaming prices and national tariffs approaches zero by 2015.[27]

The EU market for mobile roaming services is defined to include roaming for voice, texting (SMS) and broadband data. Retail roaming revenues in 2009 accounted for EUR 4.7 billion, of which 71 per cent was for voice roaming, 17 per cent was for data, and about 11 per cent represented SMS. With a total EU mobile service market of about EUR 164 billion (as of 2008), international roaming represented nearly 3.7 per cent of the total mobile service market.[28]

By 2005, national regulatory authorities had acknowledged to the Commission that they lacked suitable tools to rein in international roaming rates. The Commission responded by establishing its Roaming Regulation in 2007, setting price caps – dubbed "Euro-tariffs" – for international roaming, and mandating annual reductions. A 2009 amendment broadened the regulation to cover SMS and broadband data. As a result, international roaming tariffs (and therefore revenues) did decline after 2007. In fact, revenues for SMS roaming decreased even though volume actually increased by 23 per cent in one year (2008 to 2009).

European regulators rapidly noticed, however, that the decline in international roaming rates only went so far – then plateaued. By 2011, it became clear that the Euro-tariffs were clustering right at the price caps, indicating that operators were still levying rates as high as regulators would allow. So in mid-2011, the Commission proposed a long-term solution: "structural" reform would require operators to unbundle international roaming services from their standard retail offerings, beginning in 2014. This would allow consumers to opt for another operator to provide international roaming when they went to another country. The Commission's intent was to promote greater competition for international roaming as a discrete service, opening the market up for mobile virtual network operators (MVNOs) and other specialized operators. In the interim, the Commission proposed lowering the retail price caps on voice and SMS roaming and introducing a price cap for mobile data roaming.[29]

3.2.3.5 Infrastructure Sharing

In an effort to ease barriers to entry, some governments have required sharing of critical infrastructure (e.g., local switching facilities or international gateways) to provide a mean to share access with other operators. Thus, wireless network operators can gain access, through long-term leases, to cellular towers without having to "overbuild" redundant towers in the same areas. This can translate into lower costs, particularly for new market entrants that may have to begin competing with incumbents that already have licenses and customer lists. Lower network build-out costs, in turn, help induce bidders when the time comes to bring spectrum to market.

3.2.3.6 Auction Rules

Of course, the extrinsic factor most likely to directly influence interest in a competitive bidding opportunity – and therefore the value of the spectrum – is the design and implementation of the competitive bidding itself. Auction rules, into which policies such as set-asides or spectrum caps are built – can act as either an incentive or deterrent to bidding. No matter what those rules contain, a failure to adopt and implement such rules in a transparent and equitable manner will be a deterrent.

Auction design is critical to whether the actual value of the spectrum is realized. This is particularly the case with the higher stakes of 3G auctions. The revenue to be realized by operators is higher than for earlier, voice-based networks, because of data-based applications, while costs for network build-out may actually decline, due to more efficient technologies. High spectrum prices paid at auctions, however, may diminish the business prospects for new networks, limiting the impact of broadband services on society. Indeed, broadband will do little good if the cost of licenses is so high that operators do not have access to enough capital to undertake system build-outs.

Box 3.2: Auction Types

The spectrum auction can be used to apply to a variety of different processes that may seem to have only accidental relationships to each other. The end result, however, is always designed to be an outcome in which the most-prepared bidder – the one that theoretically values the spectrum the most – will end up with the rights to exploit the spectrum resource.

Closed, single-round tender bids – Tenders are simple to administer, one-step auctions in which the highest among the sealed-bid submissions wins. Typically, applicants must place their respective bids in a sealed envelope, which is submitted with an application package and then opened by the government on a pre-set date. A benefit of such auctions is that they are easy to administer; however, a downside is that this model is not always efficient at ensuring that licenses are valued in an objective way.

Open ascending-bid (or "English open-outcry") auctions – These rely on a sequential design used by English auction houses such as Sotheby's. ACMA has observed that this model is viewed as the most efficient "for allocating spectrum at market price where there is one or a small number of lots within a band."

Simultaneous multiple-round (SMR) ascending auctions – These are described as "simultaneous" because all licenses are eligible for bidding throughout the auction. Rather than continuous bidding, SMR auctions have successive, separate rounds. At the close of each round, bids are made public, providing information about the value of the licenses to all bidders and potentially allowing bidding strategies to be restructured in the interim. Rounds continue until bidding activity comes to an end, signaling that bidders have reached the high end of valuation on the spectrum.

The Anglo-Dutch hybrid: In Nigeria, when GSM licenses were awarded in 2001, the Nigerian Communications Commission used this model for its auction, which combined an English ascending auction and a sealed bid auction.[30] The four highest bidders were awarded licenses. Bidders were allowed to select the license they wanted, with the highest bidder having first choice.

Incentive auctions: In the U.S., policy deliberations are under way for a new auction tool – "incentive auctions" – which are designed to clear incumbents (in the U.S., case television broadcasters) from spectrum and reimburse them for its value. The relocated incumbents would receive a portion, or "carve-out," of the auction proceeds.

"Ebay" models: As of spring 2010, the Danish government was planning to conduct an auction using a computer-based, ebay approach to auction narrow channels of spectrum at 410-420 MHz and 450-470 MHz. (The first auction was set to start in November 2010). Nearby, Norway planned to conduct an auction through a commercial site similar to ebay – www.qxl.no – for two 30 MHz blocks of spectrum in the 10 GHz band.

Dynamic auctions: In 2007, Google proposed that the U.S. FCC use a "dynamic spectrum auction," similar to the real-time auction used for ad placements on its website for AdWords. The model would not necessarily have to be used by the government to assign spectrum, but could instead be a post-auction model for licensees to make capacity available to secondary users. The FCC, however, rejected the idea in its final rules for the band.

A working paper from TOBB University of Economics and Technology in Ankara, Turkey, has pointed out that from 2000 through 2007, 83 national 3G spectrum licenses were assigned by national regulatory authorities in 20 countries.[31] The paper noted the outcomes in these auctions varied widely, with revenue (per capita) in 2000 reaching EUR 650 in the United Kingdom, and EUR 615 in Germany, but only EUR 100 in Austria, EUR 240 in Italy, EUR 170 in the Netherlands, and a paltry EUR 20 in Switzerland. The paper attributed these revenue swings not only to difference in local market and economic conditions, but also to auction design choices.

The objectives of auctions have grown more multi-faceted They embody efforts to promote competition and maximize revenue, and they increasingly have to accommodate incentives for relocating incumbents. As a result of this new complexity, auction models are evolving. There are now several different types of auctions to serve as models (See Box 3.2). The actual type of auction used should reflect the individual market and policy circumstances.

In the case of Chile, for example, when regulator SUBTEL auctioned 90 MHz of 3G spectrum (1 700 MHz/2 100 MHz) in 2009, one of the goals of the auction was to promote competition by facilitating the entry of a new competitor in the market. SUBTEL reviewed the bids before companies were invited to take part in a closed tender process.32 In developing countries, in particular, a premium is often placed on simplicity and ease of administration for auction models, particularly because of the costs of hiring outside advisers and acquiring software to support more complex bidding mechanisms.

3.4 Spectrum's Value: The Bigger Picture

The challenge with valuations that are purely economic is that spectrum-based operations serve a multitude of public interest objectives, many of which provide social goods that are difficult to place a price tag on. Such valuations are complex because the value generated may be to society as a whole, in the case of national defense, emergency response or flight-safety applications (among many other examples). In the case of unlicensed spectrum uses, value may accrue as a result of technological innovations and entrepreneurship opportunities, which have downstream economic impacts that support overall economic growth or specific social objectives (e.g., facilitating the reach of wireless broadband to rural areas).

As contention for spectrum grows in more developed wireless markets, non-market viewpoints may play an important role in the debate over how spectrum can be most efficiently and effectively used for new applications.

3.4.1 Unlicensed Spectrum

Unlicensed or license-exempt spectrum use represents the idea that spectrum can add value to the overall economy, even though users are not required to pay for it. Even when licenses are not issued, equipment is still designed and sold, services are provided and paid for, and individuals use those services to generate income. It may be more difficult to measure this value, because nobody is required to put a price on it through competitive bidding. On the negative side, unlicensed spectrum use is not protected from interference, so the value of the spectrum might fluctuate based on how congested it is at any given time. Indeed, perhaps the only way to measure unlicensed spectrum's value is to calculate or estimate the total output value of all devices and services employing a given unlicensed band.

In the U.K., Ofcom's Spectrum Framework Review (SFR) suggested that spectrum use should be license exempt "if the value that is expected to be derived from the use under such an approach is predicted to be greater than if spectrum use were licensed." The SFR noted that in cases where harmful interference in unlikely (e.g., demand is less than supply), licensing may present an unnecessary overhead cost and a license-exempt model may be better.[33] In essence, by reducing the input cost of spectrum to zero, unlicensed spectrum "assignment" improves the chances of market entry and may accelerate build-out and availability of networks and services.

New technology advances – namely cognitive radio devices – are expanding the boundaries of how and where unlicensed spectrum can be used for BWA. In the U.S., the FCC in 2010 adopted final rules for the first TV "white spaces" spectrum (unused channels in spectrum allocated to broadcasting), which the agency referred to as enabling "super Wi-Fi" technology.[34] These rules provide a new approach to allowing broadband-based TV white spaces devices to gain access to spectrum below 1 GHz through use of a database and cognitive radio techniques. U.S. regulators plan to consider how to expand the use of this model to other bands. In the U.K., Ofcom is considering similar regulatory tools for exploiting the vacant spaces between TV channels, as part of a consultation published in November 2010.[35]

The popularity of the license-exempt model is not universal worldwide. The World Bank's InfoDev program has estimated that only 41 per cent of developing countries have rules for license-exempt bands, compared with 96 per cent of developed countries.[36] It may be helpful for governments to re-examine their policies with regard to license-exempt services. For developing countries, unlicensed wireless networks can provide a solution for expanding ICT deployment because they are widely available commercially, at relatively low cost, and with few technical expertise requirements for installation.[37]

In Thailand, for example, licensing appeared to hinder rollout of wireless Local Area Networks (WLANs). Once WLAN capabilities began to be included in personal computers and wireless phone chip sets, the cost of WLAN devices dropped dramatically and usage increased. In recognition of this trend, the Thai regulator exempted from licensing requirements all communications devices in the 2400-2500 MHz band with power of up to 100 milliwatts EIRP.[38]

3.4.2 Public Safety and Public Service Uses

For public sector users, including public safety operations, the economic value placed on spectrum is not readily quantifiable in pure market terms. The benefits of these services are to the public at large, rather than to specific end-users that generate revenue. Public television broadcasting, emergency response uses, military operations, science and meteorological services and safety-of-flight are prime examples of such spectrum-based activities. The challenge for policymakers is finding the right balance between valuation models that may be appropriate for private sector spectrum use, and those that take into account important policy objectives across these different user groups.

The value that public sector users place on spectrum poses an increasingly important question for policymakers when government users must relocate to make way for BWA operations, as has been the case in the U.S., India, the U.K. and elsewhere. How to compensate relocating public sector users, or how to justify their displacement, raises thorny issues about how to value spectrum uses that do not have a straight-line economic impact. A key differentiator between public sector and private sector users is that each may value the same band differently because they would use it for fundamentally different purposes (e.g., profit maximization versus broader public interest).

Can government users afford to compete with private sector users for spectrum on market-based terms for access? New Zealand completed a review of spectrum policy in 2005, which defined "non-commercial services" as those that the commercial market would not be likely to provide in a meaningful way and which, as a result, tend to be funded by government (e.g., defense and public safety communications). The review stated that "were spectrum assigned to these services commercially – that is, in competition with providers of commercial radiocommunications – the probability is that affordable spectrum would not be readily available to them. Hence, it is generally seen as appropriate that spectrum is assigned to such services by administrative rather than commercial means, incurring only a cost-recovery fee."[39]

The review added, "There are many spectrum uses where the facility to trade spectrum rights is not desirable, and value to society is perceived to be maximized through direct allocation by the Government." It provided several examples:

- Services "of a non-communications nature" (e.g., radio beacons, radar);
- Services provided in the public interest (e.g., defende, security, safety of life); and
- Services subject to international accords (e.g., maritime, aviation).

The review stated that the military "reserves bandwidth to support large-scale exercises and for deployment in the event of hostilities. This can be supplemented, under emergency conditions, with commercially-managed spectrum in adjacent bands. Consequently, the defence band could be considered as *optimally* utilized, with the acknowledgement that criteria for military efficiency do not coincide with those for commercial spectrum allocation." Ofcom's spectrum management reform efforts for the public sector, however, have extended market mechanisms to government users. As part of this, Ofcom's initiatives include a presumption that public bodies will acquire spectrum through the market except in unusual circumstances.[40]

To date, there is not a well-developed body of academic work for the economic value of public goods produced by government spectrum uses, such as market-based valuations for national security or weather forecasting. Instead, the value of the public sector spectrum use is more typically characterized in the context of spectrum-clearing value (e.g., relocation costs to make way for BWA operations) or auction revenue projections (e.g., the market value of the spectrum *were* it to be auctioned.)

Key factors that make the economic value of "public good" spectrum-based operations difficult to estimate include:

- **Lack of substitutability**: For public sector spectrum uses such as emergency response, national security or safety-of-flight operations, there is not typically a directly substitutable commercial service that performs the same mission. Therefore, there is not a directly comparable benchmark of commercial valuation for such services.
- **Value of safety-of-life**: It is particularly difficult to calculate economic valuations for public safety uses of spectrum, because it is not possible to place a market-based value on human lives saved.

In recent years, several countries have undertaken reviews of public sector spectrum use or overall spectrum management reforms that have taken into account how government spectrum should be treated in the most efficient way.

In January 2009, the Radio Spectrum Policy Group (RSPG), which is composed of the heads of the spectrum agencies in the European Union, adopted an opinion from the on "Best Practices Regarding the Use of Spectrum by Some Public Sectors."[41] It suggested that sharing spectrum between public bodies and between public and non-public bodies should be considered before spectrum is assigned. The RSPG has identified three sharing possibilities, namely frequency band sharing, time sharing and geographical sharing, and means to implement them in the most efficient way. The RSPG opinion also underlined the high importance of the international context for such services, in particular regarding defense, civil aviation and meteorology.

The opinion examined efficient use mechanisms and weighed the costs and benefits of an administrative approach versus a market mechanisms approach (e.g., user fees). The opinion did not specifically recommend either of these paradigms, noting that they are not mutually exclusive. The opinion recommended, however, that spectrum pricing and trading "be applied gradually and on a case-by-case basis, taking into account harmonization issues, interference issues, and macro-economic aspects."

4 Setting Prices for BWA Spectrum

In Section 2, this paper set the stage for the discussion of spectrum valuation and value by discussing the newly urgent perception in many countries that there is a looming spectrum "crisis" with the advent of BWA networks and services. But just how alarming is the reality, and what scenario is likely to unfold in developing countries?

The only way to answer those questions is to begin by exploring the capabilities of the rapidly developing BWA technologies, as well as their thirst for spectrum capacity. This section ties the rapidly accelerating demand for new spectrum to the technologies that are driving this demand. It then surveys what governments have begun to do in terms of allocating and assigning spectrum for the next-generation BWA services.

4.1 BWA Technology Development: 3G and Beyond

As noted in the previous two sections, it has become urgent for governments to realize the value inherent in spectrum because of the skyrocketing demand for broadband capacity in many countries. The advent of BWA services in the past decade focused attention on a convergence of technologies that came from two basic sources: mobile cellular services and wireless local area network (WLAN) standards.

ITU is coordinating the efforts of government and industry in the development of the global broadband multimedia international mobile telecommunication system, known as IMT. Since 2000, the world has seen the introduction of the first family of standards derived from the IMT concept – IMT-2000 (commonly referred to as 3G). This initially resulted in such 3G technologies as WCDMA and cdma2000. The IMT-2000 standard was subsequently enhanced to include such developments as HSPA+, EV-DO, LTE (up to Release 9) and WiMAX (based on IEEE Std 802.16e).

The ITU has spent the past several years working toward a newer generation of standards that would accommodate advanced technologies of both pedigrees. This new development is known as IMT-Advanced – a term agreed upon at the 2007 Radiocommunication Assembly in Geneva. ITU has been evaluating proposals for inclusion of radio interface technologies in the definition of IMT-Advanced. "Key features" of such technologies – which go beyond the features of previous IMT systems – include widespread interoperability, worldwide roaming capability and highly efficient use of the radio frequency spectrum to enable data transmission rates up to 100 Mbit/s at full mobility and 1 Gbit/s stationary (or low mobility).[42]

The industry has responded by further developing the 3GPP Long-Term Evolution (LTE) and WiMAX technologies. The versions that are fully compliant with the ITU's IMT-Advanced specifications are known as "LTE-Advanced" and "WirelessMAN-Advanced", respectively.[43] While earlier versions of LTE and WiMAX may be marketed as "4G" services, only these near-future reiterations actually are designed to meet the IMT-Advanced standards.

4.2 Spectrum Bands for IMT-Advanced

To achieve higher mobile throughputs, IMT-Advanced systems will rely on *orthogonal frequency-division multiple access* (OFDMA) and *multiple-input, multiple output* (MIMO) antenna technologies.[44] They also will have to come with scalable channel widths, from 5 MHz up to at least 20 MHz – and optimally even higher, up to 40 MHz channels. This will put pressure on spectrum resources in bands already crowded with legacy iterations of mobile technologies – 2G and 3G – to say nothing of other uses. Over the past two decades, the Radiocommunication sector (ITU-R) has been progressively identifying additional frequencies that can be used for IMT (including IMT-Advanced). As a result of WARC-92, WRC-2000 and WRC-2007, the following bands have been identified:[45]

- 450-470 MHz,
- 698-960 MHz,

- 1710-2025 MHz,
- 2110-2200 MHz,
- 2300-2400 MHz,
- 2500-2690 MHz, and
- 3400-3600 MHz.[46]

These frequency bands, all located below 3.6 GHz on the spectrum chart, are the recommended locations for individual countries to allocate spectrum for new 3G and 4G services. Critically, however, these bands are not always cleared for future use. Many countries, for example, continue to use the 800 MHz band for broadcasting, or the 1800 MHz band for 2G GSM cellular networks. The 2.5-2.69 GHz band is encumbered in some jurisdictions by satellite links. So, many governments are currently dealing with the process of planning where and when to reallocate or “refarm” existing bands to make way for next-generation BWA networks. *Refarming* refers to the practice of allowing existing licence-holders to retain the rights to a certain band of spectrum, but to alter or update that use to accommodate a new technology. In this context, refarming the 900 MHz or 1800 MHz band means phasing out 2G GSM networks and installing networks to provide 3G or 4G network technologies such as LTE.

Meanwhile, countries are also attempting to determine exactly how much spectrum they should plan to make available. National and international estimates have ranged from an additional 500 MHz (in the United States), to a total of 1200 additional megahertz (in the European Union).

4.3 Status of BWA Implementation

While LTE-Advanced and WiMAX-Advanced remain to be deployed, there are many examples of WiMAX, as well as HSPA+ and EV-DO networks in place. In addition, operators in some countries are well into the process of rolling out initial LTE networks. Moreover, even more governments are taking action to allocate, license and distribute spectrum for upcoming deployments. This section provides a brief (and certainly not exhaustive) global survey of the extent of BWA spectrum distribution.

4.3.1 Europe

Many European countries are in the process of allocating and licensing additional spectrum for BWA, even as the European Union implements plans to enact a five-year Radio-Spectrum Policy Programme (RSPP). The effort to roll out additional spectrum has been characterized by discussion over (1) when to make available the 800 MHz “digital dividend” spectrum that will be freed up in the conversion to digital TV (DTV) broadcasting, and (2) how to refarm existing spectrum resources from 2G GSM wireless use to 3G/4G usage. At the same time, many European countries are in the midst of distributing other spectrum, particularly in the 2.5-2.69 GHz band, which is most often called the “2.6 GHz band” in Europe. The RSPP continued to be debated as of late spring 2011, although the basic outlines of a policy were already clear. European policy-makers and lawmakers were pushing to make more spectrum available, in more IMT bands, in order to pursue the kind of innovation they feared would otherwise emigrate to North America or Asia.

In **France**, spectrum for 3G in the 2.1 GHz band had been awarded, subject to a license fee, as early as 2001. After several unsuccessful attempts to find a fourth mobile service provider to take remaining spectrum in that band, the French government in 2009 subdivided that remaining spectrum and launched three separate calls for tender. One of those bidding processes was reserved for a new market entrant, which turned out to be Free Mobile, based on a comparative procedure and the payment of a EUR 240 million fee, plus 1 per cent of related revenues. The three existing operators in France protested that this fee was significantly lower than what they had to pay some eight years earlier – in effect, amounting to state aid for a private operator. The European Commission, however, rejected their complaint in late May 2011.[47] It ruled that the French process had resulted from a transparent and open procedure and did not violate EU rules.

Meanwhile, the French regulator ARCEP moved, in early 2011, to draft rules for assigning frequencies for 4G services in the 800 MHz digital dividend band and the 2.5-2.69 GHz band. In both bands, France planned to begin accepting applications in late 2011.The planned digital switchover on 30 November 2011 is clearing the way for use of the 800 MHz frequencies by early 2012.

The government set a reserve price of EUR1.8 billion for four blocks of paired 800 MHz spectrum and EUR 700 million for 14 lots of 2.6 GHz spectrum. These translated to EUR 60 million and EUR 10 million per megahertz for the digital dividend and 2.6 GHz bands, respectively. There were strings attached: Spectrum caps would be set at 15 MHz and 30 MHz for the two bands, respectively. Also, 800 MHz licensees would have to achieve 99.6 per cent coverage of mainland France in 15 years, with an accelerated rollout timetable for sparsely populated areas.[48]

In the spring of 2010, **Germany** conducted its first spectrum auction in nearly a decade. The German regulator Bundesnetzagentur (BNetzA) auctioned nearly 359 MHz of spectrum from four different bands (the 800 MHz, 1.8 GHz, 2 GHz, and 2.6 GHz spectrum bands), divided into 41 spectrum blocks.[49] The 800 MHz and 1.8 GHz spectrum was sold in paired configurations, and the 2.1 GHz and 2.6 GHz blocks were sold in both paired and unpaired configurations. With four operators expected to bid in the auction, one source of controversy arose when BNetzA set aside only three 20 MHz blocks in the 800 MHz band. One operator was going to be left without a license in the most highly valued band.

Table 4.1: German Spectrum Auction Results – May 2010

Band	Telekom Deutschland	Vodafone	Telefónica O2	E-Plus	Total (MHz)	Total Price (€m)	€/Mhz/Pop*
800 MHz – Digital Dividend	2 paired 2 × 5 MHz blocks (20 MHz)	2 paired 2 × 5 MHz blocks (20 MHz)	2 paired 2 × 5 MHz blocks (20 MHz)	-	60	3,576.475	.727
1800 MHz	3 paired 2 × 5 MHz blocks (30 MHz)	–	–	2 paired 2 × 5 MHz blocks (20 MHz)	50	104.355	.0254
2.0 GHz	–	paired 2 × 4.95 MHz block (9.90 MHz)	Paired 2 × 4.95 MHz block Unpaired 1 × 5 Unpaired 1 × 14.2 (29.1 MHz)	2 paired 2 × 4.95 MHz block (19.80 MHz)	58.8	359.521	.0741
2.6 GHz	4 paired 2 × 5 MHz blocks 1 unpaired 1 × 5 MHz block (45 MHz)	4 paired 2 × 5 MHz blocks 5 unpaired 1 × 5 MHz block (65 MHz)	4 paired 2 × 5 MHz blocks 2 unpaired 1 × 5 MHz block (50 MHz)	2 paired 2 × 5 MHz blocks 2 unpaired 1 × 5 MHz block (30 MHz)	190	344.295	.0221
Total (MHz)	95	94.9	99.1	69.8	358.8		
Total (€m)	1,299	1,423	1,379	283.65		4,385	

* Using 2009 Population Count of 81,879,976 from World Bank.

The auction proceeds were expected to net, by at least one analyst's estimate, between EUR 6 billion and EUR 8 billion.[50] The auction netted, however, just under EUR 4.4 billion.[51] E-Plus was the bidder that failed to secure one of the three 800 MHz spectrum blocks made available. E-Plus fell short when it bid five times less than the highest bidder. The 800 MHz spectrum sold for as much as 10 times the amount of the 2.1 GHz spectrum or the 2.6 GHz band.[52] In total, the 800 MHz digital dividend spectrum represented more than 80 per cent of the total amount collected in the auction.

Some analysts have speculated that E-Plus will have to merge with another operator or other business, as it will not be able to compete with the other three providers without 800 MHz spectrum. However, the president of the BNZ, Matthias Kurth, indicated that a merger would not be viewed favorably, as each carrier was able to double its spectrum holdings. Kurth felt that four operators provided a balanced number of carriers for the largest market in Europe.[53] Notably, the spectrum acquired by E-Plus is not burdened by the conditions imposed on the 800 MHz spectrum. Table 4.1 describes the bands auctioned and the four companies that successfully secured licenses: Telekom Deutschland, Vodafone, Telefónica O2, and E-Plus.

In **Spain**, an offer to sell spectrum in the 900 MHz and 1800 MHz bands garnered just two bids, from that nation's third-largest and fourth-largest operators, Orange and Yoigo (the two largest operators, Movistar and Vodafone, were blocked from bidding). The bids, however, were far higher than the reserve prices. Orange bid almost 3.5 times the reserve price of EUR 126 million in winning the 900 MHz block, and Yoigo bid five times the reserve price of EUR 60 million for the 1800 MHz blocks. The Spanish government is looking to raise some EUR 1.5-2 billion for a collection of 3G and 4G spectrum blocks, including future sales of the 800 MHz digital dividend and the 2.6 GHz spectrum. As in France, the licences include coverage requirements, including coverage of areas with fewer than 5,000 residents in the case of Orange's 900 MHz licence.

Elsewhere in Europe:

- **Belgium**: The Belgian Institute for Post and Telecommunications announced the award of a fourth 3G license in late spring 2011 to Tecteo Telenet Bidco, a consortium of Belgian cable TV companies. It planned to hold a 4G spectrum auction for the 2.6 GHz band in late November 2011.
- **Denmark**: A government report indicated that regulators would have to allocate an additional 600 MHz of spectrum to achieve a government goal of universal 100 Mbit/s download speeds in the country by 2012.
- **Poland:** In September 2010, a consortium of smaller operators became the first entity to use the 1800 MHz band to offer LTE. The Polish government, meanwhile, also planned to auction the 800 MHz and 2.6 GHz bands
- **Portugal:** Regulator Anacom was planning in June 2011 to auction as many as six bands suitable for 4G services (450 MHz, 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz), hoping to garner at least EUR 450 million.[54]
- **Switzerland**: The Federal Communications Commission delayed a planned "big bang" auction of multiple IMT bands until 2012, with applications to be submitted in September 2011.
- **United Kingdom**: The UK plans to auction spectrum in the 800 MHz and 2.6 GHz bands in 2012; meanwhile, unlike some other European countries, it is permitting 2G operators to refarm the 900 MHz band for 3G offerings.[55]

The prevailing trend in Europe appeared to be action to auction or otherwise allocate and assign spectrum in multiple bands – most often 800 MHz and 2.6 GHz, but other bands, as well. It was common for governments to set spectrum caps on some or all of the bands being offered, as a way to encourage new entrants. In addition, many of the new licenses had build-out requirements, particularly for rural areas that might not otherwise have options for broadband services.

4.3.2 Asia and Asia-Pacific

In 2010**, India's** Department of Telecommunications (DOT) conducted two wireless spectrum auctions for third generation (3G) and Broadband Wireless Access (BWA) licenses in sequential fashion. DOT expected a total of USD 8 billion in revenues from the two auctions. In the end, the auctions raised nearly USD 23 billion,[56] an amount nearly triple the expected total.[57]

India decided to hold two sequential auctions:

1) For 3G licenses in 1.9 GHz/2.1GHz and
2) For BWA licenses in 2.3 GHz.

Meanwhile, two incumbents, BSNL and MTNL, had already been given 3G and BWA spectrum and had launched services. As part of the conditions for receiving the licenses in advance, DOT required BSNL and MTNL to pay the same amount as the highest private bid in the regions they received spectrum.[58]

India's telecommunications market is divided into 22 service areas, called "circles". In the 3G auction, DOT offered three or four 2 ×5 MHz licenses in each of the circles. Three licenses were offered in most areas. For the BWA auction, two unpaired 20 MHz bandwidth licenses were offered. Nine telecom firms applied to bid in the 3G auction and eleven firms applied to bid in the BWA auction. In both cases, DOT conducted a simultaneous auction for all 22 circles, using a multiple-round clock auction format where bidders could either accept or reject open posted bids. Bidders placed bids on each of the service areas. This type of auction was designed to prevent predatory jump bidding and reduce the risk of unsold lots. Activity rules were put in place that required bidders to preserve their rights to bid in subsequent rounds. Bidding rights were determined on an eligibility-point system, and the bidders' earnest money deposits determined their starting eligibility.

As the auction progressed, the bidders' continued eligibility was based on bidding activity in the previous round, and the bidding activity requirements began to increase, starting at 80 per cent activity and increasing up to 90 per cent and then 100 per cent. When all bidders exhausted their activity requirements, the auction ended. The rules were put in place to minimize collusion and promote transparent and open bidding.[59]

For the government, the auction was a huge success. However, the higher than expected totals raised concern that operators paid too much and that they may have difficulty funding network construction costs and recouping their spectrum costs. The operators themselves expressed worries that the auction design drove prices beyond levels that were financially prudent, though that did not stop them from bidding altogether.[60]

In **Hong Kong, China**, the designated 4G auction (of 90 megahertz of paired spectrum in the 2.6 GHz band) was completed in early 2009. The three winning bids were assessed a total of USD 196.9 million in spectrum fees – which translated into USD 0.31 per MHz pop. This spectrum was widely considered appropriate for LTE, but an additional 90 megahertz offered at 2.3 GHz (and considered appropriate for WiMAX) went unsold. It was believed that the reserve price was not met for the 2.3 GHz spectrum.[61] More recently, two of Hong Kong's existing operators, Hutchison Telephone Co. and SmarTone-Vodafone, won paired bands of spectrum in the 800-900 MHz range, which was thought to be suitable for augmenting either HSPA+ services (3G) or LTE. The regulator, known as the Office of the Telecommunications Authority (OFTA), noted that the volume of mobile data traffic mushroomed 189 per cent from December 2009 to December 2010.[62]

Singapore's third-largest operator, M1, won an additional pair of 2 X 5 megahertz in April 2011 to add to its original holdings of 3G spectrum first awarded in 2001. M1 outbid its rivals, SingTel and StarHub, pledging USD 17.38 million, which was well above the (very low) reserve price of USD 320,000. The Info-communications Development Authority (IDA), meanwhile, reportedly was planning an auction of 2.3 GHz and 2.6 GHz spectrum for 4G in early 2012. At the same time, IDA also has opened up the existing 900 MHz and 1800 MHz bands for LTE refarming in advance of that auction.[63]

Not all of the Asia-Pacific countries were proceeding in a direct line to 3G and 4G licensing, however. In April 2010, a **Philippine** court stopped that nation's auction of the last remaining 2 × 10 megahertz of 3G spectrum in the 2.1 GHz band. The same month, a congressional advisory panel indicated that spectrum fees proposed by the National Telecommunications Commission for the 2.5 GHz band were, at up to USD 252,000 per MHz, potentially too high and could lead to excessive consumer broadband rates. And a year later, a legal and lobbying battle erupted over the proposal by Smart Telecom, the mobile arm of the incumbent PLDT, to acquire the third-largest mobile operator, Sun Cellular (a subsidiary of Digitel Telecommunications). Smart's main rival, Globe Telecom, complained that the consolidation would leave Smart with more than three times as much spectrum as Globe had in the 2.1 GHz 3G band.[64]

Similarly, in **Thailand**, a court placed an injunction on the planned auction of 2.1 GHz spectrum in September 2010, pending a ruling by the country's Constitutional Court on whether the National Telecommunications Commission had the authority to carry out the sale. Thailand was in the process of forming a combined National Broadcasting and Telecommunications Commission.[65]

In **Australia**, the policy of promoting BWA development through spectrum distribution has been a bit complicated by another contender for the frequencies: the nation's public safety emergency responders. Fresh off of a series of natural disaster in recent years – including a cyclone, flooding and severe wildfires – the Police Federation of Australia urged the federal government to hold back 20 megahertz of spectrum from the digital dividend to distribute to fire, police and rescue services. The situation closely resembles a similar policy discussion in the United States to reserve the 700 MHz D Block for a nationwide interoperable public safety network. Indeed, proponents of the public safety hold-back in Australia cited the U.S. case, while opponents pointed to the plan's variance with the regional band plan adopted in the remainder of the Asia-Pacific region.[66]

4.3.3 Arab States

In the Gulf region, several multi-national operators have emerged – most notably Zain (Kuwait), Etisalat (UAE) and Qtel (Qatar). These pan-Arab operators have diversified their holdings around the region, and in sub-Saharan Africa, as well, establishing a fierce rivalry for subscribers. As a result, Etisalat serves an estimated 94 million subscribers in 17 countries, While Zain has 72 million subscribers across 24 countries and Qtel operates in 16 countries with 30 million subscribers.

Several countries have moved ahead with 3G allocations, although progress has been somewhat halting in a few of them. **Jordan** issued its first 3G license in 2009 after an abortive attempt to hold an auction. Only two of the country's three 2G carriers, Orange and Zain, bid for the license, with the third, Umniah (a subsidiary of the Bahraini company Batelco) claiming that the USD 70 million price for the license was too high. Umniah instead announced that it would develop a WiMAX network using 3.5 GHz spectrum it had won in a closed-bid tender in 2006, for just USD 11 million. Meanwhile, the Telecommunications Regulatory Commission (TRC) initially rejected the Zain and Orange 3G bids for not meeting its specifications. Ultimately, Orange won the license after a lengthy negotiation with TRC. As a result, Orange won an 18-month exclusivity period before TRC could issue a competing 3G license to another operator. Finally, two years later, Zain was preparing in early 2011 to enter the market following the lapse of Orange's temporary monopoly.[67]

Elsewhere in the region, **Bahrain** was first off the mark in announcing the first 4G LTE network in 2009, to be operated by Zain. Not far behind were Zain networks in **Saudi Arabia** and **Kuwait**.[68]

4.3.4 The Americas

Countries in both North America and South America have been proceeding to make spectrum available for 3G and, more recently, 4G services – including so-called "digital dividend" spectrum. The following sections summarize developments in several of the major economies:

- **Argentina**: The communications ministry announced plans to auction spectrum in the 830-879 MHz and 1890-1985 MHz bands in the latter half of 2011. Minimum bid prices for the spectrum were set at between USD 600,000 and USD 6 million, depending on the service area and the spectrum band. Bidders were required to post a USD 1.3 million deposit and pledge to build out coverage to their areas within five years. At least 30 per cent of the network equipment must be from local vendors in Argentina.[69]
- **Brazil**: Anatel, the national telecoms regulator, announced plans in 2010 to make available several bands for BWA. Addressing the 2.5 GHz band, Anatel announced that existing holders of

MMDS licenses would be granted authority to use a 50 MHz block to provide TDD services or resell, as well as two 10-megahertz blocks for FDD. The remaining 120 MHz was to be sold on a technology-neutral basis, either as three lots of 2 X 20 megahertz (paired) or two lots of 2 × 10 megahertz paired. The goal was to make the 2.5 GHz band available in time for the 2014 football (soccer) World Cup slated to be held in Brazil. Meanwhile, Anatel also announced plans to conduct a “super auction” of 165 licenses in five different bands: 800 MHz, 900 MHz, 180 MHz and 2100 MHz. Brazil’s regulatory structure, like many others, includes build-out requirements and spectrum caps.[70]

- **Canada**: In August 2009, Industry Canada auctioned 282 licenses in its advanced wireless service (AWS) auction of spectrum in the 2 GHz band. Fifteen companies won access to 105 megahertz of spectrum, paying a collective total of CAD 4.3 billion (EUR 2.7 billion). The result was more than four times what the government had predicted, although analysts suggested that the forecast had been deliberately kept low in order to avoid failed expectations. Since Canada had only three major wireless operators, the auction brought numerous market entrants, including some affiliated with cable TV companies. Other companies were clearly regional in scope, although they could achieve a national footprint through post-auction spectrum trading.[71]
- **Colombia**: The government was engaged in an extensive auction programme in 2011, having already sold part of the 2.6 GHz band. Further auctions were being prepared for the 1900 MHz band, the AWS band (1.7 GHz/2.1 GHz paired), 1900 GHz and the remainder of 2.6 GHz. The plans were to culminate in the sale of spectrum in the 700 MHz digital dividend band in 2012 or 2013. All this work had been pioneered by a new National Spectrum Agency (ANE) created in 2009 with a mandate to allocate and release some 300 megahertz into the market. Spectrum caps would mean that no operator would be allowed to hold more than 55 megahertz, leading operators to seek a higher cap in order to alleviate their claims of spectrum constraints.[72]
- **Mexico**: In contrast to its North American neighbors, Mexico faced a situation in which the 2.6 GHz band contained an MMDS licensee that would not go away. Rather than relinquish or resell the spectrum to a wireless operator, broadcaster MVS Telecomunicaciones planned to retain its existing license, then roll out a nationwide LTE network through a consortium of international and Mexican partners. Reportedly, firms interested in the venture included Intel, Clearwire, Japan’s KDDI and Mexican fixed-line operator Alestra.[73] In addition, Mexican President Felipe Calderon has announced that the 700 MHz band will be auctioned in 2012, then cleared in 2015, accelerating the planned analog TV switchover by seven years.[74]
- **United States**: A leader in effort to distribute spectrum via auctions, Washington had already sold large blocks of spectrum in the AWS band and in the 700 MHz digital dividend band by 2008. In addition, the 2.6 GHz band was available for technology-neutral development of wireless services, with the country’s number three operator, Sprint, employing the band to pioneer WiMAX services. These bands all will be employed for LTE roll-outs by major carriers in the near future. Nevertheless, the Federal Communications Commission (FCC) in early 2010 identified a need to reallocate a further 500 megahertz of spectrum for continued development of BWA in the U.S. Congress and the Executive Branch are actively exploring several additional bands for reallocation, including the 1755-1850 MHz band and part of the 1675-1710 MHz band, among others. In addition, pending legislation in Congress would authorize the FCC to hold incentive auctions to attract broadcasters to voluntarily sell some or all of their remaining spectrum holdings, which already were reduced in the 700 MHz digital relocation and subsequent auction.

Freeing up the digital dividend spectrum appeared to be a major pre-occupation on both continents, as regulators worked to decide whether to select the entire 698-806 MHz option, or whether to auction only the upper band above 790 MHz. In Latin America, most major economies have begun the process of realizing, or at least exploring, the digital dividend in one way or another, including Chile, Argentina, Uruguay, Brazil and Colombia, although the latter two countries have greater broadcasting interests to placate. Chile and Argentina were likely to be pioneers in using the band for BWA, and Mexico would be key in harmonizing the band plans between North America and the remainder of Latin America.[75]

4.3.5 Africa

With African countries still enjoying rapid growth in 2G mobile services, the ramp-up of 3G and 4G services has been a bit slower than in other, more saturated markets. **Uganda** made several bands available for evolving 3G services, although it did not conduct an auction. The Uganda Communications Commission (UCC) began the process by conducting an international benchmarking analysis, and by referring to international standards, to determine how much spectrum should be made available for each potential operator. The UCC attempted to make assignments of equal amounts/blocks of spectrum per operator, in conformance with the national Table of Allocations.

Meanwhile, the UCC did not set a reserve price or threshold bidding level; rather, it set prices for spectrum on a cost-recovery basis, while recognizing the value of each different band. That yielded slightly different per-megahertz spectrum fees for different bands:

- 2.3 GHz/2.5 GHz/3.3 GHz – Approximately USD 7,000.
- 1.9/2.1 GHz (3G) – USD 23,000 to USD 47,000.

Uganda used a first-come, first-served system of assignment and did not resort to competitive bidding, although policy guidelines do allow for market-based approaches such as bidding or for beauty contest selections when necessary. Neither of those methodologies has been utilized yet, because policy-makers did not feel they were necessary in the circumstances. Nevertheless, some 80 per cent of the allocated spectrum has been assigned. Build-out is ongoing; some 40 per cent of the networks have been installed to date. The UCC is planning to conduct a comprehensive study to determine, among other things, whether the spectrum fees accurately reflect market demand for spectrum in Uganda.[76]

In **South Africa**, ICASA's first attempt to license spectrum for BWA in the 2.6 GHZ and 3.5 GHz bands ran into difficulties and had to be delayed. ICASA had engineered a hybrid assignment process, involving a first-stage "beauty contest" to pre-qualify bidders for an eventual second-stage auction. But the regulator had difficulty designing an auction or finding a qualified auctioneer to run it. There were also questions concerning South Africa's band plan, which differed from that of other countries in the region.[77]

Other recent activities in Africa include:

- **Cameroon**: 4G Cameroon, a subsidiary of the Swiss-based company 4G Africa AG, has begun offering WiMAX (IEEE 802.16(e)) service in the major cities of Douala and Yaounde. Marketed under the name "YooMee," the service provides download speeds of about 640 kilobits per second for retail customers and 1 Mbit/s for enterprise customers.[78]
- **Ghana**: DiscoveryTel is deploying a 4G network built on a turnkey basis by INTRACOM TELECOM, with equipment provided by Aptilo Networks. The WiMAX-based network technology can operate in both the 2.5 GHz and 3.4 GHz bands.[79]
- **Nigeria**: In March 2010, Mobitel Nigeria Ltd obtained a 2.3 GHz license to offer 4G (WiMAX) service, beginning in Lagos. Mobitel planned to have full national coverage by mid-2012.[80]

Also, African operators will increasingly be able to take advantage of region backhaul and international backbone solutions, such as new undersea cables and (among others), the Yahsat satellite project funded by Mubadala, the investment and development arm of the Abu Dhabi government.[81]

4.4 Pricing Trends

With this survey, three key trends appear to emerge. First, the already-developed markets appear to have felt much earlier the impetus to redevelop spectrum bands for broadband usage. Driven by the profusion of applications, networks in developed economies are already starting to strain (in some areas if not others) at limited capacity. This trend would appear to overlay the existing patterns of Internet traffic, which remains at orders of magnitude greater in the transatlantic and transpacific routes than among other international traffic routes. This would point to an underlining of current trends in backbone usage, with all of the attendant issues of international access and pricing that accompany this. In other words, it could be that mobile data growth is exacerbating imbalances in Internet traffic.

Second, from a spectrum use perspective, allocation patterns appear to be driving ever lower on the international allocation chart**.** For now, equipment manufacturers and operators appear to be seeking spectrum in bands no higher than 2.6 GHz – and increasingly in the digital dividend spectrum at 700 MHz and 800 MHz. This is not surprising, given two factors (a) the availability of economies of scale as manufacturers build equipment for these bands, and (b) the nearly ideal spectrum propagation characteristics of these bands. Both of these factors promise lower network construction costs, with fewer base stations than at higher bands, and with less interference and lower per-unit equipment costs.

The third trend appears to be declining relative prices for spectrum access. The online newsletter PolicyTracker did a survey in June 2011 of more than 200 auctions of mobile service licenses over the previous decade.[82] It found that, adjusted for inflation, auction prices appeared to be declining throughout the decade, even as spectrum blocks with much better propagation characteristics were opened up for distribution. The newer bands, such as the 700/800 MHz and 2.6 GHz bands, were shaping up as relative bargains when compared with the initial 3G band (2.1 GHz) that was initially launched in the early 2000s. For example, the average price/MHz/pop for 2.1 GHz spectrum was USD 1.33 since 2000. Even when the “bubble” prices of the initial auctions were removed from the average, the average price/MHz/pop was USD 0.90. By comparison, the average price/MHz/pop for 700 MHz and 800 MHz auctions was USD 0.91, even though these bands are far more economical to employ from an infrastructure perspective. The 2.6 GHz average price/MHz/pop was an order of magnitude lower, at USD 0.07 from 2005 onwards.

PolicyTracker posited three possible reasons for the easing of spectrum prices:

- **Greater availability of spectrum** – Governments are moving with alacrity to distribute more spectrum, amid alarms of a potential “crisis” of spectrum scarcity (which has not yet appeared evident in pricing trends);
- **Stability of markets and business plans** – Unlike the advent of mobile data services 10 years ago, operators in many countries now have a mature viewpoint of the growth of their markets and have adjusted their spectrum spending patterns accordingly;
- **Industry consolidation** – PolicyTracker noted that consolidation among market players might be pruning the number of potential market entrants with sufficient capital to bid up prices in new markets.

5 Bringing It All Together: A Spectrum Pricing Checklist

Having explored the concepts underlying valuation – both in the economic and, to some extent, social contexts – this paper now turns to a practical approach to considering how to price spectrum. This section consists of a brief “checklist” of steps that should be taken to proceed from policy to payment, in terms of considering national goals, economic realities and market pressures. While not exhaustive, this checklist should provide an idea of the scope of issues and factors to be considered in pricing and distributing spectrum access.

□ **Assess and weigh each national goal to be achieved via a spectrum distribution.** Setting national policy goals should be the starting point of all attempts to attach value to spectrum as a public resource.

National Goals for spectrum distribution may include:

- Efficient and productive usage of the spectrum resource
- Rapid and effective introduction of a new wireless technology (i.e., BWA).

- Reduction of the digital divide, through the development of wireless service in remote, rural or generally low population density areas (i.e., universal access)
- Protection or promotion of social welfare and/or public service
- Minimization of potential interference and coexistence issues
- Government revenue generation

□ **Determine how much spectrum is appropriate to distribute at this juncture.** Based on the policy goals identified, and considerations of market structure and competition policy, governments may wish to consider allowing as few as two new operators, or as many as five or more.

Steps/Factors to Consider

- □ Analyze technology standards to determine optimal channel and band plans, taking into account international spectrum harmonization (e.g. ITU and regionally harmonized band plans for IMT).
- □ Assess the market (i.e., how many licenses to distribute, how much demand is there from operators, etc.)
- □ Conduct a benchmarking process to determine how much spectrum similar economies have allocated.
- □ Weigh the need for new spectrum allocations against current uses in the international and national allocation tables. In particular, take into account the need to comply with international obligations and to use spectrum in a way that can reasonably be made compatible with neighboring countries.
- □ Weigh the implications of any spectrum allocation decision on existing services in the band, in particular on the potential financial and legal implications of the reallocations that will be made necessary by this decision.

□ **Consider Non-Market Approaches.** Depending on national goals and an assessment of national market conditions, it might make more sense to utilize a non-market approach, such as license-exempt or first-come, first-served distribution of licenses. This may be particularly relevant to bands allocated for public safety or other non-commercial uses, or for applications in the fixed service (e.g. radio relays).

Steps/Factors to Consider

- □ Consider whether an unlicensed approach provides greater economic returns
- □ Consider whether a non-commercial use such as promoting the development of public safety networks, would be desirable.
- □ Consider a process of soliciting applications and awarding licenses on a first-come, first-served basis, either at no cost to the operator, or with fees designed only to recover regulatory costs.

□ **Determine the assignment method for competitive spectrum bands.** For many of the bands suitable for BWA, there likely will be several potential applicants for each available spectrum block, requiring an assignment process that will apportion spectrum rights to the most qualified and/or financially capitalized operators. Potential assignment methods can include administrative evaluations or “beauty contests,” closed-bid tenders, or open, multi-round auctions.

Steps/Factors to Consider

- □ Assess the attractiveness of the market, as well as the specific spectrum opportunity on offer, from the perspective of potential bidders.
  - Use benchmarking to gather data on similar offerings in nearby or similar countries
  - Consider a thorough risk-benefit analysis
- □ Consider resources and staff expertise to determine capability of the spectrum regulatory agency to hold auctions.
  - Outside contractors can provide expertise in designing and holding auction processes.

□ **Calculate a monetary value, defined in terms of per megahertz pop, for the spectrum offer.** The valuation will help determine a reasonable expectation of market-based revenues for the spectrum. If there is a beauty contest or other administrative distribution process, the valuation will help to set the administrative incentive price, based on opportunity cost. For auctions, the valuation will help to determine the reserve price for each spectrum block. The valuation also will help to set reasonable levels for up-front or recurring spectrum fees that will not over-burden operators or serve as a disincentive to investment.

- □ Employ international benchmarking to help determine the valuation of each spectrum block in similar economies
- □ Calculate the opportunity cost associated with investing in the spectrum opportunity on offer
- □ Utilize a *net project* costing approach to calculate the value of the spectrum as an input to the total value of the built-out future network.
- □ Discount the valuation based on any potential negative market barriers or market conditions (i.e., market-specific or situational factors), such as a worldwide capital shortage, over-supply of spectrum or difficult terrain/build-out conditions.

□ **Design a competitive tender or auction.** *If* it is determined that a competitive bidding process or auction is the desired assignment method, proceed to discuss and set rules for bidding.

- □ Draft rules for use of the spectrum (i.e., license parameters, coverage obligations, obligations relating to the interference caused to/by other services in the band or in adjacent bands, technology neutrality)
- □ Clarify the international situation (i.e. what is the situation of interference that may be caused to the licensed network in border areas, what are the commitments taken by the government to protect the services of other countries and those taken by other goverments to protect the licensed network)
- □ Clarify the obligations in terms of protection of the public against electromagnetic waves
- □ Set license terms and conditions (i.e regulatory fees, term limits, renewal criteria, etc.)
- □ Set auction rules
  - Consider spectrum distribution goals
  - Consider steps to curb collusive behavior
- □ **Best Practice**: Seek public input and promote transparency of rule-setting
- □ Spread the word!
  - Draft prospectus materials covering full range of spectrum and market environments
  - Conduct operator outreach activities such as road shows, visits and responses to queries
  - **Best Practice**: Continue emphasis on transparency, openness and responsiveness

- **Pre-qualification.** Even in the case of competitive bidding, governments commonly ask potential bidders to report their qualifications in terms of financing, operational experience in other countries, and management capabilities.

  Factors to Consider

  - Establish bidder criteria a clear and open manner
  - Publish pre-qualification criteria as part of the initial announcement of the bidding opportunity.
  - **Best Practice**: After the solicitation of bids is sent out, pre-qualification criteria should not be altered
  - **Cautionary Note**: Any failure to adhere to published, transparent pre-qualification criteria will undermine the auction's credibility

- **Auction infrastructure and procedures.** Depending on how complex the auction will be, governments will need to establish computer systems, obtain computer hardware and software, and train personnel to carry out the auction process. These are highly specialized capabilities, and governments may need to obtain them from vendors or consultants, either domestically or from other countries. In fact, governments may conduct bidding processes to determine which entity is best capable of running the auctions – i.e., a bidding process to determine who will run the bidding process!

  Steps/Factors to Consider

  - Employ a neutral approach to designing and operating the auction
  - Design and installation of auction software and hardware is important to the integrity and effectiveness of the auction.
  - Develop security and cyber-security of the auction facilities – this is of paramount importance. With large sums of money at stake, operators can be tempted to hack into computer systems, or physically gain access to auction facilities, either to gain information, to coordinate/collude in bidding activities, or even to alter results. The physical and electronic integrity of bidding processes and facilities is a real – and crucial – consideration.
  - Develop contingency and troubleshooting plans
  - **Best Practice**: Test end-to-end auction procedures, systems, and technologies used prior to the actual auction

- **Follow-up policies and rules.** A competitive bidding process to distribute spectrum does not end once the auction determines the winner(s). There are several key steps after the auction, which governments should not ignore. These include ensuring that winning bidders actually make up-front initial auction payments without delay or default, and that they adhere to schedules for business incorporation, construction permits, customs clearances, build-out milestones, etc.

  Factors to Consider

  - Formulate and publish policies and rules for post-auction payments (including any installment payment plans) well in advance
  - Determine and publish penalties and policies for auction payment defaults
  - Set re-auction timing in case of payment or other default
  - Monitor and follow-up on rules requiring business processes, equipment importation, permitting, network build-out milestones, etc.

6 Conclusion

As with any endeavor associated with the "soft science" of economics, there is no single rubric to value spectrum across all uses, all jurisdictions, or all periods time. Economists have developed useful concepts and tools to help represent the value that spectrum can have as an input to commercial wireless networks and services. At this juncture, however, it is not clear that governments are universally employing these tools, or that these tools have been refined sufficiently to uniformly forecast or "predict" the market value of spectrum.

Perhaps there are too many variables, representing fluctuations not only across different markets, but over time. In addition, there are no easy answers for comparing values among spectrum bands that continue to be used by different kinds of users (government agencies, commercial wireless companies and even individuals) and for vastly different purposes (transmitting voice and data, remote sensing, radars, weapons systems and baby monitors).

Yet, development of commercial valuation, carefully nurtured over the past two decades, is rapidly growing in importance in considerations of spectrum, for better or worse. It certainly will strongly influence the way spectrum for BWA services will be distributed for the foreseeable future. So large are the bandwidth requirements – as well as the potential revenues – that it is extremely unlikely that any methodology other than market forces (or a proxy such as AIP) will be used to distribute 3G and 4G spectrum, at least in countries where spectrum access already is constrained. This means that there will be a growing body of economic data and best practices to help instruct regulators as to how to determine opportunity costs, set bidding thresholds and design auctions. Indeed, many countries are adoption auction processes and generating data that can be benchmarked for even more market-based distribution programmes.

Meanwhile, there is more work to be done in extending valuation to spectrum uses that are not direct, quantifiable inputs into economically productive enterprises – and for users that are not profit-making or profit-generating entities. As a basic starting point, it should be possible to draw inferences on value from the productivity generated by unlicensed spectrum use, if only indirectly. Studies could be undertaken to quantify the investment into equipment, marketing and operations of services and products that utilize unlicensed spectrum. Such techniques could then be extrapolated to attach a value to public sector uses of spectrum, even if such spectrum is never sold or traded.

Even so, such valuation exercises can represent only the quantifiable or economic valuation of spectrum – the amount any entity is willing to pay to prevent any other user from obtaining the exclusive right to it. A broader perspective may be needed to take into consideration the social value of spectrum – the value of spectrum used for non-profit-making enterprises such as weather prediction, scientific inquiry, emergency response or national defense. Individuals certainly have an expectation that they will benefit from these activities, but they usually do not think of themselves as "customers" of these societal benefits. Indeed, individual consumers usually are uninformed about spectrum-use decisions that are made on their behalf by their governments and thus have no way to signal to their representatives how much they are willing to "pay" for spectrum. Governments, similarly, have no mechanism (other than general taxation) to "charge" citizens for spectrum used in the interest of the common good. Until this disconnect is addressed, spectrum *value* will continue to have multiple meanings – one for making money, and one for making policy.

1 See "The World in 2010, ICT Facts and Figures, The Rise of 3G", ITU, available at www.itu.int/ITU-D/ict/material/FactsFigures2010.pdf.

2 See "Spectrum Pricing", V Nozdrin, ITU Paper, Radiocommunication Seminar, 29 September-3 October 2003, Lusaka, Zambia.

3 See Wellenius and Neto, 2007.

4 See "Using Market-Based Spectrum Policy to Promote the Public Interest", Gregory L. Rosston and Jeffrey S. Steinberg, Federal Communications Law Journal, Volume 50, Number 1, 1997, available at www.law.indiana.edu/fclj/pubs/v50/no1/rosston.html.

5 The concepts of "property rights" and "flexible use" go hand-in-glove and often are used almost interchangeably. Technically, however, the *property rights model* originated to describe the concept of auctioning spectrum rights for original distribution – a concept in which the "buyer" gains exclusive access to a block of spectrum (for a defined period of time) via a market transaction. Later policy innovations added the flexibility element, allowing licensees to determine how to use the spectrum licensed to them. The two concepts, however, are not identical, and in fact many licenses have been auctioned to companies without granting them any real flexibility of use.

6 Marks, Phillipa, et al., "Estimating the Commercial Trading Value of Spectrum", Plum Consulting report for UK Office of Communications, 2 July 2009, p. 3. ("Plum 2009 Ofcom report").

7 See Review of Radio Spectrum Management, Professor Martin Cave for Department of Trade Industry, Her Majesty's Treasury, March 2002, available at: www.ofcom.org.uk/static/archive/ra/spectrum-review/2002review/1_whole_job.pdf ("2002 U.K. Review of Radio Spectrum").

8 Id.

9 Id.

10 Plum 2009 Ofcom report, P. 2.

11 See Plum Final Report.

12 See Administrative Incentive Pricing of Radiofrequency Spectrum, Final Report of ACMA, Plum Consulting, Oct. 23, 2008 ("Plum Final Report").

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