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Smart Regulation for a Broadband

Reports (Background Documents)

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.

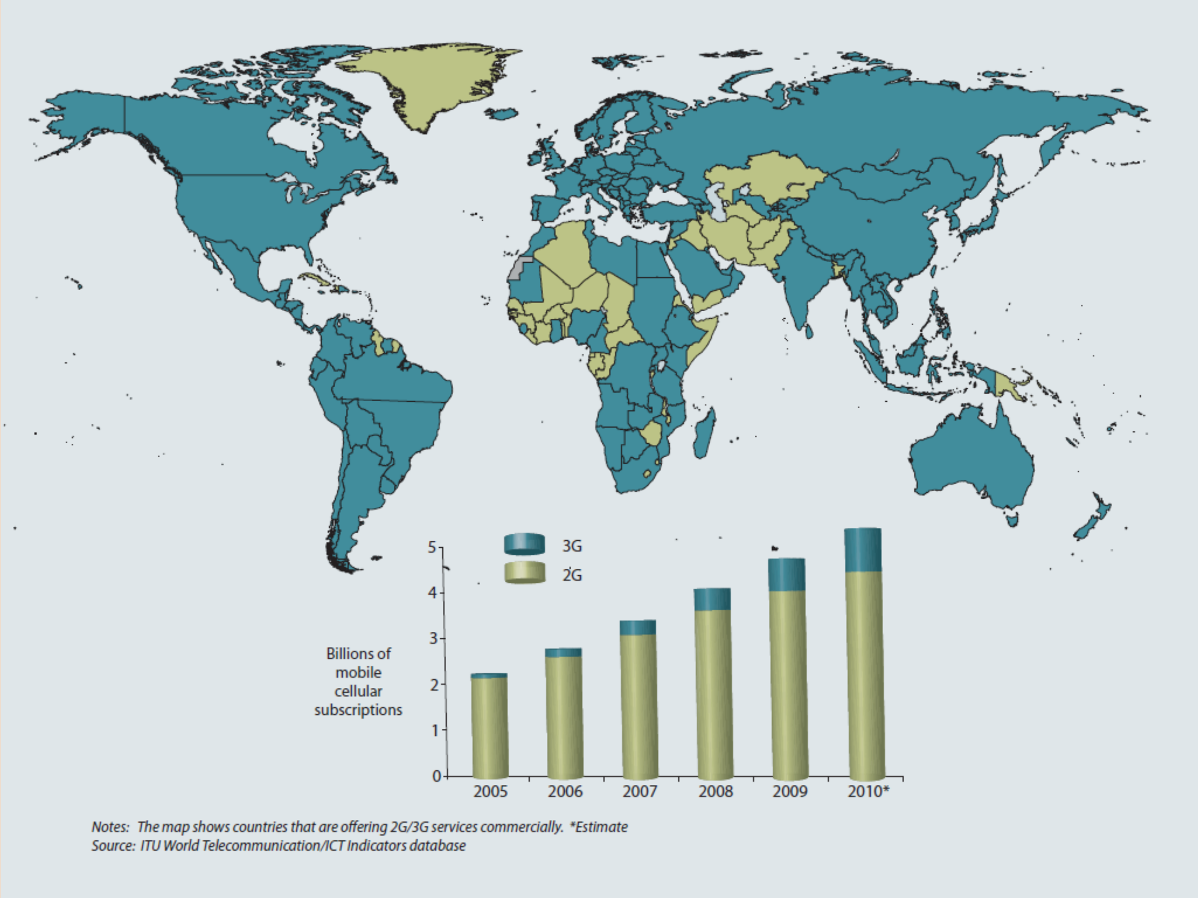
This paper explores the current economic philosophies and public policy debates over spectrum valuation – particularly in light of the overwhelming demand for new spectrum resources for broadband wireless access (BWA) services. It reviews the growing body of thought about valuation, as well as the variables 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.

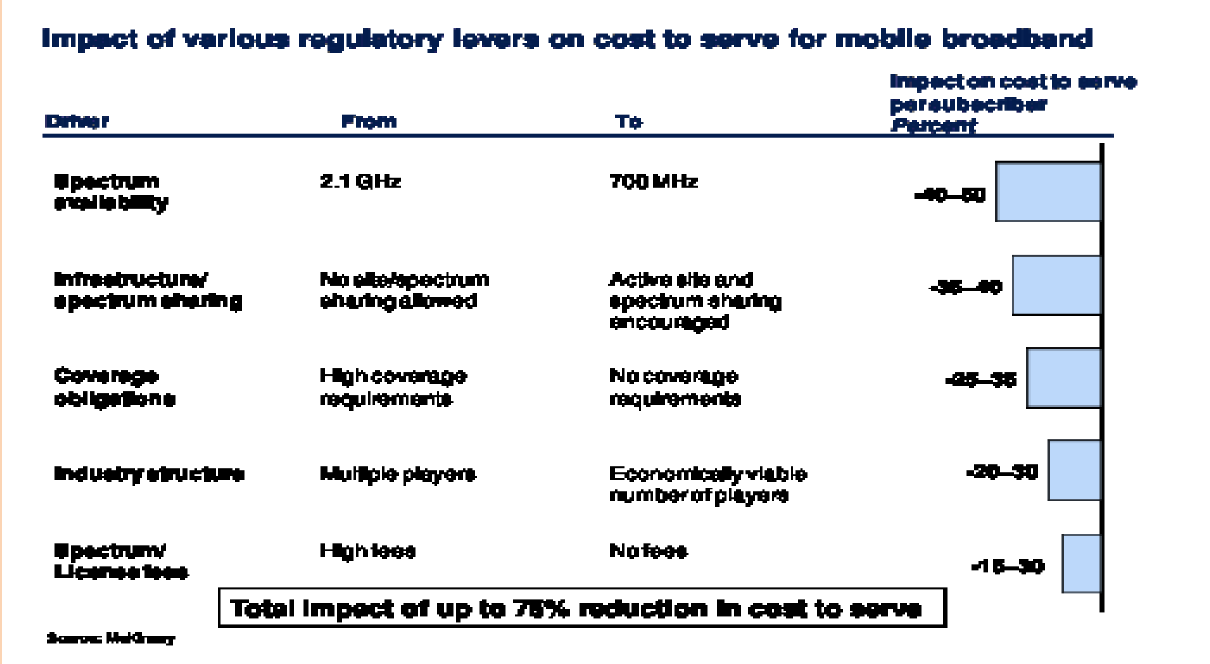
- **Spectrum protection obligations:** another important valuation element of spectrum is the level of interference protection that future licensees will be offered/required to offer to/from the services authorized in:

  - 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.



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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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Regulation of Global Broadband Satellite Communications

GSR Advanced Copy

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Work in progress, for discussion purposes

Comments are welcome!

Please send your comments on this paper at: gsr@itu.int by 7 October 2011.

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

This report has been prepared for ITU by Rajesh Mehrotra, Founder and Principal Consultant, Red Books

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1.1 Introduction: Satellites for smart broadband solutions

Commercial satellites had a shaky start. When the first working model of an artificial satellite by Hughes Aircraft was displayed from the top of the Eiffel Tower, in 1961at the Paris Air Show, the sceptics remarked that it was as high as it would go[1]. Today, with over 900 satellites orbiting the Earth[2] the proponents of satellite technology are having the last laugh.

Around the mid 1990s, "packet-switching technology" and "the Internet" – both of which led directly to the development of broadband technology, satellite and terrestrial networking enabled multimedia traffic, voice/video/data/fax, to be carried over 'converged' data networks. The terms Voice Over IP (VoIP) and IP Telephony (IPT) were introduced to describe how circuit switched voice signals were converted into data packets for transport on IP networks.[3] Since the opportunities for convergence of data, voice and multimedia (video) on the same network are now offered by IP, satellites, with their inherent strength to cover mass geographical coverage are offering a sound solution. Satellites are therefore seen as powerful transmission tools for broadband applications.

But many regulatory barriers and uncertainties need to be overcome, at both the international and national levels.

This paper defines the universe of broadband satellite technology and explains why it is so vital for the expansion of multimedia services and applications around the world. In order to help readers fully appreciate the potential of satellites, this paper will briefly describe their system architectures, the technical characteristics of air interfaces, [4] and the different broadband services and applications that can be delivered through satellite systems. Subsequently, the paper deals with international, regional & national practices for satellite system approaches for broadband delivery. Description of satellite as a component of `IMT-advanced' and use of satellites for disaster relief work is then explained. ITU practices for use of spectrum/orbit resource and some of the important satellite coordination issues that have the potential to block new satellites (including the ones that may serve the broadband markets) and that are to be discussed during the ITU World Radiocommunication Conference-12 (WRC-12) early in 2012, are then introduced. Aspects concerning the economics of satellites systems and market entry issues are followed by thoughts on best satellite regulation practices and challenges to further broadband access for all.

1.1.1 What is broadband and what does satellite broadband mean?

Broadband, which also may be referred to as `wideband' *i*s used frequently to indicate some form of high-speed access. There is however, no universally accepted definition for this term.

Broadband is frequently used to indicate an Internet connection at 256 kbit/s in one or both directions[i]. The FCC definition of broadband is 4.0 Mbit/s. The Organization of Economic Co-operation and Development (OECD) has defined broadband as 256 kbit/s in at least one direction and this bit rate is the most common baseline that is marketed as "broadband" around the world[5]. However, for the purposes intended in this paper, the term `broadband' refers to data rates that correspond to the user rate of 2 Mbit/s and higher (also refer section 1.2.4).

Not everyone is able to access DSL (Digital Subscriber Line) or cable service, particularly in rural areas, where the subscribers may not be well served by the phone centre. For those left out, satellite broadband can be the answer. The Internet feed is beamed from satellite to a dish installed at the subscriber's home. Typically, a two-way Internet access via satellites rather than dial-up, capable of delivering speeds equal to or greater than 2 Mbit/s downstream, and 1 Mbit/s upstream [6], would fall in the category of satellite broadband. Broadband satellite[7] also refers to systems that have the capability to receive and transmit `rich media content' from the satellite to the network end-users and between the end-users whether at home or in the office. Satellite broadband can also include a hybrid solution, where the "middle mile is provided via satellite and extended to end-users via terrestrial IMT technologies.

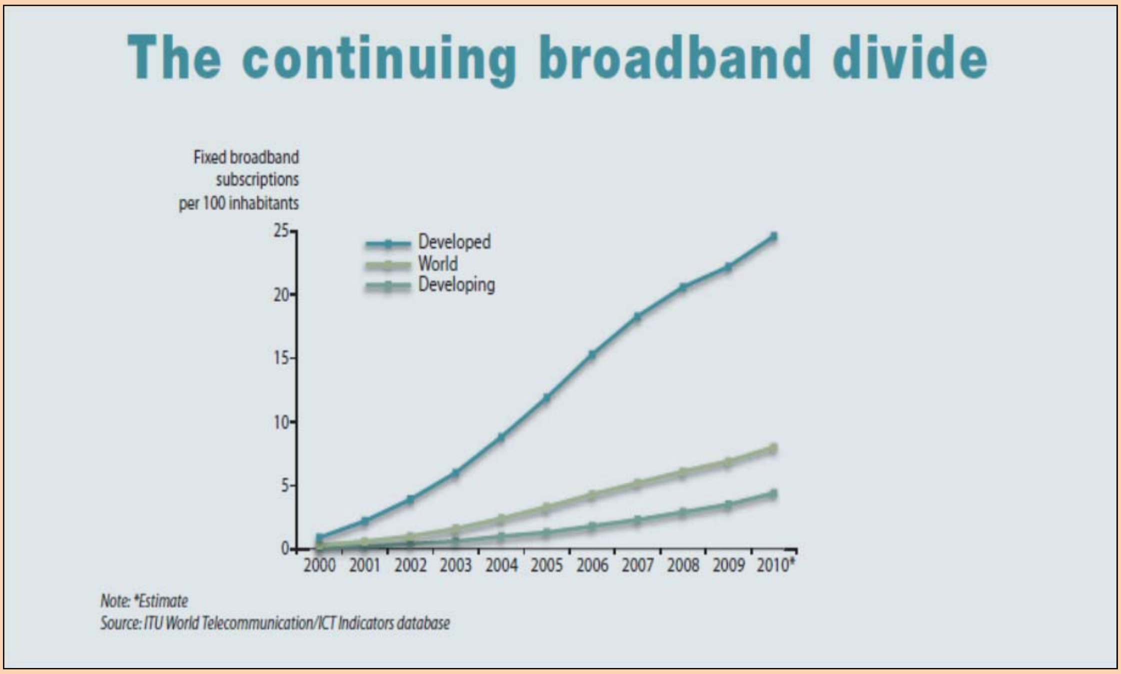
1.1.2 Why satellites for broadband delivery?

According to ITU World Telecommunication/ICT Indicators database[8], "There has been strong growth in fixed (wired) broadband subscriptions, in both developed and developing countries: at the end of 2010,

fixed (wired) broadband subscriptions reached 8% penetration, up from 6.9% penetration a year earlier. Despite these promising trends, penetration levels in developing countries remain low: 4.4 subscriptions per 100 people compared to 24.6 in developed countries."

Recognizing the fact that the Internet is a wealth generator and an important component in improving the lives of citizens, the answer is to deploy a network that has large coverage, is able to overcome long distances and inhospitable terrain and can be rapidly put in place. This is not an easy task. Satellite technology, however, is ideally suited to achieve this task.

Fig. 1.1: The Continuing Broadband Divide



Source: http://www.itu.int/ITU-D/ict/material/FactsFigures2010.pdf

The percentage of the world's population using Internet is just 28.7[9]. The chart below shows the statistics as of 30 June 2010. Africa, a continent where approximately 90 per cent of the citizens do not have Internet access, has fibre optic cable running around its coast but very little has been laid inland. There is little or no infrastructure for Internet access, often limited to urban areas, and they have wired and wireless voice access which are barely capable of providing dial-up Internet access[ii].

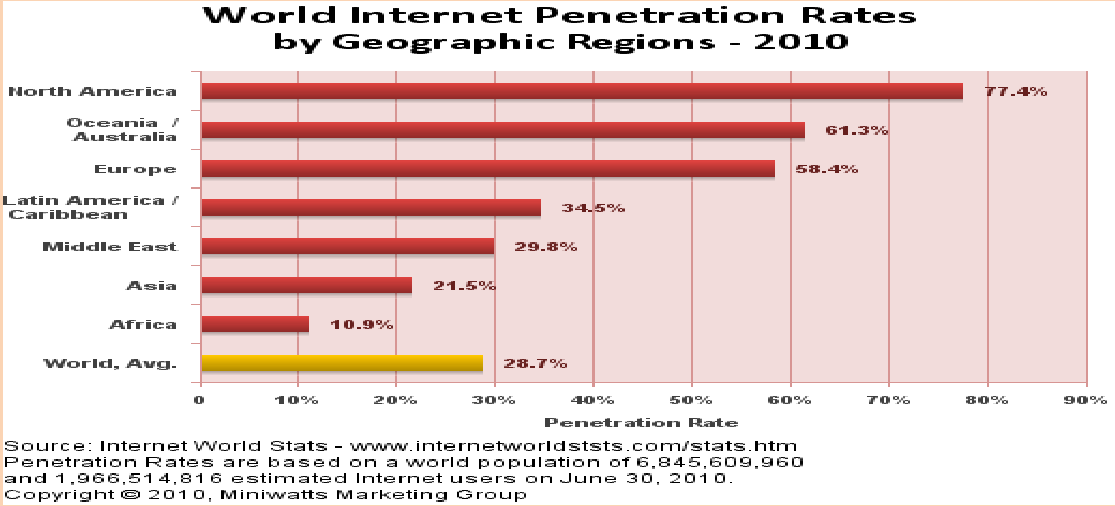
Satellite is an attractive option for businesses and government offices that cannot access other communications services, normally due to their remote or rural location. Compared with terrestrial installations, remote sites can be deployed very quickly with satellite access. Satellite broadband enables new applications that provide services to mobile sites – for example, ships, trains, planes and vehicles.

1.1.3 Satellite used for broadband communications – advantages and limitations

Satellites have been successfully serving the traditional markets i.e. telephony and broadcasting, covering large geographical areas using single beam/transmission. For satellite providers, their footprint is virtually limitless. There is a great demand for two-way broadband access over large geographical areas not served by telecommunication infrastructure. Satellite broadband is expected to serve as a `local-loop' in such areas.

Satellite telecommunications technology has the potential to accelerate the availability of high-speed Internet services in developing countries, including the least-developed countries, the land-locked and island nations, and economies in transition. There is a close link between the availability of a large-scale broadband infrastructure and the provision of public education, health, and trade services and on-line access to e-government and e-trade information. The use of ICT has helped in boosting economic growth in Africa, for example [10].

Fig. 1.2: World Internet Penetration Rates by Geographic Regions – 2010



Source: http://www.internetworldstats.com/stats.htm

Satellite represents instant infrastructure, independent of terrain or distance. Satellite can provide solutions in various ways – backhaul and last mile via wireless, Internet cafes, or directly to dishes at home.

Effectiveness of satellite broadband is more pronounced when it serves wide areas with global, regional or national coverage. There are no 'last mile issues' as there are with some traditional communication providers and the reliability is unmatched in situations when natural disasters or acts of terrorism knock out other modes of communications. Although satellites are generally designed for a 15 year life they often provide service for periods of 18 years or longer. Satellites are inherently highly reliable and provide a very high availability (up-time) compared with terrestrial solutions like fiber/copper cable or terrestrial wireless – particularly in developing countries where long sparse distances need to be covered.

However, costs have been coming down in recent years to the point that it is becoming more competitive with other broadband options A new generation of applications that need much high throughput requirements have emerged and satellites are meeting these high throughput needs. High satellite capacity – of the order of 100 Gbps coupled with multiple beams and multiple gateways, is resulting in a 100 to 1 reduction in cost per Mbps when compared to the 1 Gbps Ku band conventional satellites. Satellite systems are optimised for services like Internet access, Virtual Private Networks (VPN), personal access, etc. The adoptions of High Throughput Satellite-provisioned satellite broadband access services are believed to introduce a true paradigm shift in satellite broadband access services and will allow the industry to finally begin the process of "remaking" the satellite broadband access market into an offering that should compare favorably to a DSL services in many unserved or underserved markets."[iii].

Meanwhile, there are inherent latency (the time it takes to send and receive a message – 540ms to 800ms for a geostationary satellite in a typical environment) issues associated with the delivery of broadband using geo-stationary satellites. Latency is however not a problem for many applications like basic email access and web browsing. Thanks to improved technology – like TCP & protocol acceleration techniques[11], in most cases, latency is barely noticeable except for in real-time applications requiring real-time user input (like on-line video games). Since latency is due to the distance between the satellites and the earth, satellites in lower earth orbits have less latency than geostationary satellite networks.

Besides there are frequency dependent atmospheric/rain-attenuation problems for satellite signals especially in tropical areas – which creates issues primarily for higher frequencies like Ka-band. However with improved technology in place to mitigate latency and attenuation issues (see section 1.2.6), the underlying advantage of true global broadband access availability of satellite broadband (i.e. data and web-based applications) is unmatched.

1.2 Satellite services and systems

Today there are about 40 available radiocommunication services, including satellite services as described in Box 1.1. This section contains a description of the satellite orbits, the technical characteristics of the `radio interface' for global broadband satellite systems. Use of the fixed satellite service (FSS) for high-speed Internet services and the benefits of `new generation satellite broadband' and mobile satellite services are also described in this section. The network architecture for broadband satellite networks are covered in Annex 1.1 of this paper.

1.2.1 Definition of satellite services and systems for broadband delivery

Broadband delivery using satellites is all about accessibility. Since it provides ubiquitous connectivity, satellite broadband is best suited for areas underserved or un-served by terrestrial networks. A number of satellite services have been utilized for broadband delivery (see Box 1.1).

BOX – 1.1 ARTICLE 1 – Terms and definitions

Fixed-satellite service, Mobile-satellite service, Broadcasting -satellite service and certain other related terms are defined in Volume 1 of the Radio Regulations in Article 1 that deals with `Terms and definitions'.

1.21 fixed-satellite service: A radiocommunication service between earth stations at given positions, when one or more satellites are used; the given position may be a specified fixed point or any fixed point within specified areas; in some cases this service includes satellite-to-satellite links, which may also be operated in the inter-satellite service; the fixed-satellite service may also include feeder links for other space radiocommunication services.

1.25 mobile-satellite service: A radiocommunication service:

– between mobile earth stations and one or more space stations, or

Between space stations used by this service; or

– between mobile earth stations by means of one or more space stations.

This service may also include feeder links necessary for its operation.

1.39 broadcasting-satellite service: A radiocommunication service in which signals transmitted or retransmitted by space stations are intended for direct reception by the general public.

In the broadcasting-satellite service, the term "direct reception" shall encompass both individual reception and community reception.

1.41 radiodetermination service: A radiocommunication service for the purpose of radiodetermination involving the use of one or more space stations.

This service may also include feeder links necessary for its operation.

1.115 feeder link: A radio link from an earth station at a given location to a space station, or vice versa, conveying information for a space radiocommunication service other than for the fixed-satellite service. The given location may be at a specified fixed point, or at any fixed point within specified areas.

Source: Volume 1 of the ITU Radio Regulations – Article 1

1.2.2 Description of satellite orbits

The choice of system configuration and satellite orbit for broadband communication depends primarily on the requirement of geographical coverage, type of service (IP broadband, broadcast or multi-casting, emergency communication, mobile satellite, fixed satellite, etc.), look angle of the satellite from ground stations (higher look angle means less ground noise), availability of spectrum orbit resource, cost & designed life-time of satellite network, etc.

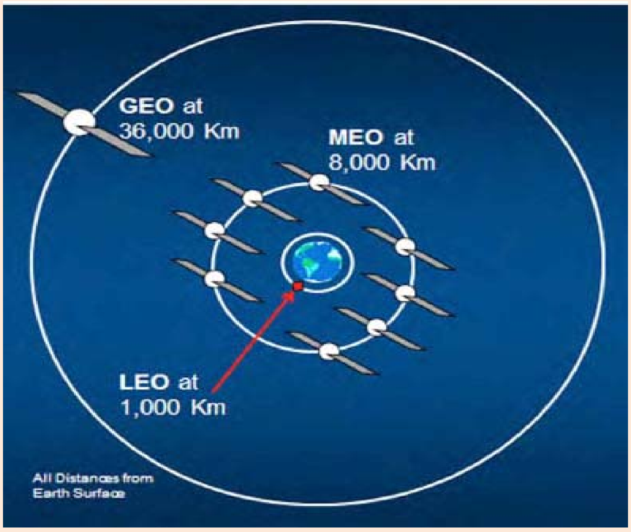
A *geostationary satellite* is a *geosynchronous satellite* whose circular and direct *orbit*[iv] lies in the plane of the Earth's equator and which thus remains fixed relative to the Earth; by extension, a *geosynchronous satellite*[v] which remains approximately fixed relative to the Earth[vi].

A geostationary satellite (GEO) at a height of about 36000 km (actually 35,786 km) above the Earth goes around once every 23 hrs and 56 minutes and maintains continuous positioning above the Earth's sub-satellite point on the equator. Tracking of the satellite by small ground stations is therefore not necessary. Also, only a few satellites can provide global coverage making this option most economical and least complicated in most cases in terms of high speed switching and tracking. There is of course a transmission delay of 250millisecond to complete up/down link and the look angle elevations at higher latitudes is poor.

A medium earth orbit satellite (MEO) systems with its altitude ranging from 8,000 to 15,000 km above the Earth requires a larger number of spacecraft, typically a constellation of about 10 to 15 satellites to maintain constant coverage of the earth. Reduced latency and improved look angles to ground stations at higher altitudes is an advantage over GEOs. Typically, MEOs have a shorter in-orbit lifetime than GEOs and require more expensive and complex ground station antennas for tracking the satellites.

A low earth orbit satellite (LEO) at a height of around 1000 km allows larger signal strength on the surface of the Earth with lower free space losses than GEOs and MEOs since these spacecraft are typically around 40 times nearer to the Earth's surface than GEOs. This permits use of smaller user antennas and terminals. With lowest latency, better frequency reuse, lower free space path loss and with better look angle even at higher altitudes, LEOs are easier to operate with using low gain ground antennas. Nevertheless, LEO constellations need larger numbers of satellites to provide constant Earth coverage. They are more difficult to track and operate, have shorter in-orbit lifetimes due to orbit degradation and commonly result in higher expenditures to build, deploy and operate.

Fig. 1.3: Satellite Orbits



Source:[*http://www.satmagazine.com/cgi-bin/display_article.cgi?number=1473951770*](http://www.satmagazine.com/cgi-bin/display_article.cgi?number=1473951770)

1.2.3 Technical characteristics of air interfaces for global broadband satellite systems

Also called a "radio interface," the air interface defines primarily the frequency, channel bandwidth and modulation scheme. While operational experience with the use of satellite broadband systems has demonstrated their usefulness & practicality, there are several architectures that allow seamless transportation of broadband signals over different networks.

Generic description of the network architecture for broadband satellite networks and a brief overview of air interface standards approved by various standardization bodies[12] are described in Annex 1.1.

1.2.4 Global broadband Internet access by fixed-satellite service systems

A preliminary study on the possibilities of providing access to the Internet at a high data-rate via satellite has been carried out by the ITU. Fixed satellite service (defined above in Box 1.1) was chosen for this purpose. This study looked into spectrum requirements and technical and operational characteristics of user terminals (VSAT) for global broadband satellite systems' with the aim of providing high-data rate access to the Internet for developing counties at affordable prices[vii]. It describes in some detail the coverage, up-link and down-link transmission parameters and payload arrangements that would provide access to the internet at transmit and receive data rates of the order of 2 Mbit/s.

The following issues were raised under this study:

1. What are the spectrum requirements for the provision, on a worldwide basis, of high-speed Internet services?
2. What are the frequency bands that could be identified in the short, medium and long term for the provision of high-speed Internet services?
3. What are the technical and operational characteristics that could facilitate the mass production of simple Very Small Aperture Terminal (VSAT) equipment at affordable prices?

The details of this study were discussed and debated during the World radio Conference 2007 (WRC 07)[viii]. However, it was felt that Internet applications are already being developed and implemented today in the 4/6 GHz (C-band), 11/14 GHz (Ku-band) and 20/30 GHz (Ka-band) FSS allocations, without the need for any changes to the Radio Regulations[ix].

1.2.5 Additional spectrum for Mobile Satellite Service

In many regions and countries worldwide, the use of satellite communication systems to provide mobile telephony and data applications services has increased in recent years. However, further development and a deployment of these systems have been constrained primarily due to the shortage of spectrum resources.

ITU-R has undertaken studies to identify possible bands for new allocations to the MSS in the Earth-to-space and space-to-Earth directions, taking into account sharing and compatibility, without placing undue constraints on existing services in this band. Based on the results of studies, an appropriate amount of spectrum was identified for the MSS systems in the 4-16 GHz range to overcome the shortfall of spectrum for the present and future MSS systems. The total requirements for the MSS in the 4-16 GHz range for the year 2020 are estimated to be between [240 and 335 MHz] – the square brackets indicate that there is a need for further studies in each direction.[x]

The MSS applications envisaged in this report are related to small, typically handheld, portable devices, with a maximum data rate of 144 kbit/s. Current terrestrial mobile systems using 3G technologies (such as High Speed Downlink Packet Access (HSDPA)) are providing data rates of up to 7.2 Mbit/s (download) to a user and higher data rates are likely to be introduced in the future, particularly when terrestrial IMT-Advanced systems are deployed. The use of such high data rate applications in terrestrial mobile networks is likely to put pressure on MSS systems to provide higher data rates.

Two new studies have been conducted to estimate the spectrum needs for MSS systems with data rates of up to around 2 Mbit/s. These studies are intended to support the provision of "broadband MSS" service to land, maritime and aeronautical users, using small directional antennas. Such MSS broadband data rates require much more spectrum than is currently available for MSS.

Potential frequency bands for new MSS allocations are:

Frequency band20	MSS direction (DL = downlink, UL = uplink)
5 150-5 250 MHz	DL
7 055-7 250 MHz	DL
8 400-8 500 MHz	UL
10.5-10.6 GHz	DL
13.25-13.4 GHz	DL
15.43-15.63 GHz	UL

An input report to WRC-12[xi] describes in detail the compatibility issues in each frequency band with existing radiocommunication services and the possible mitigation techniques. It also describes advantages and disadvantages of proposed methods to assess spectrum requirements for broadband services.

1.2.6 Satellite system approaches to broadband

This section provides a brief description of the latest advancements in broadband satellite technology. Traditional satellite technology utilizes a broad single beam to cover entire continents and regions. Introduction of multiple narrowly focused spot beams and frequency reuse makes the satellite capable of maximizing the available frequency for transmissions. Increasing bandwidth by a factor of twenty or more, as compared to traditional satellites translates into better efficiencies. Despite the higher costs associated with spot beam technology, the overall cost per circuit is considerably lower as compared to shaped beam technology.

Fig 1.4: Broad beam versus spot beams

Broad single beam

Spot beams

Source: http://www.satelliteone.com/support-files/Spot_Beam_Short.pdf (Spot beam technology) [13]

Satellite broadband services are offered in five basic technology categories: [7]

- C band (4/6 GHz) FSS (fixed satellite services)
- Ku band (11/14 GHz) FSS (fixed satellite service)
- Ka band (20/30 GHz) bent pipe (with no onboard processing in the satellite)
- Ka band (20/30 GHz) with satellite on board processing
- L band (1.5/1.6 GHz) MSS (Mobile satellite service)

Note: Although the terms `L', Ku' & `Ka' are not defined or referred to, in ITU Radio Regulations, following are the bands represented by these terms:

Band	Frequency Minimum (GHz)	Frequency Maximum (GHz)
L	1	2
Ku	10	15
Ka	15	32

The first generation satellite broadband made use of the Ku band fixed satellite service for providing two- way connections using one single satellite beam. In the late 1990s, the first generation two way broadband satellites met with `limited success' that was attributed to:

- high cost of space segment and subscriber terminals;
- less than optimal network throughput and operational performance.

In the USA, there were only two surviving projects from that era. One was WildBlue [14], which was acquired in December 2009 by ViaSat Inc [15], which previously had operations in military, government and commercial satellite communications. The other was HughesNet [16], which is currently operated by Hughes Communications. [17]

ViaSat's decision to build its own satellite, called ViaSat-1 was delayed and is now slated for launch in 2011. Hughes also ordered a high-throughput Ka-band satellite, called Jupiter, to be launched in 2012. ViaSat-1 and Jupiter will each provide more than 100 gigabits per second of capacity, which is approximately 50times the capacity offered by a typical conventional Ku-band satellite.[18]

Japan too, in February 2008 launched its Extra-High-Speed Broadband Satellite. Called The "KIZUNA", it is a communications satellite that enables speed data communications of up to 1.2 Gbps.[19] EUTELSAT'S "KA-SAT", a `High Throughput Satellite' with 70 Gbps capacity to serve users across Europe and Mediterranean Basin, was launched on 26th December 2010.[20]

The new generation `Ka band' broadband systems deploy spot beam technology where satellite downlink beams illuminate a smaller area of the order of 100s of kilometers instead of 1000s of kilometers. The coverage looks like a honeycomb or a cellular pattern. This enables frequency reuse that results in a drastic increase in the overall capacity of the satellite. This is analogous to comparing a DTH (direct-to-home) broadcast signal to a cellular phone signal. New generation satellite broadband is being customized to:

- address target markets;
- reduce bandwidth costs;
- increase capabilities to meet the growth in subscriber population.

The system capacity increase is 30 to 60 times the capacity of the Ku band FSS approach. This is what makes the spot beam technology economically attractive and a viable business proposition to meet the growing bandwidth demand of end-users.

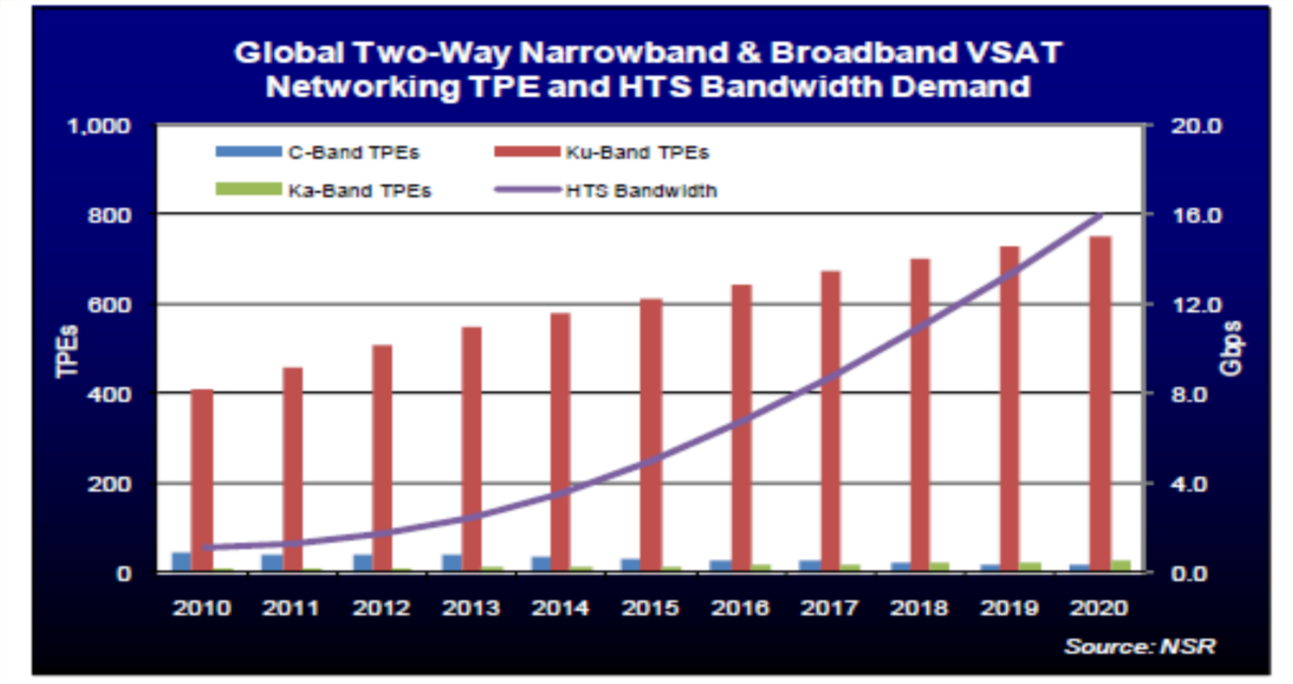
Figure 1.5 [21] shows that Ku band transponder demand shall dominate all through the period 2010 to 2020. However, the demand for Ka band HTS shall begin to show around 2013.

Although Ka and higher bands are attractive from the point of view of the amount of frequency bandwidth that the satellite can potentially use, there are limitation that could dampen the enthusiasm of using them if specific

techniques were not implemented in the satellite system to guarantee the capacity and the availability and the quality of service.

Attenuation and scintillation effects of atmospheric gas (atmospheric propagation degradations that affect the quality of transmission and the link availability), clouds and rain become more pronounced with the increase in frequency above 1 GHz and are of particular importance for Ka and higher bands. While this attenuation causes signal fading, there are `Fade Mitigation Techniques (FMT) [22], that are implemented to overcome the situation.

Fig. 1.5: Global transponder Capacity demand for VSAT networking and High Throughput Satellite



Source: http://www.newtec.eu/uploads/media/1._Christopher_Baugh_-_NSR.pdf

The high bandwidth available in the Ka spectrum and frequency re-use capabilities across multiple beams enables the delivery of more capacity at faster speeds to smaller dishes – opening the door to upgraded services at lower costs.

1.3 Overview of satellite broadband services

This section contains an overview of some of the regional, global and national satellite broadband systems and services.

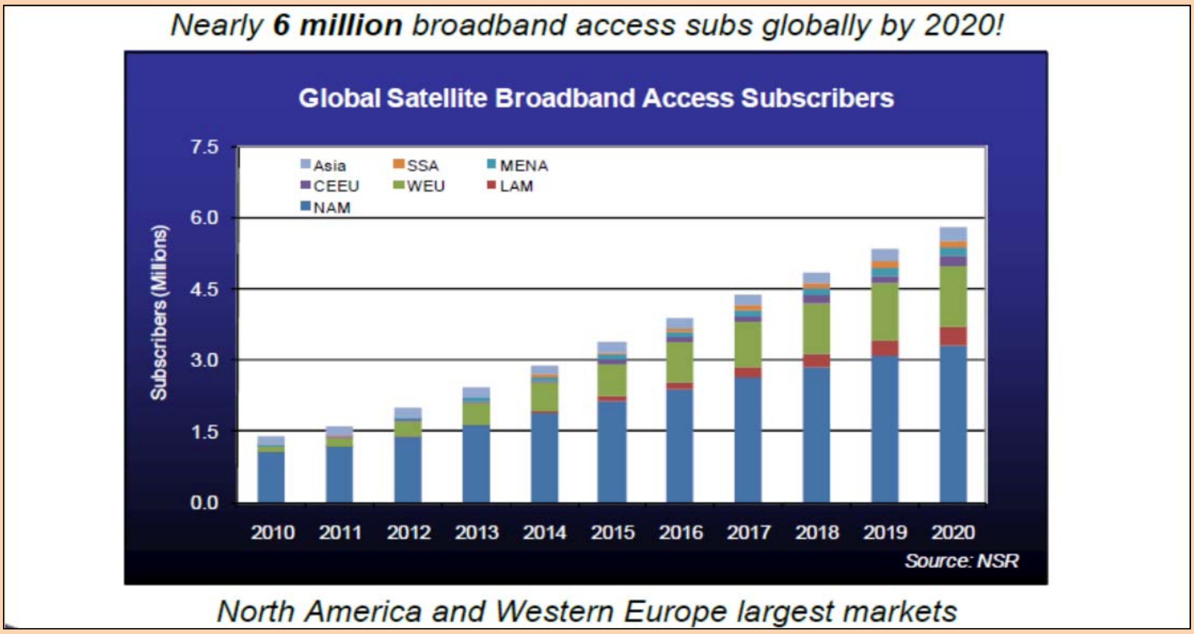
Provision of Internet is critical for innovation, economics and for social well-being**.** Broadband delivery in various geographical regions are therefore increasingly taking into consideration and including the satellite broadband options to bridge the digital divide.

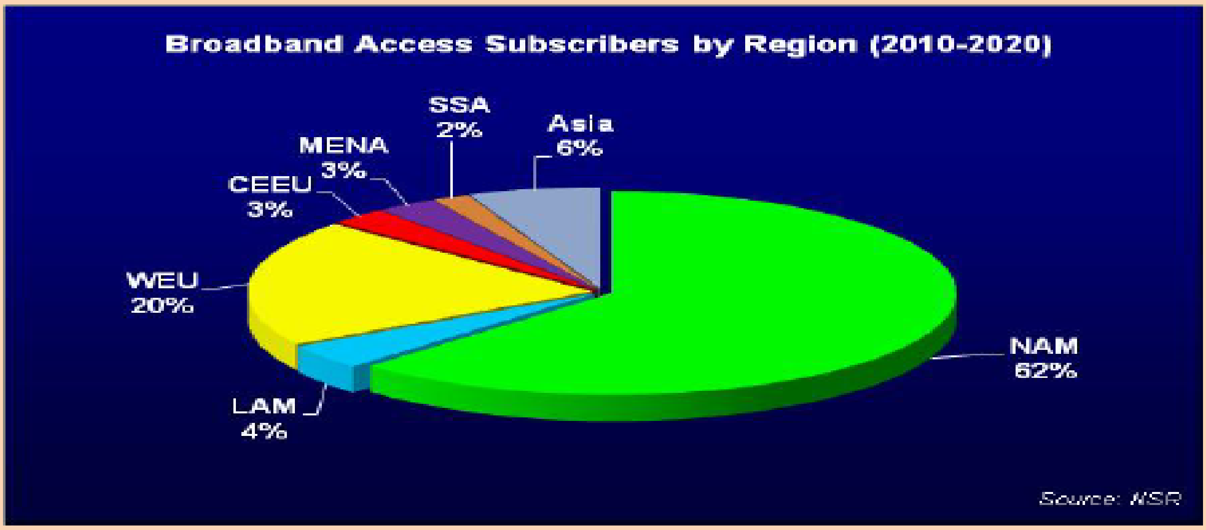
1.3.1 Regional approaches to satellite broadband services

Figure 1.6 below depicts the present status and the trend for the growth of global broadband access subscribers. From 1.5 million in 2011 to about 6 million in 2020 the number of satellite broadband subscribers and also their rate of growth are dominated by those from North America and Western Europe.

Unlike the Asian region where the expected growth in satellite broadband subscribers is small, the same is appreciable for other regions. Migration to Ka band `High Throughput Satellites' for broadband delivery is the key to this growth. The demand for broadband is rapidly exhausting the available capacity of existing Ku-band satellites. Large and small enterprises increasingly depend on media-rich applications for the growth of their businesses. Governments need high-bandwidth applications to deliver services to their citizens. And consumers want to watch movies, make VoIP phone calls, and browse the Web—all at the same time. Ka-band technology is now making all this possible over satellite. The high bandwidth available in the Ka spectrum and frequency re-use capabilities across multiple beams enables the delivery of more capacity at faster speeds to smaller dishes.

Fig. 1.6: Regional Trends in Broadband Access





Source: http://www.newtec.eu/uploads/media/1._Christopher_Baugh_-_NSR.pdf [23]

A few of the regional approaches to the provision of satellite broadband are now described.

European Union (EU): Europe's broadband map shows that at least 13 million households are still beyond the range of ADSL (Asymmetric Digital Subscriber Line) and 17 million access the Internet at speeds below 2 Mbps, which closes the door to many media-rich applications that users today expect to use on a daily basis.[24]

In a significant portion of the rural population all over Europe there is no access to terrestrial broadband. The table below gives the broadband connectivity forecast for Europe.

Table 1.2 Broadband Connectivity Forecast, Europe

Countries	Forecast of Broadband Availability		
	Segment	2008	2013
UK, France, Belgium, Denmark, Luxembourg, Holland, Austria, Sweden & Malta	Urban	98%	99%
	Rural	92%	95%
Italy, Germany, Finland & Ireland	Urban	97%	97%
	Rural	62%	78%
Spain, Portugal, Estonia, Cyprus & Slovenia	Urban	96%	97%
	Rural	61%	75%
Czech Republic, Hungary, Poland, Slovakia, Greece, Latvia & Lithuania	Urban	94%	95%
	Rural	15%	34%

Source: "Final Report Technical assistance in bridging the `digital divide" (ESA & Price Waterhouse Coopers) http://www.nsr.com/ – Broadband Satellite Markets, 4th Edition [25]

The European Union in its broadband policy aims to have 100% broadband coverage by 2013, and to increase coverage bandwidth to 30 Mbps for all Europeans by 2020 with 50% or more of European households subscribing to Internet connections above 100 Mbps.[26]

Although terrestrial broadband technologies are expected to play a vital role in the fulfilment of these broadband policy objectives, satellite broadband technology and specially the use of `High Throughput satellites' with the use of multi-beam technology (see box No.1.2.) would play a major role in meeting these objectives at a much faster rate than their terrestrial counterparts.

BOX No. 1.2

KA-SAT

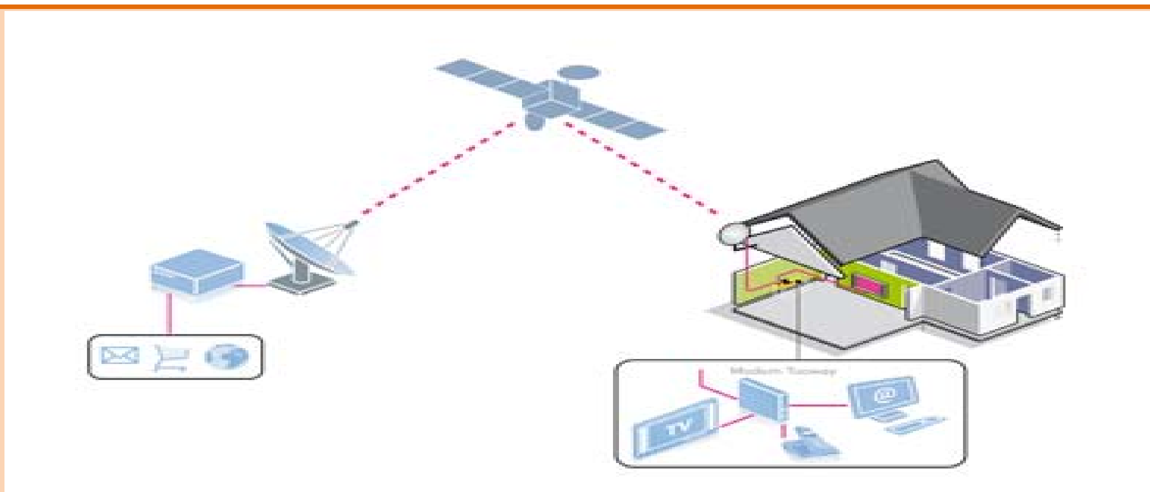
For the provision of broadband Internet access services across Europe and also a small area of the Middle East, **KA-SAT,** owned by Eutelsat[27] is an example of satellite based broadband system for IP services that deploys spot beam technology. Positioned at its geostationary orbit location at 9° East, KA-SAT features high level of frequency reuse enabling the system to achieve a total capacity of more than 70 Gbps. It represents 38 times the capacity of a standard telecommunication satellite operating in K_u band. Each spotbeam generates an area of connectivity about 250 Kms. wide having a capacity of 900Mbps. KA SAT has a 82 beam structure.[28]

KA-SAT coverage over Europe and the Mediterranean Basin (different colours show frequency reuse)

Source: http://www.eutelsat.com/satellites/9e_ka-sat.html [27]; http://www.webcitation.org/5vI9KSD8A [27]

High Throughput Satellite Goes Live [24]

KA-SAT `High Throughput Satellite' delivers a download speed up to 10Mbps and upload speed of 4Mbps for its consumers that is about 10 times the speed of previous satellite Internet solutions. [24, 29] This heralds the launch of Eutelsat's new-generation ` Tooway™ broadband service' using high capacity Ka band satellite system. Tooway™ is a bi-directional satellite solution. The small outside satellite dish connects the personal computer or home network directly to the Internet directly via the satellite without the need for a telephone line.



Source: http://www.tooway.com/Solutions [29]

Africa: Africa has an Internet penetration of only 10.9% in 2010. An Intergovernmental Commercial Satellite Organization[30] called RASCOM (Regional African Satellite Communications Organization) through RascomStar-QAF[31] (a private company registered in Mauritius) implemented RASCOM's first communications satellite project.

The administration of Côte d'Ivoire was the notifying administration for the satellite network `RASCOM' and was responsible for carrying out international satellite coordination and notification procedures with International Telecommunication Union (ITU). Côte d'Ivoire was finally able to obtain international recognition for the orbital location 2.9 degrees E and have the orbit/ frequency details for RASCOM registered in the MIFR (Master International Frequency Register).

The satellite RASCOM-QAF1R located at 2.9 degrees East and operated by Pan-African satellite operator RascomStar-QAF, was successfully launched in August 2010. It replaced RASCOM-QAF1 that was launched earlier in December 2007. Its Ku band (12/14 GHz) covering two zones over Africa (North zone and South Zone) provides TV Broadcasting and high rate Internet and C-band covering one single zone over Africa is used for thin route trunking and bandwidth lease service. `RascomStar-QAF TElecommunication Services' gateways are the connection points of the service to terrestrial PSTN networks.

O3b Networks[32, 33, 34] are expected to bring higher capacity, lower latency, lower cost broadband access to more than 150 countries across Asia, Africa, Latin America and the Middle East. O3b Networks is short for the "Other Three Billion," the nearly half of the world's population that has little or no access to the Web. The O3b Networks satellites will continuously circle the Earth. As each satellite passes a region, it will pick up the Internet traffic there and then pass it to the next satellite before going out of range.

The O3b Satellite Constellation is designed for telecommunications and data backhaul from remote locations. Scheduled for commercial service in early 2013, it will initially be made up of 8 satellites with plans to extend this to 16. The constellation is owned and operated by O3b Networks, Ltd. O3b satellites will be deployed in a circular orbit along the equator at an altitude of 8063km (medium earth orbit). The satellites shall use Ka band and provide optimal coverage between 45° north/south latitudes. Use of Medium Earth Orbit (MEO) will reduce the latency from 250 milliseconds (for a geostationary satellite) to approximately 100 milliseconds.

Nigerian Communications Satellite (NIGCOMSAT) [35]: NIGCOMSAT Limited incorporated, a pan African satellite operator, has been responsible for the operation and management of Nigerian Communications Satellite NIGCOMSAT-1 as sub-Saharan Africa's first communications satellite, which was launched in May 2007and located at 42.5°E.

In April 2008, NIGCOMSAT-1 lost power from the southern solar array. The satellite failed in November 2008 due to a technical error of the satellite's northern solar array and was sent to a graveyard orbit as it became apparent, that the satellite could not be recovered. [36]

With 40 transponders (30 active and 10 redundant), NIGCOMSAT-1 had footprints over the Earth that ran across Africa, Europe and the Middle East. Designed to operate in the C-band (4 transponders), Ku band (14 transponders), Ka band (8 transponders) and L band (2 transponders), it was designed to provide voice, data, video, Internet, and global positioning/navigational functions. NIGCOMSAT-1 has better look angles and shorter latency for intra-Africa communication traffic and high fade margin compensation for attenuation losses due to rain.

NIGCOMSAT –1 was designed to cater for telecommunication, broadcasting, Internet & multimedia services together with tele-education and tele-health services. The use of Ka band was for broadband services at lower cost arising from the frequency re-use techniques, competitively priced transmission capacity, small antennas and reduced terminal prices.

On March 24, 2009, the Nigerian Federal Ministry of Science and Technology, NigComSat Ltd. and CGWIC signed the NIGCOMSAT –1R satellite in-orbit delivery contract. NIGCOMSAT –1R is expected to be delivered in 2011 as a replacement for the failed NIGCOMSAT –1. [37] The replacement satellite NIGCOMSAT-1R would have modifications to its payload with enhanced power for the Ka band to provide the most optimal and cost effective voice, data, video, Internet and application service/solutions.

Ka-band satellite has now become one of today's fastest-growing technologies because of the growing demand for capacity and there are other Ka band satellite broadband services being offered in Africa. [38]

South America: Satellite Ka-band initiatives are also under way in the region of Central America / Latin America (CALA). Hughes, which is a part of Hughes Network Systems LLC is one of the major internet service providers in Brazil. The company utilizes a Ka-band SPACEWAY satellite to provide Internet access especially to the rural communities even the Amazon Forest. For many rural citizens, satellite Internet will be the only Internet access available as DSL, Cable, and often even dial up do not reach some of the more rural areas of Brazil. Hughes has especially focused their efforts in providing the country's educational sector with Internet access. The company has been working in conjunction with the Amazonas Board of Education to provide educational material via satellite Internet to approximately 10,000 students in rural communities.[39]

PrimeNet is one of Brazil's top value-added resellers (VARs) of satellite services that will resell Hughes high-speed satellite Internet access service to small- and medium-sized businesses across the Brazilian territory, with a special focus on the Center-West, North, and Northeast regions. [40]

`Hughes do Brasil' is a service organization focused on the local market and has been the leading supplier of satellite services to Brazil since its launch in 2003. It provides a full suite of HughesNet® services, delivering data, video, voice, and IP multimedia communications to a growing base of customers throughout the region.

The Communications and Transport Ministry of Mexico (SCT) selected Hughes to support the Mexican government's connectivity program to expand broadband access to rural areas of the country. Hughes satellite terminals that will enable public schools, hospitals, libraries, and government offices to connect to the Web and each other via broadband Internet access.[41]

The satellite network VENESAT-1, also called SIMON BOLIVAR –1 was launched in 2008 for Venezuela to boost its telecommunications, film and TV industries, culture and education. Located at 78° W, SIMON BOLIVAR –1 has 14 C-band transponders (radio and TV signal), 12 Ku-band (data and high speed Internet) and 2 Ka-band (future digital TV signal transponders) to cover most of South American continent and part of Caribbean areas, and provide communications and broadcasting services to Venezuelan as well as the surrounding region.[42]

North America – Federal Communications Commission (USA) released their plan on March 15th 2010 containing a blueprint for upgrading Internet access for all Americans, with Internet speeds up to 25 times the current average.[43]

The National Broadband Plan called `Connecting America: The National Broadband Plan', is a roadmap for the future of the Internet in America (http://www.broadband.gov/) [43] 200 million Americans had fast Internet access at home in 2009; the plan aims to have 100 million American households get Internet speeds of 100 megabits per second (Mbps) by 2020.

Satellite industry has opined that satellites are a key part of the solution to bringing broadband to everyone.[44, 45] They are also advocating stimulus to bring satellite-based services to remote communities.[46]

Current Satellite Broadband Providers/Offerings [47] include HughesNet [48], StarBand [49] & WildBlue [50] etc.

JUPITER [51], the next-generation, high-throughput, Ka-band satellite from Hughes is expected to provide over 100 Gbps additional capacity in North America. Scheduled for launch in the first half of 2012, JUPITER is expected to provide service for 15 years or more. To put it in context, each single JUPITER beam has the approximate capacity of an entire conventional Ku-band satellite—making JUPITER equivalent to approximately 50 conventional Ku-band satellites—truly transformational for the industry. JUPITER is an expansion of a Ka-band system deployed in 2007 using the Spaceway-3 satellite. Spaceway-3 employs onboard (regenerative) processing and has a total throughput of approximately 10Gbps. As of August 2011 the Spaceway-3 satellite served 464,000 subscribers.

`ViaSat-1' from ViaSat/WildBlue is scheduled to launch in 3Q2011 and has similar capabilities and North American coverage to JUPITER. ViaSat-1 is an expansion to an existing WildBlue Ka-band network employing two satellites – WildBlue-1 and ANIK-F2 – serving more than 500,000 subscribers in the USA. Telesat operates the Canadian Ka-band payload of ANIK-F2 for providing consumer satellite broadband service in Canada.

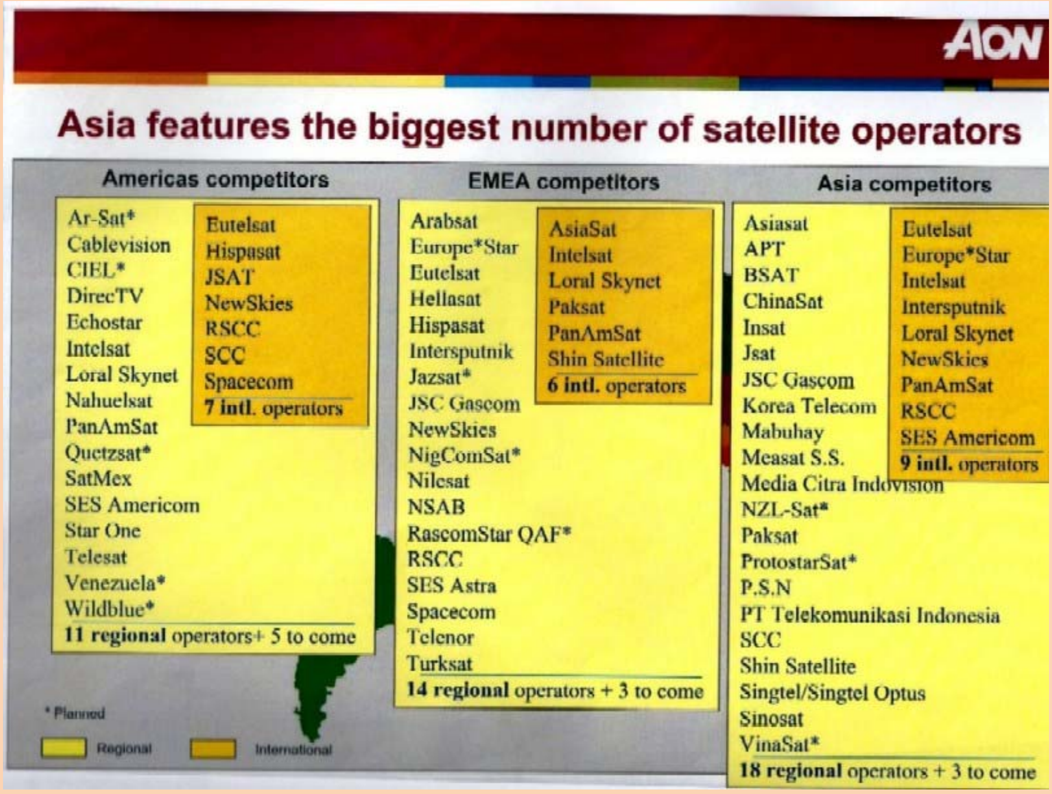
Asia & Pacific: Whereas 60% of the world population lives in Asia, out of this, 60% lives in the rural Asia with poor network penetration and telecom infrastructure [52]. Much of this can be attributed to the geographical terrain that is difficult and mountainous. This makes it very attractive for satellite operators. Asia features the biggest number of satellite operators with 18 regional and 9 international operators (See Fig.1.7).

Table 1.3 Application and attractiveness (Asia), 2005-2011

Application	Sub-categories	Attractiveness for growth
Video	Video distribution	Medium
	DTH	High
	Contribution/OUTV	Medium
Telephony	Voice backhauling	(Negative)
Networking	Corporate Networks/VSAT	High
	Direct Internet Access	Medium-High
	Internet Trunking	Low-Medium
Others	--	Low
Mobile Satellite Service		Low-Medium

Source: http://www.apscc.or.kr/pub/coverstory_july2005.asp (Asian Satellite Services: A promising future) [52]

Fig. 1.7: Asia features the biggest number of satellite operators



Source: http://www.satellite-links.co.uk/directory/aonexplorer.html

The demand was assessed for the period 2005 –2011 for various categories like video, telephony, networking and MSS (Mobile satellite service) and depicted in the table below: [52]

Demand for Video/DTH (Direct to home) is the driving force in Asia and so is the demand for VSAT applications due to mountainous terrain. As of today there is no dearth of demand for DTH services in the Asian region with India (25 million subscribers in 2010 & expected to reach 35 million by 2014) [53] leading the way. [54]

It is felt that the key reason why satellite operators have been moving to Ka-band in Europe and North America has been due to congestion in the C- and Ku-band frequency bands, especially for the higher bandwidth broadband type services. Today, we have not yet seen that level of congestion in the wider Asia-Pacific region or strong demand for broadband DTH services. In some of the more developed markets in the region, such as Australia, there may be opportunities today. An additional challenge with Ka-band in South and Southeast Asia region is rain attenuation. Large swathes of the region are subject to monsoon rainfall. As you move into the higher frequency bands, this poses increasing challenges.[55]

Asia-Pacific Satellite Communications Council (APSCC) in its second quarter 2011 report [54] has commented upon the wide-beam Ka-band and High Throughput Satellite (HTS) Trends in the Asia-Pacific market. According to their assessment there is relatively little available commercial wide-beam Ka-band capacity, while the sole HTS currently in the region is the Thaicom-4 satellite. Some salient features of the Thaicom-4 satellite are mentioned below.

Thaicom-4 (IPSTAR): [56] Thaicom-4 (IPSTAR) is a multiple spot beam bent-pipe satellite without on-board regenerative payload. It provides full nationwide broadband satellite services in 14 countries in Asia-Pacific: Australia, Cambodia, China, India, Indonesia, Japan, Malaysia, Myanmar, New Zealand, Philippines, South Korea, Taiwan, Thailand and Vietnam. IPSTAR has 18 gateways located in 14 countries that it serves. The user-beams operate in Ku-band and the gateway services operate in Ka-band.

Located at 119.5 degrees East IPSTAR has 84 spot beams, 3 shaped beams has a 45 Gbps maximum bandwidth capacity and provides a variety of services e.g. managed VPN cellular backhaul, SNG (Satellite News Gathering), rural telephony, retail broadband, disaster recovery and emergency communication, distance learning, among others, for the government, business and industry sectors.

1.3.2 Global broadband satellite delivery

Following an introduction to some of the regional broadband satellite approaches, now a word about provision of global broadband IP services for a variety of applications.

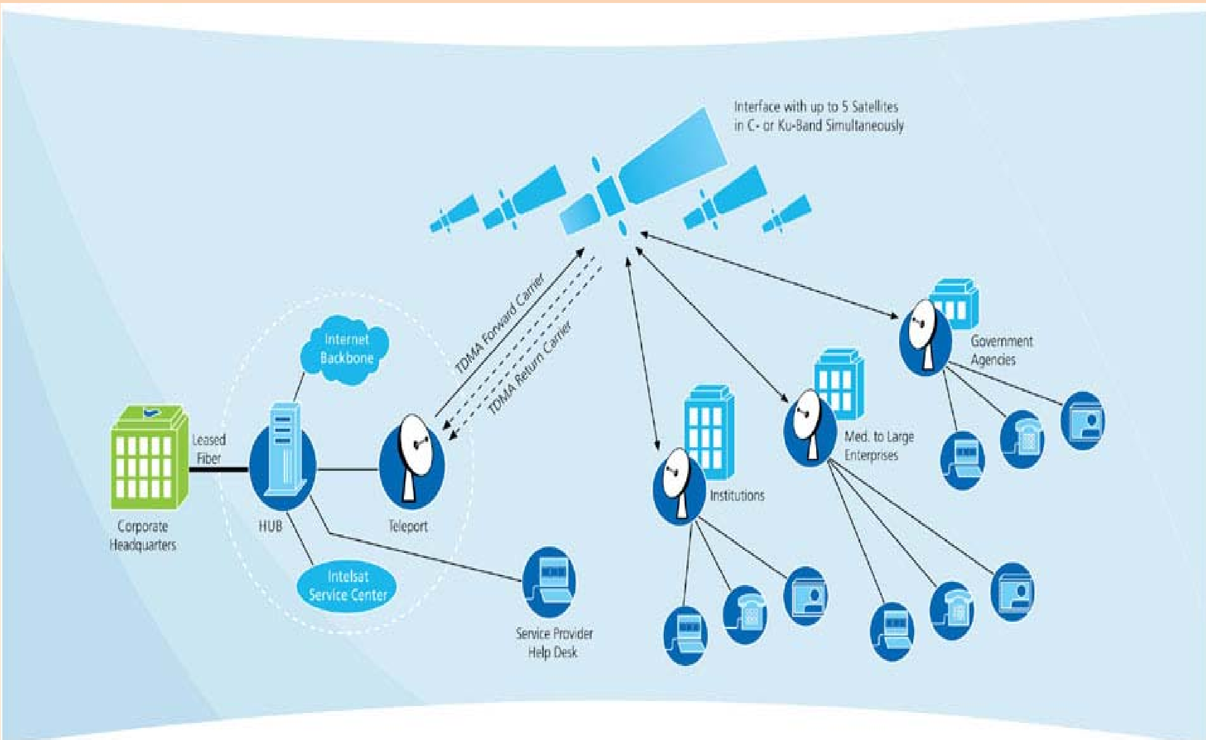
Intelsat Network Broadband [57]: As of March 2011, Intelsat operates a fleet of 52 communications satellites. Intelsat enables management of customer's network across multiple satellite and regions with the use of only one `hub station'. This arrangement supports the following applications:

> Web Browsing, Digital Media Streaming, E-mail, Multicasting, File Transfers, Wi-Fi Hotspots, VPN, Voice over IP (VoIP), Extranet/Intranet/e-Commerce, Video Conferencing, Distance Learning

Intelsat's commercial grade broadband access, faster than DSL, provides converged voice, data & video applications anywhere in the world. `IntelsatONE' infrastructure of the Intelsat, allows multiple scaleable networks to be built with a common `hub' platform using C band (4/6 GHz) and Ku band (11/14 GHz) frequencies.

Intelsat's broadband network offers per-site data rates of up to 18 Mbps on the outbound and 5.5 Mbps on the inbound.

Fig1.8 Network Broadband Infrastructure



Source: *http://www.intelsat.com/services/telecom/network-broadband.asp* [57]

Inmarsat [58] **– The Inmarsat *Global Xpress™*** : Inmarsat has a current fleet of 11-satellites that provide mobile voice & data communications globally – on land, at sea or in the air.

In 2010, Boeing, the US aerospace manufacturer, was contracted to build three Inmarsat-5 (I-5) satellites. The first is scheduled for completion in 2013, with full global coverage expected by the end of 2014.

This is a new constellation of Inmarsat-5 satellites that will form part of a new US$1.2 billion worldwide wireless broadband network called Inmarsat *Global Xpress™*. Each Inmarsat-5 will carry a payload of 89 Ka-band beams – capable of providing capacity across the globe and enabling Inmarsat to adapt to shifting subscriber usage patterns over their projected lifetime of 15 years.

The Inmarsat *Global Xpress™* network will take advantage of the additional bandwidth available in the Ka-band to offer download rates of 50Mbps and upload speeds of 5Mbps from mobile user terminals as small as 60cms.

Services will be tailored initially for the government, energy and maritime markets. The Inmarsat-5s will operate independently from the L-band satellites offering complementary services for a wide range of mobile and fixed solutions.

At present, Inmarsat's Broadband Global Area Network – BGAN – provides both simultaneous voice and data, globally, on land. With its Standard IP data service, it provides the user with a data connection speed up to 0.5 Mbits/s, which is suitable for applications such as email, Internet and intranet and VPN access to corporate networks.

BGAN is delivered via three satellites that make up the Inmarsat-4 (I-4) network. All three I-4 satellites cover the surface of the earth, except for extreme polar-regions. Hence, one can establish a broadband data or voice network irrespective of geographical location.

For the purpose of aeronautical communication, Inmarsat installation enables applications for both the cockpit and the cabin – from safety communications, weather and flight-plan updates, to email, Internet and phone services.

Inmarsat's maritime communication services provide ocean coverage on a global basis, except the extreme polar-regions. Services include simultaneous voice and data up to 432kbps, Global voice, fax, 64/128kbps ISDN, packet data, GMDSS (Global Maritime Distress and Safety Service).

SES S.A – Besides Intelsat and Inmarsat there are other global broadband service providers – SES S.A.[59] based in Luxembourg, has a fleet of 47 satellites. Originally founded as **S**ociété **E**uropéenne des **S**atellites in 1985, it was renamed SES Global in 2001 and later simply 'SES' as the group management company of SES Astra, SES World Skies and other satellite and satellite service companies in which SES holds a stake, QuetzSat, Ciel, O3b Networks and Astra TechCom Services being the principal ones.

SES has been a major player in the development of the direct-to-home market in Europe and the IPTV market in the U.S. In Europe, SES Astra supplies ASTRA2Connect a satellite-based, broadband internet access for residential users. The product is used to offer TV reception, internet access and telephony to end users in remote locations where terrestrial broadband services are not available

1.4 Understanding challenges and opportunities

This section explains the IMT advanced system and its satellite component[xii]. IMT advanced at present is only at a conceptual stage and the subject of interoperability between WiMAX & broadband mobile space networks using HAPS (High Altitude Platform Systems – platforms located in the troposphere) and HTS (High Throughput Satellite), is being studied.

Further on in this section, the use of FSS & MSS for warning and relief operations during natural disaster & emergency situations is briefly covered. The Tampere convention – that concerns trans-border use of telecommunication equipment by humanitarian organizations for relief work is also described in this section. Lastly, the environmental impact of satellites and issues relating to control of space debris and the initiatives by the `Committee on the Peaceful Uses of Outer Space (COPUOS)', are briefly covered.

1.4.1 Satellite as a complement to terrestrial backbone network – Satellite component of the IMT advanced

IMT-Advanced systems are mobile service systems that provide access to a wide range of telecommunication services, including advanced mobile services supported by mobile and fixed networks, which are increasingly packet-based.[60]

IMT-Advanced systems support low to high-mobility applications and a wide range of data in accordance with user and service demands in multiple user environments. IMT-Advanced also has capabilities for high quality multimedia applications in a wide range of services and platforms anywhere, providing a significant improvement in performance and quality of service.

To understand the general idea on the satellite component of IMT in terms of application scenarios, service, system, radio interface, network aspects, specific features, minimum technical requirements, it is important to get familiar with the recent progress made in the work of ITU[xiii].

In May 2011, ITU-R[xiv] has estimated the time schedule for completing the Recommendation on development of radio interface for the satellite component of IMT specifications – by around September 2013.

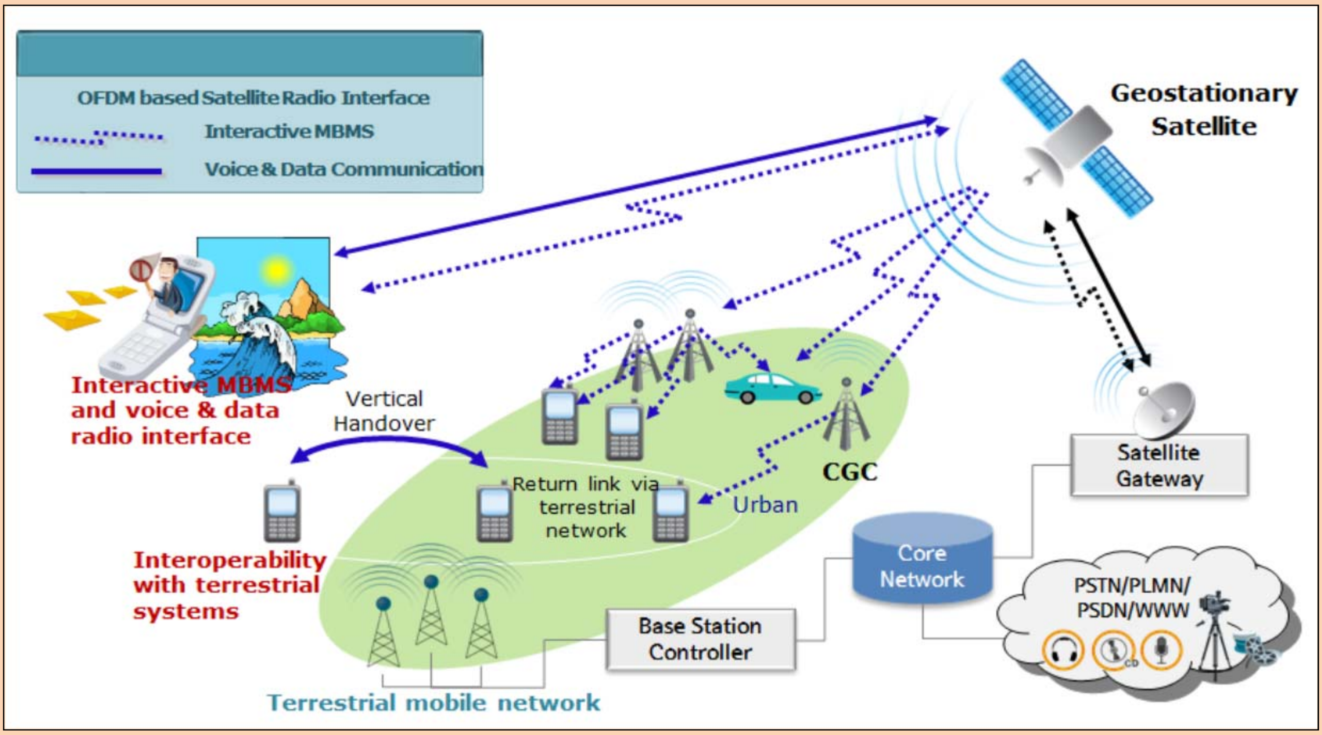
The application scenarios include:

- two-way communications using multi-beam with frequency reuse scheme;
- interactive digital multimedia broadcasting using multi-beam.

The satellite radio interface of IMT-Advanced should be compatible, and have a high degree of commonality with, a terrestrial radio interface.

An example of IMT-advanced system architecture using the SAT-OFDM is shown in Figure 1.16.In order to provide the terrestrial fill-in service, vertical handover of satellite component with terrestrial part may be considered as one of the most important techniques. Vertical handovers refer to the automatic fall-over from one technology to another in order to maintain communication.

Fig 1.9: An example of IMT- advanced system architecture using the SAT-OFDM



Satellite: It will provide services and applications similar to those of terrestrial systems outside terrestrial and complementary ground component (CGC) coverage under the inherent constraints imposed by power limitation and long round-trip delay.

CGC (Complementary Ground Component): In order to provide mobile satellite broadcasting/multicasting services, they can be deployed in areas where satellite reception is difficult, especially in urban areas. They may be collocated with terrestrial cell sites or stand-alone.

IMT-Advanced terrestrial component: Satellite component can provide voice and data communication service in regions outside terrestrial coverage. The areas not adequately covered by terrestrial component include physically isolated regions, gap of terrestrial component and areas where terrestrial component permanently, or temporarily, collapses due to disaster.

Source: Doc 4B/TEMP/90-E dated 4 May 20 http://www.itu.int/md/R07-WP4B-110502-TD-0090/en

The two-way communication scenario is regarded as coverage extension and service continuity of the terrestrial part. In the scenario, handover technique with terrestrial part would be most importantly considered. For the cost-effective handover, future satellite radio interfaces should be compatible and have a high degree of common functionality with an envisaged LTE based terrestrial radio system.

Indeed, the satellite component has an advantage over terrestrial component for delivery of same content to spread over a wide geographic area.

1.4.2 Integrated MSS Systems – Use of satellite spectrum to combine terrestrial networks with satellite systems

Integrated MSS systems are employing both a satellite and a ground component that are complementary and where the ground component as well as the network management system are controlled by the satellite resource. In this system, the ground component uses the same portions of MSS frequency bands as an associated operational mobile satellite system[xv].

MSS needs to be protected from harmful interference that may be caused by the introduction of the ground component of Integrated Systems. Some administrations that are planning to implement or are implementing Integrated Systems within their national territories have imposed technical limitations, in rules and authorization actions to protect other radiocommunication services. Sharing studies performed by the ITU-R has determined that the coexistence between independent systems in the MSS and systems in the mobile services in the same spectrum without harmful interference is not feasible in the same or adjacent geographical area. However, ITU-R is currently carrying out studies on sharing, technical or regulatory issues with regard to integrated MSS and ground component systems[xvi].

The Conference Preparatory Meeting (CPM) for World Radio Conference (WRC 12) held in February 2011, considered the interim procedure for notification and recording of `Complementary Ground Component ("CGC") of integrated MSS systems in the L band (1525-1559 & 1626.5-1660.5 MHz). The issue and the views expressed by administrations are summarized the CPM Report[xvii].

Since ITU-RR require that any frequency assignment to a transmitting station capable of causing harmful interference shall be notified to the ITU, modifications are proposed to the RR[xviii] to introduce CGC data elements and a new Resolution is also proposed for notifying and recording of CGC stations as part of an integrated MSS system. Additionally, modifications have been proposed[xix] to include this new Resolution and also to recommend a definition to the integrated MSS systems. ITU-R has been invited to complete these compatibility studies by 2015 taking into account the existing systems and also those proposed to be used soon. Administrations have also been invited to include CGC stations in their bilateral and multilateral consultations.

One view from the administrations expressed during the CPM was to provide interim notification and recording procedures in the RR to take into account the deployment of CGC in the L band i.e. 1525 – 1544 MHz, 1545 – 1559 MHz, 1626.5 – 1645.5 MHz and 1646.5 – 1660.5 MHz and also to provide such procedures for those administrations who are having CGC on their territory but are not the notifying administrations of the corresponding integrated MSS system.

Another view from the administrations was that it is premature to consider this matter at this stage since the technical and compatibility studies are ongoing and the information available on technical characteristics of the terrestrial component i.e. the base station and terminals, is not complete.

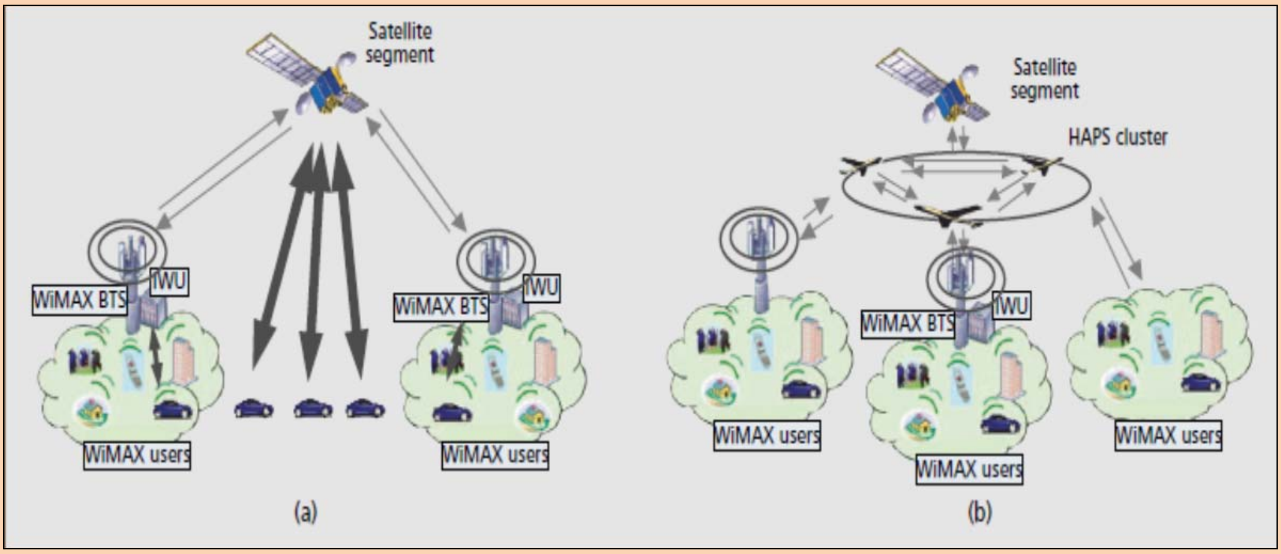
The advent of CGC (called "ATC – Ancillary Terrestrial Component" [61, 62] in North America) was a bit controversial in the US. The wireless carriers alleged that the satellite operators were simply using the "auxiliary" excuse as a way to open the door for providing a basically terrestrial network using satellite spectrum allocations. This was poignant for the wireless carriers, which paid for their spectrum at auction, while in the US, licenses for international satellites are awarded without payment (beauty contest). The FCC's rules tried to make a stringent dividing line between (a) a satellite system that uses terrestrial repeaters to fill in coverage holes, and (b) a mainly terrestrial system that has a satellite to use as a "fig leaf" to pretend it is providing MSS. The various systems that have been proposed (SkyTerra, TerreStar, ICO, etc.) [63] have continued to suffer various financial vicissitudes. So that brought the FCC to the question of LightSquared [64, 65], as the last best hope for broadband using the L Band. LightSquared is a mobile satellite service (MSS) provider with two space vessels that cover North America. It operates in the 1.5-1.6 GHz, part of what the FCC calls the L-Band. In November of 2010 the company applied to the FCC for more expansive rules that would allow it greater leeway to transmit satellite broadband signals to its "Ancillary Terrestrial Component" (ATC). LightSquared would thus reuse its space frequencies to offer wholesale broadband via ground transmitters. When the company applied for this regulatory largesse, it tried to convince the FCC that the proposal would pass the agency's "integrated service" rule—providing both MSS and ATC.

But it looks like the LightSquared network will have to be redesigned to avoid interfering with GPS [64, 65] and even Galileo. Evidently, this issue gets to the central theme of this paper: how do regulators establish rules that will clear the way for satellites to contribute to overall broadband development?

1.4.3 Interoperability between WiMAX & broadband mobile space networks:

A combination of broadband satellites and HAPS (High Altitude Platform Systems – platforms located in the troposphere) could provide such 2-way communication architecture. Connecting the WiMAX network by means of a terrestrial network that terminates at a satellite hub station is an option to enhance coverage – as illustrated in the figure below. A more flexible solution could allow the WiMAX subscriber station or base station to directly access the space infrastructure.[66] These concepts are under study.

Figure 1.10: System architecture:



a) Based on satellite including gap filling functionality

b) Using integrated HAP (High Altitude Platform)/satellite configuration

Source: Interoperability between WiMAX and Broadband Mobile Space Networks; Romeo Giuliano, Michele Luglio, and Franco Mazzenga,; IEEE Communications Magazine • March 2008 http://awin.cs.ccu.edu.tw/magazine/IEEE_com/2008/015.pdf [66]

1.4.4 Use of FSS & MSS for warning and relief operations during natural disaster & emergency situations– the Tampere convention

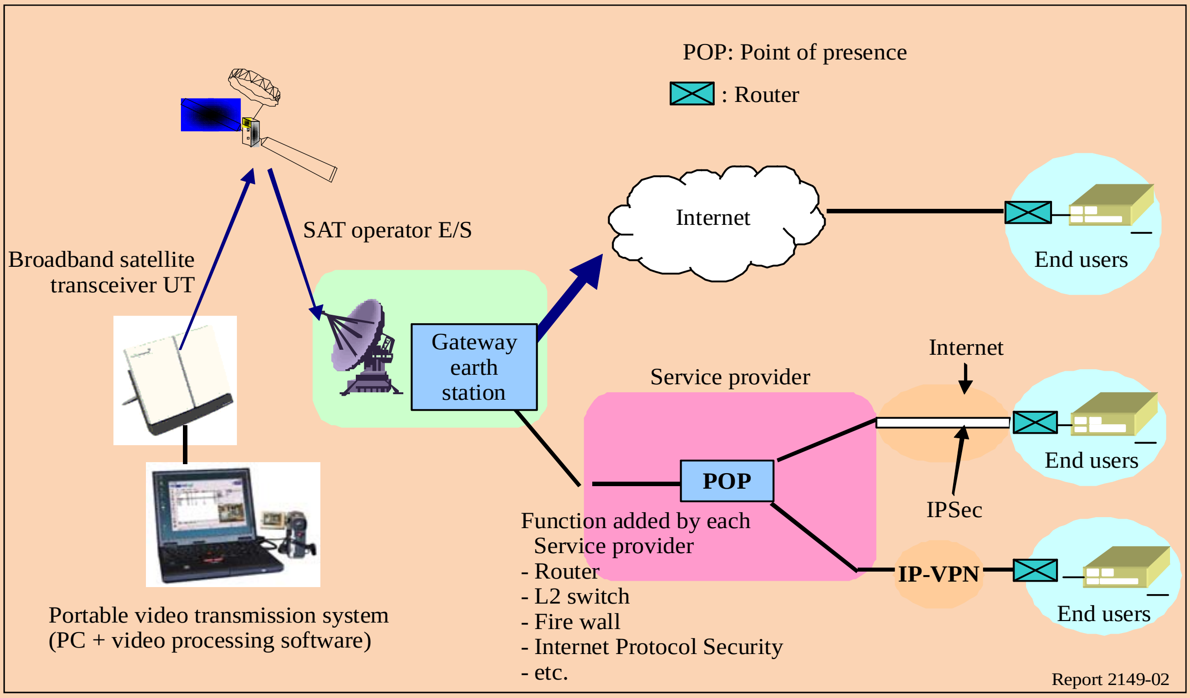
Fixed satellite and mobile satellite services (FSS & MSS) terminals have the attributes to be easily deployed and provide wide area coverage that is independent of local infrastructure, for providing immediate means of telecommunication to help in relief operations during natural disaster and emergency situations.

A recent ITU-R report[xx] details two modes in which MSS can be applied for disaster relief communications.

Geo-stationary MSS systems with high gain multiple spot beam design are also used for relief operations. These have the capability of digital beam forming that allows re-configuration of the coverage and distribution of the system resources (spectrum and power) as and when needed. GSO MSS systems can provide wide-area coverage without the use of ISLs (Inter Satellite Links) or multiple gateways. There are MSS configurations for real-time image transmission for static or moving pictures.

General concepts of the network structure are shown below in Fig. 1.17. The MSS earth station can process TCP/IP (Transmission Control Protocol/Internet Protocol) and the MSS terminal in the disaster stricken area is a portable packet data transmission terminal. It has data port to connect with a personal computer (PC). This PC is connected to a video capturing device with some video processing application software. Video data is coded and stored in PC's hard disc and transferred when the link between two PCs is established through the MSS system.

Fig. 1.11: Example-static and/or moving picture transmission with use of MSS via Internet



Source: ITU-R Report M.2149 http://www.itu.int/pub/R-REP-M.2149 `Use and examples of mobile-satellite service systems for relief operation in the event of natural disasters and similar emergencies'.

MSS component can also be used for backhaul of emergency terrestrial services. A pico-cell/small cellular area can be set up for emergency purposes and connected through satellite links to gateway earth station and hence to the outside world.

A number of existing and planned MSS systems [67] provide disaster relief communication. Some of these are; Inmarsat, Thuraya, HIBLEO-2/Iridium, HIBLEO-4/Globalstar, SkyTerra, TerreStar and AceS.

Besides the use of MSS, there are in use examples of systems in the fixed-satellite service (FSS) in the event of natural disasters and similar emergencies for warning and relief operations.[68] VSATs, vehicle mounted earth stations and transportable earth stations can access an existing FSS for emergency communications. These operate in disaster area with a `hub' earth station that uses large antenna size. The networks can operate in 14/12 GHz, 30/20 GHz with antenna sizes ranging from 1.2 to 3m and also in 6/4 GHz where antenna size is larger i.e. from 2.5 to 5 m. Other satellite resources and e.i.r.p. (effective isotropic radiated power) are studied using ` link budget' (accounting of all of the gains and losses from the transmitter, through the medium – free space, cable, waveguide, fiber, etc.- to the receiver in a telecommunication system) calculations.

Recommendations about the use of frequency band for regional and global use of systems in the FSS and the number of existing/operating systems in each band and other recommendations/ references are available from ITU's Radiocommunication Bureau.[69]

There are agreements between ITU and a number of agencies and organizations on the use of systems, including FSS systems, for disaster-related telecommunications.[70] Satellite and terrestrial broadcast infrastructure are also used for public warning, disaster mitigation and relief.[71]

The Tampere convention [72]: Trans-border use of telecommunication equipment by humanitarian organizations is often impeded by regulatory barriers that make it extremely difficult to import and rapidly deploy telecommunications equipment for emergency without prior consent of the local authorities.

Tampere Convention came into force on 8 January 2005 and has so far been ratified by 43 administrations. It calls on States to facilitate the provision of prompt telecommunication assistance to mitigate the impact of a disaster, and covers both, the installation and operation of reliable, flexible telecommunication services.

Regulatory barriers that impede the use of telecommunication resources for disasters are waived. These barriers include the licensing requirements to use allocated frequencies, restrictions on the import of telecommunication equipment, as well as limitations on the movement of humanitarian teams.

1.5 International Regulation Issues – Use of spectrum and orbital resource

Over the last 48 years, from the Administrative Radio Conference in 1963 and up to and including the last World Radiocommunication Conference in Geneva (WRC-07), many ITU conferences have addressed the regulation of spectrum/orbit usage by stations of the space radiocommunication services.

The ITU Member States have established a legal regime, which is codified through the ITU Constitution and Convention, including the Radio Regulations. These instruments contain the main principles and lay down the specific regulations governing the following major elements:

- frequency spectrum allocations to different categories of radiocommunication services;
- rights and obligations of Member administrations in obtaining access to the spectrum/orbit resources;
- international recognition of these rights by recording frequency assignments and, as appropriate, orbital positions used or intended to be used in the Master International Frequency Register.

The above regulations are based on the main principles of efficient use of and equitable access to the spectrum/orbit resources laid down in the ITU Constitution.[xxi]

This section is intended to underline the principles behind the satellite coordination and notification procedures[xxii]. These mandatory procedures and their successful completion provide administrations the rights of international recognition[xxiii] and protection to the spectrum and orbit resources coordinated by them[73].

International coordination of satellite systems provides certain flexibility in the grant of operating license to satellite network operators. This aspect will be explained in section 1.7.

Box 1.3 below summarizes the orbit spectrum allocation procedures. Basic elements that govern frequency spectrum/orbit usage by stations in space radiocommunication service**s** follow the established legal regime–based on ITU Constitution & Convention & the Radio Regulations (an international treaty document). Nobody owns any orbital position but Member administrations have rights and obligations to obtain access to the spectrum/orbit resources. States are thus obliged to establish appropriate supervision and control mechanisms on space networks.

The next (WRC-12) is expected to deal with many pressing issues dealing with use of orbit-spectrum resource (virtual and paper satellites) that is not commensurate with the international regulatory procedures and has the potential to block off new broadband satellites that could be used to serve developing economies.

Box 1.3: Orbit spectrum allocation procedures

ITU regulations & legal framework: ITU regulations form an independent legal regime, however, the major principles are based upon – UN Declarations and Treaties. No. 196 of the ITU Constitution (Article 44) [74] stipulates that, “In using frequency bands for radio services, Members shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations, so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries”. **Frequency spectrum/orbit usage:** Basic elements that govern frequency spectrum/orbit usage by stations in space radiocommunication services follow the established legal regime–based on ITU Constitution & Convention[75] & the Radio Regulations:

– Spectrum allocations to different categories of radiocommunication services;

– Rights and obligations of Member administrations to obtain access to the spectrum/orbit resources;

– International recognition of these rights by recording frequency assignments and, as appropriate, orbital positions used or intended to be used in the Master International Frequency Register.

Nobody therefore owns any orbital position but uses this common resource, provided that international regulations & procedures are applied. States are thus obliged to establish appropriate supervision and control mechanisms on space networks.

Radio Regulations (RR): Radio waves follow the laws of physics. They do not stop at national borders and therefore, interference is possible between radio stations of different countries – this risk is high in satellite communications. One of the main purposes of Radio Regulations (RR) is to ensure – interference-free operation of radiocommunications. There are two mechanisms for sharing orbit/spectrum

– A priori planning procedures guaranteeing equitable access to orbit/spectrum resources for future use (planned satellite services)

– Coordination procedures with the aim of efficiency of orbit/spectrum use and interference-free operation satisfying actual requirements – on first come first served basis (non-planned satellite services)In the `a priori planning procedure' frequency/orbital position plans have been laid down to guarantee for equitable access to the spectrum/orbital resources & predetermined orbital position & frequency spectrum is set aside for future use by all countriesIn the "First Come, First Served" coordination procedure – right is acquired through coordination with administrations concerned by actual usage; by efficient spectrum / orbit management; by homogeneous orbital distribution of space stations and by continuing responsibility of administrations for their networksArticle 9 of the RR consolidates all coordination procedures; Appendix 4 of RR specifies all data elements; Appendix 5 of RR states criteria for identification of administrations with which coordination is to be effected or agreement sought and Article 11 and Resolution 33 of the RR contain provisions detailing the requirement for notification/recording of frequency assignments.International coordination and notification of satellite networks for international recognition and protection

Successful coordination of space networks or earth stations gives an international recognition to the use of frequencies by these networks/stations. The relevant provisions involve three basic steps:

Advance publication (Section I, Article 9 of RR) – aim is to inform all administrations of plans to deploy a satellite system using a geostationary or a non-geostationary satellite and its general description;

Coordination (Section II, Article 9 of RR) – is a further step in the process leading up to notification of the frequency assignments for recording in the Master Register;

Notification (Article 11 of RR) – final step leading to recording of the frequency assignments in the Master Register providing the right to international recognition and protection (Article 8 of the RR).

The World Radio Conference 1997 (WRC-97) adopted Resolution 49 on the administrative due diligence applicable to some satellite communication services as a means of addressing the problem of reservation of orbit and spectrum capacity without actual use – or in other words to address the problem of paper satellites. For this purpose administration are required to send to the Radiocommunication Bureau of the ITU, due diligence information relating to the identity of the satellite network and the spacecraft manufacturer (name of the manufacturer, date of execution of the contract, delivery window, number of satellites procured) before the period established as a limit to bringing into use a satellite network.

Source: Orbit/Spectrum allocation procedures – Registration Mechanisms (Y.Henri) – Biennial Seminar of the Radiocommunication Bureau – Geneva, 2006: http://www.itu.int/md/R06-SEM.WORLD-C-0001/en

1.5.1 Regulatory Challenges: – Virtual satellites & other International coordination issues – Possible solutions

Independent information available today on the real use of the spectrum/orbit resource shows some divergence from the corresponding information submitted by administrations to ITU. This means that "paper satellite" issues – or, more precisely, fictitious frequency assignments recorded in the MIFR – still exist, with the majority of such assignments recorded with the indication that they have been brought into regular operation in accordance with the notified satellite network characteristics. [76]

The problem that there are a `number of frequency assignments recorded in the Master Register and declared in use which appear not to be in regular operation', is referred to as the problem of "virtual satellites".

These aspects were highlighted during an ITU workshop organized by the BR in Geneva in May 2009. [76]:

Radiocommunication Bureau issued a communication[xxiv] to all administrations requesting them to review the use of their recorded satellite networks & urged them to remove unused frequency assignments/networks from the Master Register. In parallel with this request, the Bureau also took recourse to certain provisions of the Radio Regulations[xxv] to enforce the removal of unused frequency assignments from the MIFR when their use had not been suspended in accordance with the Radio Regulations.

The Bureau is currently pursuing action along these lines in several cases, at its own initiative and also at the initiative of some administrations – in application of the relevant provisions of the Radio Regulations. Table 1.4 below shows the status of satellite networks that were surveyed by ITU's Radiocommunication Bureau:[77]

Table 1.4 Satellite networks considered by the ITU as `not corresponding to any existing operating satellite'

Number of satellite networks that were considered by the ITU as `not corresponding to any existing operating satellite'			
67 satellites networks were surveyed in mid 2009	**93 satellite networks in C & Ku bands from 16 Administrations and 3 intergovernmental satellite organizations were surveyed in December 2009**	**137 satellite networks in Ka band from 17 Administrations and s1 intergovernmental satellite organization were surveyed in April 2010**	**Status as of 1 March 2011**
15	34*	74	Confirmed in regular use
12	41	15	Suspended under No. 11.49 of the Radio Regulations
30	18	35	Suppressed
10	-	13	Still pending
***16** in application of Article 48 of the Constitution of ITU[78]			

Source: Report to the 56th Meeting of the Radio Regulations Board (RRB) http://www.itu.int/md/R11-RRB.11-C-0003/en

`Cleaning up' of the Master Register is now one of the major tasks of the Radiocommunication Bureau[79] and for this purpose the support of the administrations would be vital. Only the administrations with a more realistic approach to the choice of technical parameters for their satellite systems and better regulatory practices that allow the scarce orbit/frequency resource to be equitably and fairly shared by all, would permit the later entrants to coordinate and use their satellite networks without harmful interference.[80]

1.5.2 Cleaning up of the ITU's Master International Frequency Register (MIFR) poses challenges

The goal is to `clean-up' the radio spectrum and the satellite orbit for `real' satellite systems', provide them with maximum protection and place minimum administrative burden for their use. There has been a tendency for `hording' or `warehousing' of orbital slots and spectrum giving rise to regulatory distortions.

The World Radio Conference 2012 (WRC-12) [81]shall consider possible changes to "Advance publication, coordination, notification and recording procedures for frequency assignments pertaining to satellite networks"[xxvi]. This matter, including the issues related to "virtual satellites" has been the subject of intense debate during the CPM for WRC 12[xxvii].

From the point of view of coordination of satellite networks and to achieve international recognition & protection for the frequency assignments, it is important to have an appreciation of these issues and their alternative solutions. These are expected to come up for debate during the WRC-12 in early 2012.

1.6 Economics of satellite systems

1.6.1 When does it make economic sense to use satellite systems?

Currently, satellite platforms serve only a small fraction of the overall broadband users, currently estimated at more than 500 million and climbing at a steady pace.[82] So far, satellites have only been considered as a favourable option to complement the terrestrial broadband infrastructure. Well into the early 1990s the growth of Internet and VSAT matched each other but subsequently, the delivery of Internet over the terrestrial networks became much cheaper and grew much faster because of the easy and cheap availability of modems, ISDN equipment and ADSL.

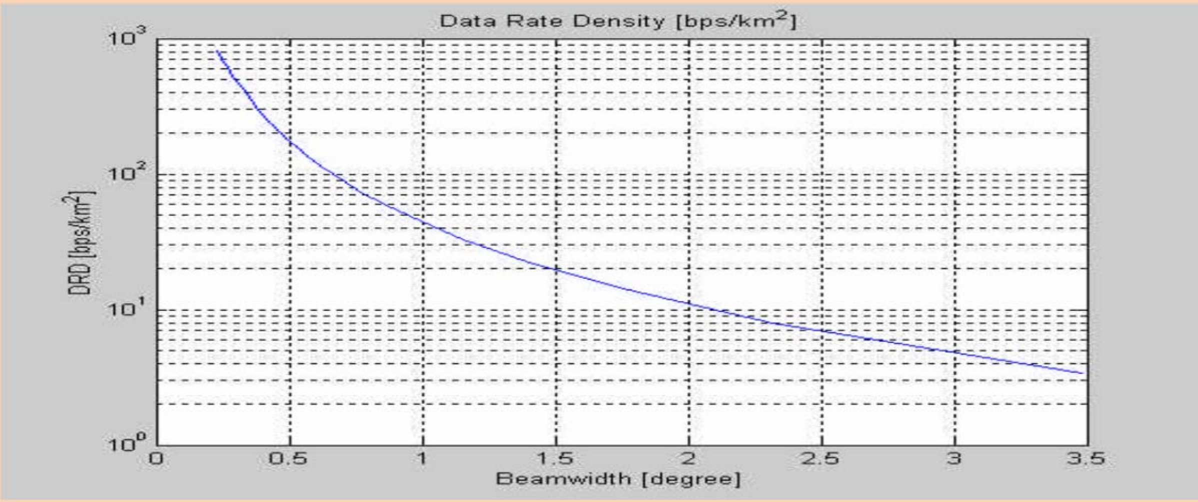
Nevertheless, satellite terminals can be deployed very quickly to bridge the digital divide, and at least offer a temporary solution in cases where a cheaper long-term solution could be provided by terrestrial infrastructure. Terrestrial broadband access cost increases at lower user density but satellite broadband access cost is independent of user density. Among the different competing designs for the last mile solution, space systems exhibit strong flexibility. Satellite Broadband Access is available at any location in the satellite coverage and the Service quality is distance independent.

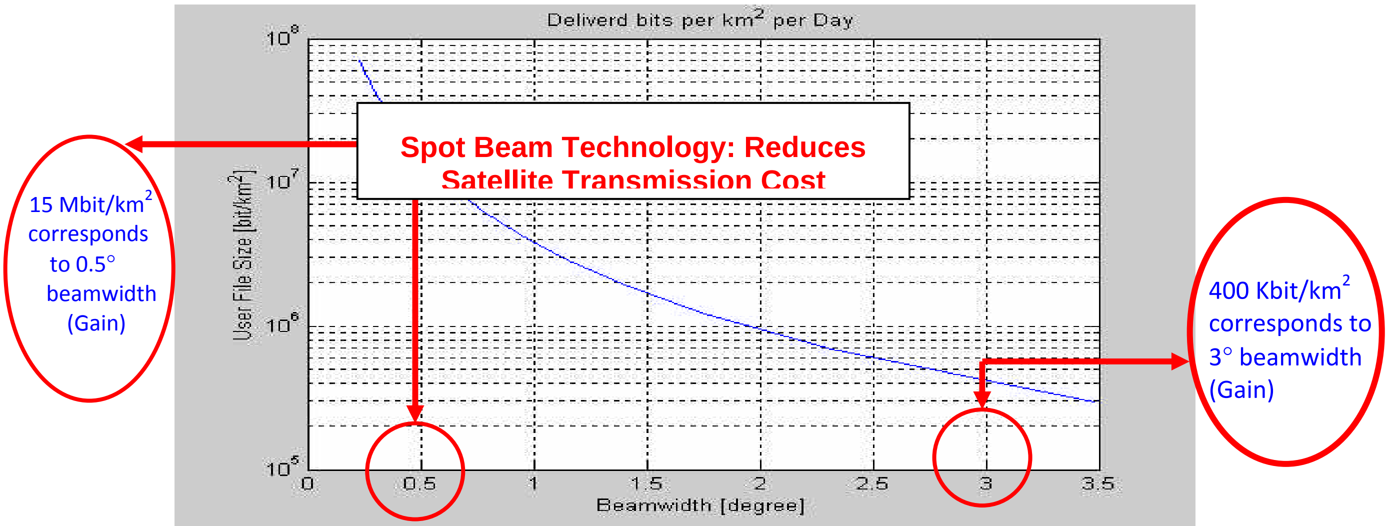
In an ideal implementation of satellite broadband, the satellite service element would see competing service providers leverage a common space platform with different ground segment (VSAT) equipment types to service consumers and enterprise level customers. The element of competition is very important in offering differing broadband capabilities, different contention rates on services to arrive at varying price points and capabilities to enable consumers to have a choice of broadband service offerings, download limits, equipment cost/efficiency/reliability etc.

Satellite access can be efficient for rural users. Broadband access platforms are shared by a large number of users who are not simultaneously active. The level of activity per user also fluctuates over time. These dynamics support the deployment of satellite as a "shared" solution which can be designed to support the specific demands of a particular country. Because the total satellite throughput is fixed, and the resource is shared between users, these systems are more efficient when they can take advantage of time-zone differences to even out the variation of service quality to users. Satellite systems often need to implement a "fair use" policy to restrict access or total usage for applications that require high throughput (like video streaming). Future technologies and developments (like smarter modems/set-top-boxes, multicast capabilities, and prescheduled and predictive algorithms for pre-fetching of content) will contribute to enhanced user experience for satellite services.

In many cases, access to an always-on broadband service is much more critical than whether the service hits a particular speed benchmark. Satellite broadband can deliver an always-on service for approximately the same price as terrestrial alternatives, but the service quality will likely remain inferior to the highest throughput terrestrial technologies. Satellite broadband is now considered an alternative for rural and low-population areas when compared with DSL services that are speed constrained because they are to locations that are 11'000-15'000 feet or further from the Central Office (CO) of the telecommunications provider.

Fig 1.12: A Decrease in satellite antenna beam-width (Gain) leads to increased capacity-data rate density (bps/km²)





Source: http://telecom.esa.int/telecom/media/document/IBC%202004%20Digital%20Divide%20Satellite%20Solutions%20Talk1.pdf

(Digital Divide Satellite Solutions – IBC 2004 Amsterdam RAI- M.Wittig)

For provision of broadband at such a large scale, a satellite option may make a lot of economic sense. At least two areas where sufficient progress has been made and that are helping in reducing the costs of satellite delivery are: one, use of spot beam technology (example: Ka band – (HTS) High Throughput Satellite) and second, the use of hybrid technology that brings about synergy between terrestrial and satellite components for broadband delivery.

On the hybrid technology front, ITU's Radiocommunications Bureau[xxviii] is discussing detailed specifications of the radio interfaces for the satellite component of International Mobile Telecommunications-Advanced (IMT-Advanced). The draft ITU-R Recommendation on this subject is under discussion.

Next generation of satellites with high throughput – High Throughput Satellites (HTS) – and deploying spot beam technology and frequency reuse could provide broadband service to millions of users during the next decade who would be otherwise un-served or underserved by terrestrial technologies. (The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot).

The governments can make satellite markets more economically viable by reducing national barriers to competition so that additional satellite networks could compete to provide services. The governments could also subsidize the building of their own satellite industries.

1.6.2 Present economic status & outlook for the satellite industry

Gains made by the satellite industry in various sectors and its existing economic status are now described briefly.

The `2011 State of the satellite industry report' released by the Satellite Industry Association (SIA) [83] on June 20th 2011 shows a 5% growth in overall world satellite industry revenues in 2010. Global 2010 revenues for the satellite industry totaled $168.1 billion, representing 11.2 % average annual industry growth rate over the past 5 years.

Satellites services revenues surpassed the $100-billion mark and satellite ground equipment doubled its overall revenues over the past five years.

Futron Corporation [84] polled over 80 satellite companies to assess the performance of four satellite industry sectors:

Satellite services: Satellite Services revenues resulted in 9 percent growth globally over 2009, reaching $101.3 billion.

Satellite manufacturing: Satellite Manufacturing revenues, reflecting in-year satellites launched,

declined by 20 percent worldwide to $10.8 billion, compared with the $13.5 billion in 2009. Overall, however, global satellite manufacturing showed aggregate growth of 38 percent over the past 5 years.

Satellite launch: revenues, reflecting in-year launches, decreased by 4 percent in 2010.

Ground equipment: Satellite Ground Equipment revenues continued to increase, growing 3 percent over 2009 to $51.6 billion. Consumer-related ground equipment led this expansion, including satellite TV, broadband, mobile satellite terminals, and GPS devices.

Satellite broadband access is poised to grow almost 15% annually over the coming 10 years forecasts NSR (Northern Sky Research) in latest market research report on “Satellite Broadband Internet Access Services Leading the Push in Revenue Growth” in April 2011[85]. The total satellite broadband market is expected to generate $9 billion in revenues by 2020, driven primarily by satellite broadband Internet access and VSAT networking to enterprises.

Satellite broadband access service is expected to become a US$ 5.1 billion industry by 2020 a fourfold increase as compared to 2010.

Increased potential to exploit HTS (High Throughput Satellites) [86] is seen as a tangible response to the challenge of bridging the digital divide using space technology. The satellite backhaul services primarily the `cellular-backhaul' is also poised to see a 175% growth in backhaul sites installed globally during the next 10 years. HTS offer very high data rates at low prices and represent an important trend in commercial satellite industry. These are now being preferred for low cost broadband services.

1.7 Market Entry: Existing practices and overcoming drawbacks

To address changes in the telecommunications environment such as the advancement of Internet technology to supply data, voice, and video, the revision of the laws and regulations governing these markets has become necessary. The growing convergence in the telecommunications sector has thrown up additional regulatory challenges. Amongst other gains, addressing these issues would foster emergence of competition in what were previously considered to be monopolistic markets. The existing regulatory framework need not be imposed on new and/or converging technologies that are not easily classified under their existing framework.

Deployment of broadband satellite services at national, regional or global levels bring in with it, a horde of regulatory issues. These issues may stem mostly at the national level but have far reaching consequences. Restrictive regulatory practices deny the benefits of technological advancements that can manifest in terms of material losses and can also deny socio-economic gains.

Non-adherence and abuse of the international orbit-frequency coordination procedures, monopolistic practices, burdensome authorization conditions and dissimilar fiscal treatment, requirements of national presence are not conducive to the growth of satellite broadband delivery.

This section identifies regulatory bottlenecks and restrictive licensing rules that could discriminate against satellite service providers by denying them the competitive advantage and slow or prevent effective provision of satellite based services. Corresponding regulatory solutions are then highlighted.

1.7.1 Licensing and access practices in place for Satellite systems and Earth stations (VSAT)

The RR set the international framework for licensing of satellites[xxix] "No transmitting station may be established or operated by a private person or by any enterprise without a license issued in an appropriate form and in conformity with the provisions of these Regulations by or on behalf of the government of the country to which the station in question is subject."

Licensing of satellite services is based on two primary requirements –to manage spectrum resources so that harmful interference is prevented and to protect public safety. (i.e., use of fencing, secure areas and warning signage). Public safety also constitutes restrictions on the design and configuration of transmission parameters in order to ensure that transmissions do not exceed appropriate levels and restrictions on the proper installation and use of transmission equipment (i.e., requiring adequate training for equipment installers and operators).

The purpose of licensing is to grant permission to operators/users to use frequencies under certain conditions. Among these conditions are standard of service, efficient use of the spectrum, avoidance of interference and avoidance of overloading when the same channel is assigned to more than one user, etc. Licensing involves dialogue between the administration and the end user of the radio frequency spectrum.

Licensing covers: i) technical aspects (e.g. quality of service, sharing/collocation of facilities, interconnection, type approvals, spectrum management, etc) ii) commercial aspects (e.g. competition, pricing, Universal access/service obligations, etc) iii) administrative aspects (e.g. licensing conditions and procedures, coordination, etc).

The wide variety of licensing approaches applied throughout the world has served as an impediment to the provision of satellite services. Development and implementation of harmonized licensing regimes, both across service types and within regions and sub-regions, is essential.

When the introduction of new and advanced technologies is coupled with liberalization, competition and a harmonized licensing process, it creates increased access and facilitates innovation.

- The specific objectives of licensing are to:
- Simplify access to satellite market for a potential new entrant
- Define conditions of operation, rights and obligation of licensees – To stimulate investment in the satellite market all the stakeholders are required to be provided with enough information about their rights and obligations so that they might make informed investment decisions. Certainty is a key factor for ensuring the development of investment initiatives.
- Contribute to the creation of a level playing field and promote competition – mechanisms for managing the co-existence of many operators in complementary, supplementary or competing segments.

Conditions for consumer protection – defining relationships between consumers and licensees with regard to pricing, billing practices, consumer complaint procedures, reciprocal responsibilities, dispute resolution, limitations of liability for service, and mandatory services to consumers.

- Transparent and predictable regulatory regime and safeguard industry development in the region- For satellite operators to gain confidence in the industry and the market so that they are encouraged to plan long-range activities and/or conduct research.
- Manage scarce resources: – regulators to allocate fairly, efficiently and in the public interest, scarce resources such as radio spectrum. In instances where allocated scarce resources are not utilized, under-utilized or misused, the license conditions allow regulators to reclaim the resources concerned.
- Define targets and obligations to be attained by all licensees.

Any discrimination in favor of existing service providers or limiting the number of independent service providers for the provision of satellite services to consumers, does not lead to an open and competitive market.

For the satellite component to be a part of the overall infrastructure, a vibrant market for satellite services (like in the banking system) is needed and this can be created through regulatory certainty, liberalization, equity and transparency and by promoting competition

Licenses issued by administrations for the ground segment of a satellite system fall in two groups:

- authorization requirements for satellite service providers and
- individual licensing for earth station facilities.

Service Provider Licensing is for quality assurance to their customers.

Some administrations also license the private VSAT services- not usually connected to the PSTN. Such licensing process may cause time delays and confusion. Besides, certain administrations also required the VSAT or mobile terminal to be licensed individually – in addition to requiring a network operator's license.

A new approach to regulating VSATs – "blanket licensing" – began to be implemented sometime ago and it has been successful. VSATs are configured based upon technical criteria – involving power level, frequency, etc. – that mitigate the risk of interference. Thus, a single blanket license can be issued covering a very large number of VSAT terminals. For mobile systems, international frequency co-ordination procedures and the use of harmonised standards practically eliminated the risk of harmful interference and a growing number of countries were able to exempt the circulation of terminals from individual licensing requirements.

This approach has worked well in the United States [87] which, is home to the largest installed base of VSAT networks. However, the United States isn't the only country to adopt blanket licensing. Indeed, 43 European nations adopted a policy principle that provides for blanket licensing of receive-only and interactive VSAT terminals.[87]

The policy was adopted through the regional Conference of European Postal and Telecommunications Administrations (CEPT) and is now being implemented by individual national administrations. Also, these approaches have worked well in regions that include North and South America, Asia, Africa, and Europe not only for the regulator but for the industry and for end users as well. Besides, the trend by individual regulators for blanket licensing based on their national interests, is on the increase.

1.7.1.1 Dealing with technology neutrality and measures to ease access for market entry:

Various satellite technologies cater modern services to consumers. In order to facilitate fair competition between these technologies, regulators strive, to the extent possible, to make their regulations, licensing requirements and regulatory fees technically neutral.

Relative costs and benefits of each available technology are the main parameters that are weighed against each other by an Internet service provider (ISP) to build its network. If discriminatory regulatory requirements make one or more of these technologies relatively unattractive, the ISP will likely be forced to choose the technology that is least encumbered from a regulatory perspective, rather than the technology that can provide the best service at the lowest price.

To make regulations technology-neutral, regulators need to strictly limit their regulations and licensing requirements for technology & infrastructure facilities (whether terrestrial, satellite, etc.), using them solely to (1) protect the public safety and (2) manage scarce public resources, such as frequency spectrum when there is more than a negligible risk of harmful interference. Technology neutral regulations and licensing requirements will bring in the desired effect of more competition, increased demand and cost savings.

The key to technology neutrality is not to pick "winning" technologies and thus forego the possibility that a provider could implement more cost-effective technologies, either now or later. Another key aspect is equity. The same rules should apply to all licensees, no matter who they are and what industry they represent. Anyone who can meet the technical and economic standards set by the licensing can use any technology they wish.

There is no one particular wireless technology that can solve all development problems. The future will see a mix of various technologies and the market should be permitted to determine, over time, which ones best suit particular applications. Administrations are encouraged to maintain general technology-neutral regulatory policy principles that would facilitate the expansion of wireless services.

Licensing rules focus on the space and the terrestrial segments of satellite networks. For this, due care is required to see that licensing requirements do not become barriers to free trade, but accomplish legitimate regulatory requirements.

1.7.2 Open access: Open skies and International Gateway liberalization

While placing licensing requirements on the space segment portion of a satellite network, administrations have focused on two areas – requiring authorizations for domestic landing rights and requiring authorizations for the use of specific frequency segments. Both trends are discussed below.

1.7.2.1 Open access to satellite networks – Open skies

Up until 1980s-and to a large extent, into the 1990s, even with the advent of independent satellite companies, intergovernmental satellite organizations carried the international satellite traffic. Commercial satellite companies began to be licensed and empowered to have their own satellite systems and bring in the much-needed competition for the space segment. Satellite market, today, represents an interesting mix of commercial and government owned entities that are jostling to meet the ever-increasing demand for satellite services.[88]

Administrations have in the past, relied on policies that provide protection to their national satellite systems. These "Closed Skies" policies required service providers to use only locally owned satellite capacity. Besides, organisations such as Intelsat, Eutelsat and Inmarsat were inter-governmental organizations owned by the telecom incumbent and telcos around the world and access to space segment could only be bought via these.

Tremendous demand for Internet, data, voice, video and other essential services is best addressed by policies that permit open and direct access to all satellite resources assuming that these resources have been properly co-ordinated through the ITU. The "footprint" of a satellite – the area of the Earth illuminated by a satellite – does not match national borders. This makes it necessary to regulate this matter through international agreements such as those painstakingly developed by the ITU[xxx] as a result of multiple study cycles and world conferences.

ITU's coordination process[xxxi] is designed to mitigate interference among satellite networks. Once the entire process of coordination has been gone through, the satellite service can be provided in any of the service areas associated with the coordinated satellite network.

Therefore, if a satellite operator is licensed to use a satellite from the country that owns it and has coordinated it through the ITU, no duplicate licensing requirement should be imposed on the use of that satellite to provide services in any other country.

This non-discriminatory approach by domestic and non-domestic satellite service providers to have direct access to all available satellite resources and to the markets constitutes the policy referred to as "Open Skies". This involves permitting increased access to orbital resources, regardless of the satellite operators' country of origin.

This is being embraced gradually by most administrations that have realized the tangible benefits of these policies. This idea should also find reason with others.

"Open Skies" policies require satellite operators to compete for customers interested in obtaining C-band, Ku-band and Ka-band satellite bandwidth. It has been proven that this competition can result in more options for local customers with a significant boost in quality and lowering of prices.[89]

European satellite Operators' Association (ESOA) [90] in its " Market Access Principles & Open Skies Policy for Satellite Communications" has elaborated on the "Open Skies" model:

"Open Skies Policy allows nationally authorised service providers to choose any satellite operator or satellite services to the specific service area(s) required for their end users (national and international)"[90]

1.7.2.2 Does open access mean open skies or does the issue relate to ground segment sharing?

The "Open Skies" policies gave rise to more `down-to-Earth' policies for operators of Earth stations to allow access to their facilities by multiple satellite service providers.

This access to Earth station facilities is either through collocation or through provision of backhaul services. -Certain administrations have spelt out clear conditions for collocation at Earth stations i.e. those requesting such a facility are required to have lease agreements with the satellite networks/systems they wish to access.

In Malaysia, operators of facilities included in a published Access List Determination are required to provide access upon written request, unless they are unable to do so under terms of the Mandatory Standard on Access.[91] The Malaysian policy allows entities seeking access to either self-provide backhaul service – to a submarine cable or satellite earth station – or to acquire backhaul from another operator. The policy also allows collocation at a satellite earth station, as well as a submarine cable landing station.

In Singapore, the dominant carrier SingTel has published a separate schedule (Schedule 8C) in its RIO (Reference Interconnection Offer), which spells out the terms and conditions for collocation at its three earth stations (Bukit Timah, Sentosa, and Seletar). The RIO stipulates that parties requesting collocation must already have obtained one or more satellite transponder lease agreements (or an Inmarsat land earth station operator agreement) with the satellite system(s) it wants to access. In addition, the access seeker must have obtained all required licenses and be a facilities-based operator (FBO). [88]

In essence, therefore open access to Earth stations would also promote cost reduction, increase demand and bring in more competition and avoid wasteful infra-structural duplication.

1.7.2.3 International Gateway (IGW) liberalization

In the case of satellites, IGW is the earth station facility that links domestic networks to a satellite system to aggregate and distribute incoming and outgoing international voice, video and data traffic.

Some satellite services provide for direct transmission to individual terminals. These include VSAT (very small aperture terminal), direct-to-home broadcasting and mobile satellite services. In such cases, earth stations serve as the venues where broadcasting content is uploaded to the satellite, or where traffic is handed off through interconnection to the public switched telephone network (“PSTN”).

The original model for owning earth stations was vertical integration. Within the global consortiums such as Intelsat and Inmarsat, each member country’s designated satellite operator would own and operate the earth stations to link to the consortium’s satellites. Thus, one entity (either a company or government agency) would control access to the satellites. Even for mobile satellite and direct-to-home (DTH) broadcasting systems, vertical integration was the rule, with satellite companies distributing terminals manufactured (often under license) particularly for their discrete services. [88]

Insufficient access to international network capacity, deriving in many cases from vertical integration, often results in high prices for broadband access. For many developing countries, the connection to the global information grid is limited and therefore high costs for access to international networks are passed on to businesses and consumers. These high prices reduce the demand and the incentive/motivation for the service provider to invest in additional network capacity.

Liberalizing the access to these gateway facilities can lower infrastructure costs and promote infrastructure sharing, while multiplying the amount of international capacity available to operators. This boosts the international traffic, promotes competition for access to international networks and therefore results in lowering of prices. Experiences in several countries, such as India and Singapore that have implemented IGW liberalization, have demonstrated these benefits.[88]

1.7.3 Regional harmonization of regulatory network

Regulatory challenges are being addressed at the regional and sub-regional levels by administrations that share similar objectives. The underlying force is the realization that satellite-based systems are one of the most effective forms of wide-area and, often, cross-border solutions for information and telecommunications worldwide.

Various initiatives to facilitate satellite harmonization are also being developed and implemented by Administrations, both at the national and regional levels leading to an increase in the level of competition for service provision and an increase in the number of satellite service licenses.

Type approval and equipment registration in the regional context and satellite licensing are some of the key areas where Administrations have focused their efforts to coordinate and harmonize satellite regulatory approaches.

1.8 Bringing it all together: Regulatory best practices for satellite industry

For the satellite industry, the pace of growth of broadband, delicately hinges on the regulatory practices. Realization by the regulatory agencies in general, that "less is more" makes way for imposing less regulatory requirements for more access to essential communications and an important means of enhancing competitiveness.

Concrete measures towards this goal should keep in mind the following points:

- Any limitations on the number of service providers for provision of satellite services or preference for domestic operators or burdensome authorization conditions for use of foreign satellite systems may adversely affect competition, investment in new infrastructure or reduction in service costs.
- An obligation for satellite operators to establish a local technical or commercial presence in the country where the satellite's footprint comes down, but where the satellite operator himself does not provide any service on the ground, would be a hindrance to satellite service provisions. This is primarily because the costs of opening, staffing and maintaining such a local office would make satellite service provisions not worthwhile in the country, unless the market is extremely extensive. Furthermore, this may be construed as an unintended restriction of access by non-domestic service providers.
- A requirement for the satellite operators to obtain a license/permit/authorization for the use of orbit/spectrum resource on country-by-country basis should be avoided.
- Foreign ownership restrictions should be avoided as well as any requirements for non-domestic satellite operators to align with national/domestic incumbents be removed. Any residual ownership interest in a monopoly or dominant carrier, because of old policies hinders & harms domestic economic development and growth.
- There should be no discrimination between foreign and national satellite systems. Licensing procedures should be efficient, transparent and equitable regardless of whether they are for domestic or foreign operators.
- Formulation of the 'open-skies' policy brings in competition and provides multiple options to the end-user. In contrast, policies to provide protection to country's own satellite capacity and an obligation by service providers to use it can stem competition and quality of service.
- Transparency is an important aspect of telecommunication service regulation as it improves accountability and private sector confidence for investment. The lack of transparency in some countries constitutes a significant barrier to entry by new competitors, particularly since many service providers are forced to abandon plans to provide services in these countries rather than shoulder the significant expense of ascertaining the regulatory requirements.
- Transparency requires that laws and regulations that concern provision of satellite based services and details of requirements for licensing and permits be readily available. Listing on national regulatory agency's website is very helpful and results in timely and predictable decisions.

Here it is also important to mention that the rights and & obligations of the ITU's Member States as well as the mechanisms of sharing orbit/spectrum resource recognize the inherent international nature of the satellites communication and aim to provide interference free operation of satellite networks by international coordination procedures as contained in the Radio regulations. This statement underscores the fact that market mechanisms or national regulatory policies conform to international practices. National spectrum allocation policies need to be conducive to satellite operators for making long-term financial investment – more so, considering the fact that from "conception" to the point when a satellite system begins to provide gainful returns, could take over a decade. In this context, regulatory framework for satellite systems need to be efficient and should produce timely as well as predictable decisions in order to ensure the continued infrastructure investments required to deploy these networks.

Finally, harmonization of licensing frameworks could improve the overall global satellite connectivity. Therefore, for an increasingly harmonized regional regulatory framework, effective national deregulatory approaches are being debated. In organizations such as Inter-American Telecommunications Commission (CITEL) in the Americas, the Asia Pacific Telecommunity (APT) and Asia Pacific Economic Co-operation group (APEC) in Asia, the Conference Europeene Posts et Telecommunications (CEPT) and the European Union (EU) in Europe, Arab Spectrum

Management Group (ASMG), Africa Telecommunication Union (ATU), Regional Commonwealth in the field of Communications (RCC) and on many sub-regional levels, harmonizing country policies and regulations are leading the way for a better overall global satellite connectivity.

As with terrestrial networks, broadband is affecting and changing the future prospects of satellite technologies. With the demand for network capacity growing by leaps and bounds, satellites once again offer the potential to leapfrog earth-bound limitations and provide greater bandwidth across the globe. In order to reach its global potential, the satellite sector will need to embrace a global vision – and it will need regulatory certainty and liberalization on a global scale. In an era in which radiofrequency spectrum usage is increasingly constrained, the logjam over use of combined terrestrial and satellite networks will have to be broken up. Licensing and access to national markets will have to continue on a path toward greater openness, even as more countries gain access to satellite launch capabilities and orbital locations. The technology exists right now to create a profusion of interconnected broadband networks in space, with a vibrant and competitive market to access them. The question is really not how high humanity's broadband dreams can ascend, it is whether our institutions and organizations have the capacity to build as high as our dreams.

ANNEX 1

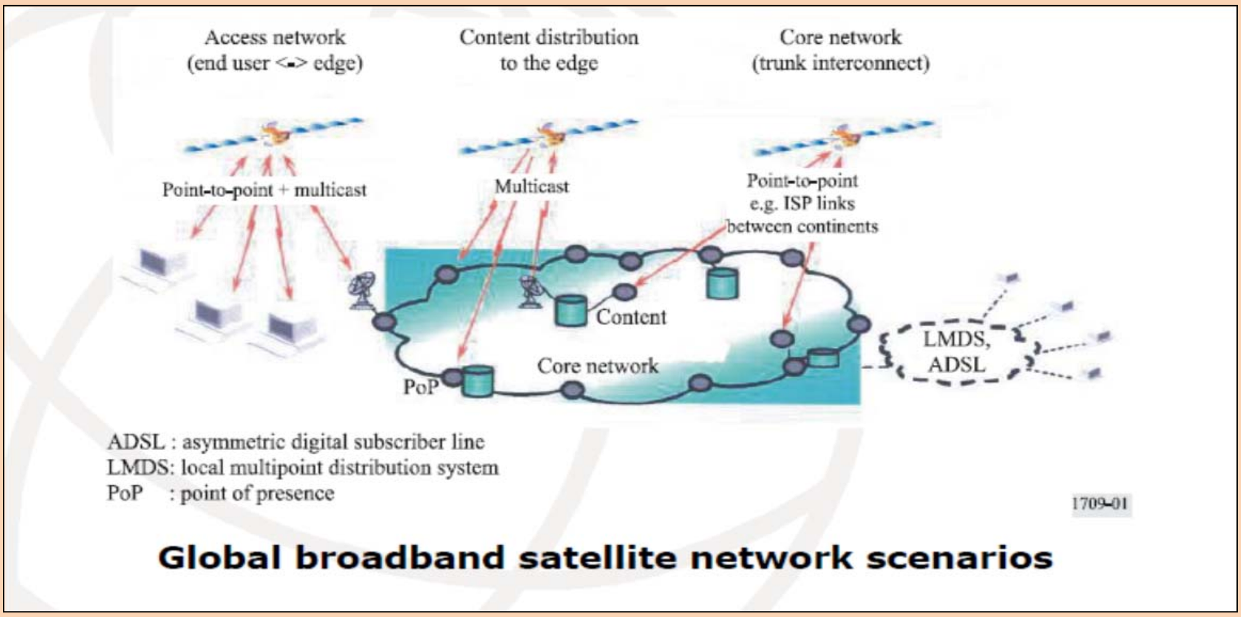
A.1.1 Generic description of the network architecture for broadband satellite networks

RECOMMENDATION ITU-R S.1709-1[12] defines the *generic satellite network and protocol structures* that can be used by designers of broadband radiocommunications based on the use of satellites.

A `global broadband satellite network architecture' in Fig.1.14 consisting of the following scenarios:

- *Access network*: providing services to end-users.
- *Distribution network*: providing content distribution to the edge.
- *Core network*: providing trunking services.

Figure 1.14 Global broadband satellite network scenarios



Source: RECOMMENDATION ITU-R S.1709-1-Technical characteristics of air interfaces for global broadband satellite systems

Services: Following services are provided by the broadband satellite network:

Point-to-point – Multicast/broadcast – Content distribution.

Broadband applications: Broadband applications supported by satellite networks are:

Entertainment: Video-on-demand – TV distribution – Interactive games – Music applications – Streaming

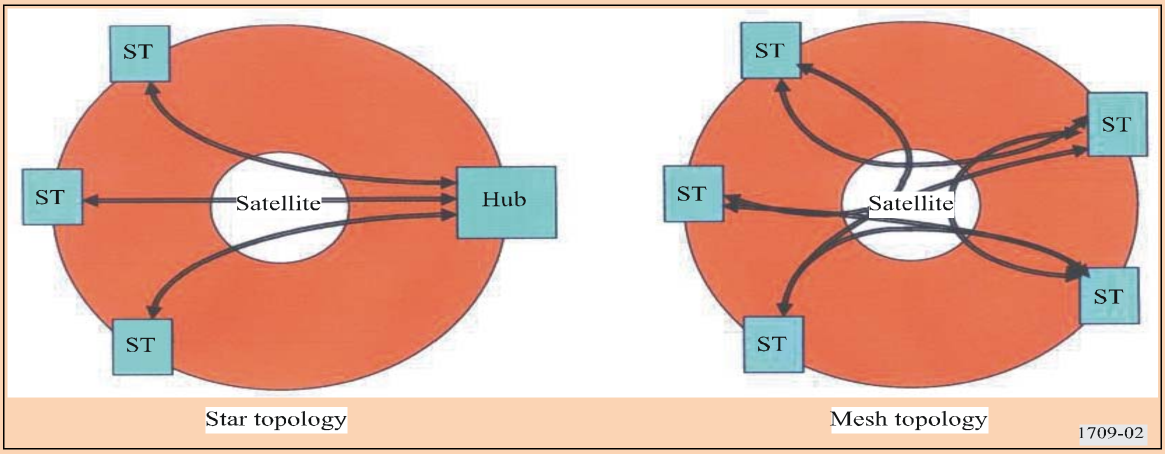
Internet access: High-speed Internet access – Electronic messaging – Multimedia applications - Distanc learning – Telemedicine.

Business: Videoconferencing – Business-to-business – Home security

Voice and data trunking: IP-transport – Voice-over-IP – File transfers.

Topologies: The network may use either a mesh or star topology as illustrated in Fig. 1.15:

Figure 1.15 – Star and mesh topology



Source: RECOMMENDATION ITU-R S.1709-1-Technical characteristics of interfaces for global broadband satellite systems

- A star network topology is defined by the star arrangement of links between the hub station (or Internet access point) and multiple remote stations. A remote station can only establish a direct link with the hub station and cannot establish a direct link to another remote station.
- A mesh network is defined by the mesh arrangement of links between the stations, where any station can link directly to any other station. The star topology can be considered as one special case of the mesh topology.

NOTE 1 – A star topology can be used to provide mesh connectivity by establishing an indirect link between remote stations via the hub station.

Non-regenerative or a regenerative satellite architecture: A global broadband satellite-system network may use either a non-regenerative or a regenerative satellite architecture:

- A non-regenerative architecture refers to a single architecture, commonly called “bent-pipe architecture”. This architecture does not terminate any layers of the air interface protocol stack in the satellite – the satellite simply transfers the signals from the user links to the feeder links transparently.
- A regenerative architecture is the range of other architectures that provide additional functionality in the satellite. In these architectures, the satellite functions terminate one or more layers of the air interface protocol stack in the satellite.

A.1.2 Brief overview of air interface standards approved by various standardization bodies

For providing satellite broadband, i.e. high speed Internet and multimedia, there are many possible ways. However, certain fundamental features are very similar like user access to the system, protocol access, air interface and satellite dependent and independent functions.

Three standards for broadband satellite networks have been developed and detailed in the RECOMMENDATION ITU-R S.1709-1:

Internet Protocol over Satellite (IPoS) by TIA (Telecom Industry Association);

Digital Video Broadcasting –Satellite (DVB-S), interactive channel for satellite distribution systems by ETSI (European Telecommunication Standards Institute);

`Air interface specifications for global broadband communications between earth stations and regenerative satellites’ that is based on ETSI BSM/RSM-A (Broadband Satellite Multimedia/Regenerative Satellite Mesh).

Table 1.6 below summarizes the three standards.

Table 1.6 – Comparison Table between Air Interfaces ETSI EN 301 790 V.1.3.1, TIA-1008-A and ETSI RSM-A

Item	ETSI EN 301 790	TIA-1008-A	ETSI RSM-A
Network topology	Star or mesh	Star	Star or mesh
Modulation	QPSK (Quaternary/Quadrature phase shift keying)	CE-OQPSK (Constant Envelope-Offset Quaternary/Quadrature phase shift keying)	CE-OQPSK (Constant Envelope-Offset Quaternary/Quadrature phase shift keying)
Outbound traffic access method	DVB-S Digital Video Broadcast-Satellite	DVB-S Digital Video Broadcast-Satellite	High rate TDMA (Time Division Multiple Access)
Outbound traffic data rate (Mbit/s)	1 to 45	1 to 45	100, 133.33, 400
Inbound traffic access format	MF-TDMA (Multiple Freq.- Time Division Multiple Access)	MF-TDMA (Multiple Freq.- Time Division Multiple Access)	FDMA-TDMA (Freq. Division Multiple Access -Time Division Multiple Access)
Inbound traffic data rate	No restriction	64 kbit/s, 128 kbit/s, 256 kbit/s, 512 kbit/s, 1 024 kbit/s, 2 048 kbit/s	128 kbit/s, 512 kbit/s, 2 Mbit/s, 16 Mbit/s
Protocols	DVB/MPEG2 TS outbound, AP/AAL5/ATM inbound (Digital Video Broadcast / Motion Pictures Expert Group2 Transport Stream outbound) Access Point / Asynchronous Transfer Mode Adaptation Layer type 5 / Asynchronous Transfer Mode inbound)	Multilayered protocol	IETF IP Network Protocols Internet Engineering Task Force – Internet Protocol

Source: RECOMMENDATION ITU-R S.1709-1-Technical characteristics of interfaces for global broadband satellite systems

Three standards outlined above can be used for high-speed Internet access services for individual households or collective residential services. Seamless interconnectivity between terrestrial and satellite networks is paramount for broadband using satellites.

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77. See "Report to the 56th Meeting of the Radio Regulations Board (RRB)" at: http://www.itu.int/md/R11-RRB.11-C-0003/en

78. See " Constitution of ITU: Chapter VII – Special Provisions for Radio ARTICLE 48 – Installations for National Defence Services" at: http://www.itu.int/net/about/basic-texts/constitution/chaptervii.aspx

79. See " Cleaning up the Master International Frequency Register" – blog post by Rajesh Mehrotra http://redbooks.ch/2010/10/29/second-post/

80. See " Efficient Use of Spectrum/Orbit – Small things can help, too -Avram Sion / Hon Fai Ng BR/SSD/SSC (BR Workshop, Geneva, 6 May 2009) at: http://www.itu.int/en/ITU-R/space/workshop EfficientUseGeneva/wseffuse09003.pdf

81. See "World Radiocommunication Conference 2012 (WRC-12) (Geneva, Switzerland, 23 January-17 February 2012) at: http://www.itu.int/ITU-R/index.asp?category=conferences&rlink=wrc-12&lang=en

82. See "Next Generation of Satellite: High Capacity, High Potential" – April 1, 2011 | Via Satellite | Giovanni Verlini – at: http://www.satellitetoday.com/broadband/applications/01/Next-Generation-of-Satellite-High-Capacity-High-Potential_36421.html

83. See:http://www.sia.org/PDF/FINAL%20Press_Release_State%20of%20the%20Satellite %20Report%202011%20JUNE%202011.pdf

84. See: http://www.futron.com/index.xml

85. See "Revenues for Broadband Satellite Services to Exceed US$9 Billion by 2020"at:

http://www.nsr.com/index.php?option=com_content&view=article&id=431:revenues-for-broadband-satellite-services-to-exceed-us9-billion-by-2020&catid=81:press-releases&Itemid=144

86. See " HTS and KA-SAT: Changing the European Telecom Landscape...An Interview with Eutelsat" at: http://www.nsr.com/index.php?option=com_content&view=article&id=351&catid=102&Itemid=175

87. See: http://www.satellitetoday.com/via/32364.html

88. See " International sharing: International gateway liberalization" by John Alden, Vice President, Freedom Technologies, USA – Trends in Telecommunication Reform 2008-six degrees of sharing-http://www.itu.int/ITUD/treg/publications/ITU_Trends2008_Chapter6.pdf

89. See " Fighting the Good Fight: The Global VSAT Forum Crusade" at: http://www.gvf.org/solutions/index.cfm?fuseaction=satcom1

90. See "ESOA" at: http://esoa.net/upload/files/policy/OpenSkies_for_Sats_Dec08.pdf

91. See Malaysian Communications and Multimedia Commission, "FAQs on Determination on Access List (1 of 2005) and Mandatory Standard of Access (2 of 2005)", downloaded from: www.skmm.gov.my/what_we_do/access

i This is according to the working definition of BDT. The Telecommunication Standardization Sector of ITU in its ITU-T Recommendation I.1135 – Vocabulary of terms for broadband aspects of ISDN – defines broadband [wideband] as ` Qualifying a service or system requiring transmission channels capable of supporting rates greater than the primary rate'. ITU-T Recommendation I.1126 – Vocabulary of terms for ISDNs – defines the term `primary rate access' as `A user-network access arrangement that corresponds to the primary rates of 1544 kbit/s and 2048 kbit/s..'

ii See `Backhaul To The Future...' By Justin R. Phillips, Vice President of Marketing, Microsat Systems Canada, Inc. at: www.satmagazine.com/cgi-bin/display_article.cgi?number=1473951770.

iii NSR (Northern Sky Research) in "Broadband Satellite Markets, 10th Edition, April 2011

iv *Geostationary-satellite orbit:* The *orbit* of a *geosynchronous satellite* whose circular and direct *orbit* lies in the plane of the Earth's equator.

v *Geosynchronous satellite:* An earth *satellite* whose period of revolution is equal to the period of rotation of the Earth about its axis.

vi See No. 1.189 of the ITU Radio regulations, 2008 Edition, Volume 1"

vii See ITU-R Study Group 4, Question ITU-R 269/4, at: http://www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rsg4&lang=en and " RECOMMENDATION ITU-R S.1782 – Possibilities for global broadband Internet access by fixed-satellite service systems" at : http://www.itu.int/rec/R-REC-S.1782-0-200701-I/en

viii Under Agenda Item 1.19

ix See "Radio Regulations 2008 Edition, Volume 1"

x The World Radiocommunication Conference (WRC 12) will consider possible additional allocations to the mobile-satellite service[x], in accordance with Resolution 231 (WRC-07).

xi See " **Final Report of the CPM to WRC-12" at:** http://www.itu.int/md/R07-CPM11.02-R-0001/en, Chapter 5 and WRC-12 Agenda item 1.25.

xii This is the subject of study in the ITU-R Study Group 4 (Working Party 4B).

xiii More specifically during the deliberations of the Working Party 4B (WP 4B) of the ITU-R Study Group 4.

xiv See "Systems, air interfaces, performance and availability objectives for FSS, BSS and MSS, including IP – based applications and satellite news gathering" – ITU-R WP4B Meeting from 2011-05-02 to 2011-05-06 at: http://www.itu.int/md/R07-WP4B-110502-TD-0090/en

xv An Enhanced Cooperative Transmit Diversity in Integrated MSS systems, Hee Wook Kim, Do-Seob Ahn, Kunseok Kang and Bon-Jun Ku, Satellite Wireless Convergence Research Division, Electronics and Telecommunications Research Institute, (ETRI), Korea, at: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05586894

xvi Following Recommendation 206 (See Volume 3 of ITU Radio Regulations.

xvii **"Final Report of the CPM to WRC-12" at:** http://www.itu.int/md/R07-CPM11.02-R-0001/en, Section 5/7/6A

xviii Appendix 4

xix In particular to Recommendation 206

xx See " Use and examples of mobile-satellite service systems for relief operation in the event of natural disasters and similar emergencies" at: http://www.itu.int/pub/R-REP-M.2149

xxi See No. 196 of the ITU Constitution (Article 44)

xxii As contained in Articles 9 and 11 respectively, of ITU Radio Regulations.

xxiii See Article 8 of ITU Radio Regulations.

xxiv Circular Letter CR/301 dated 1 May 2009, " Removal of unused frequency assignments (Space Services) from the Master Register" at: http://www.itu.int/md/R00-CR-CIR-0301/en

xxv E.g. No. **13.6** of the RR

xxvi Under Agenda Item 7 [97] of WRC-12

xxvii Without dwelling into the details of all the issues here because of their complexity and long description, a reference is provide to these in the CPMReport. This report describes each of them in detail with background information and possible solutions.

xxviii In its work in Study Group 4 & more specifically in Working Party 4B (WP 4B) [68]

xxix See article No.18.1 of ITU Radio Regulations (RR).

xxx Articles 9 and 11 of the Radio Regulations

xxxi Elaborated in Article 9 of ITU Radio Regulations. Article 5 of the RR that deals with `Frequency Allocations' has allocated band for various satellite services e.g. FSS, MSS, etc.