Regulation of Global Broadband Satellite Communications

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Work in progress, for discussion purposes

Comments are welcome!

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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.

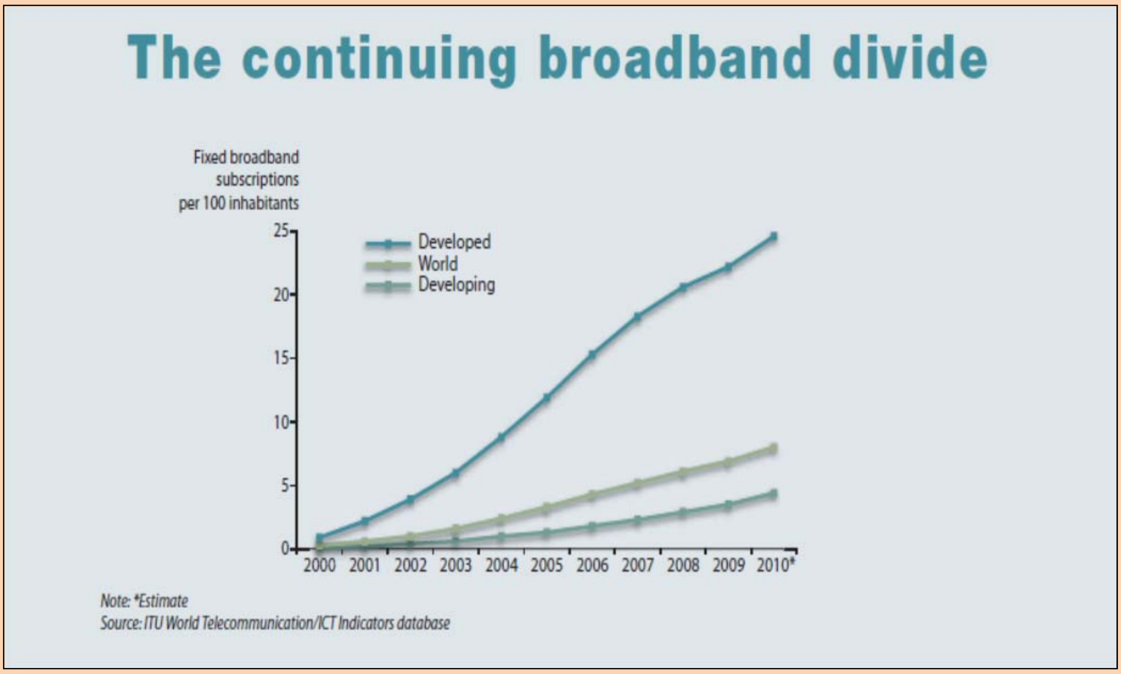
1.1.2 Why satellites for broadband delivery?

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].

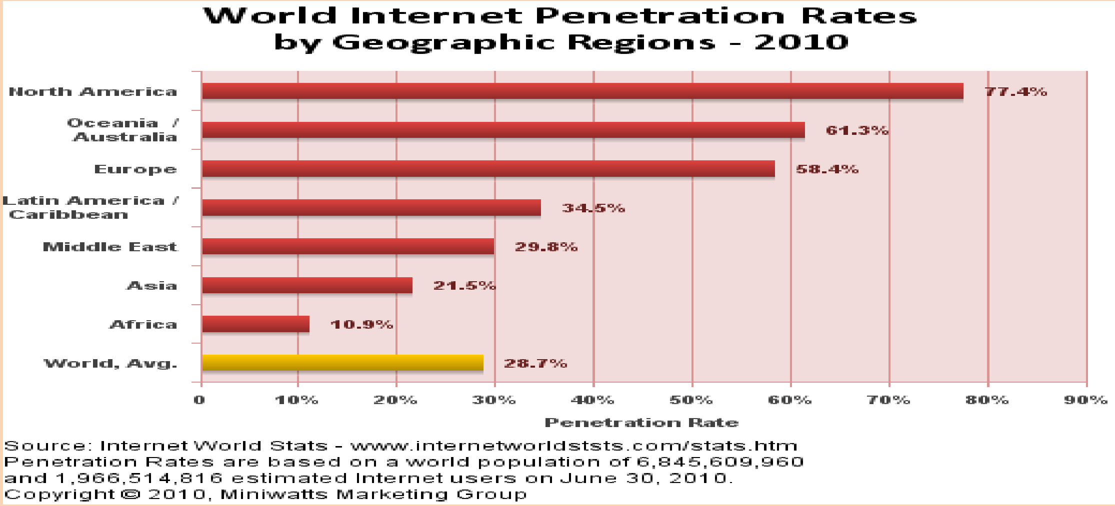
Satellite is an attractive option for businesses and government offices that cannot access other communications services, normally due to their remote or rural location. Compared with terrestrial installations, remote sites can be deployed very quickly with satellite access. Satellite broadband enables 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.

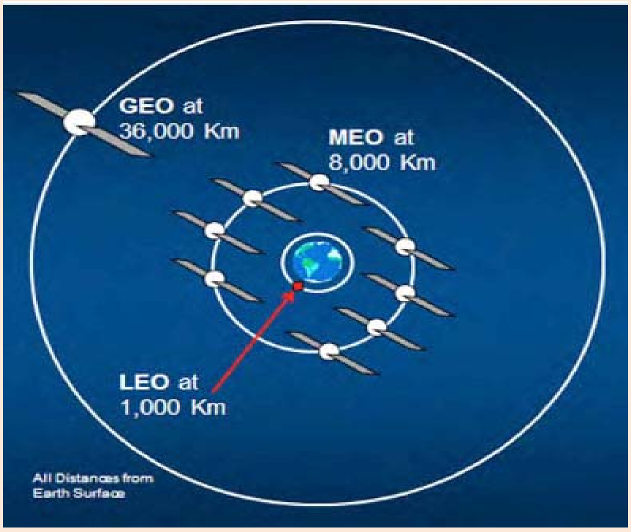
A *geostationary satellite* is a *geosynchronous satellite* whose circular and direct *orbit*[iv] lies in the plane of the Earth's equator and which thus remains fixed relative to the Earth; by extension, a *geosynchronous satellite*[v] which remains approximately fixed relative to the Earth[vi].

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

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

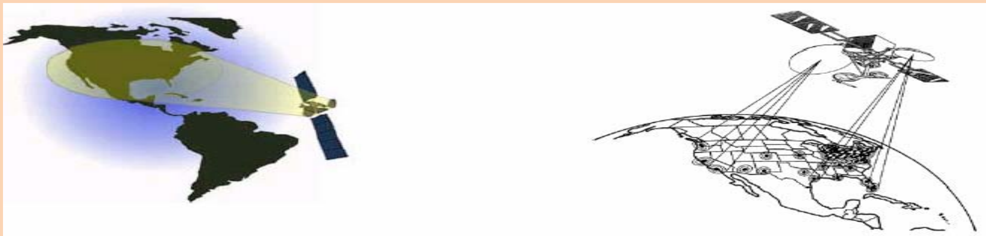
An input report to WRC-12[xi] describes in detail the compatibility issues in each frequency band with existing radiocommunication services and the possible mitigation techniques. It also describes advantages and disadvantages of proposed methods to assess spectrum requirements for broadband services.

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.

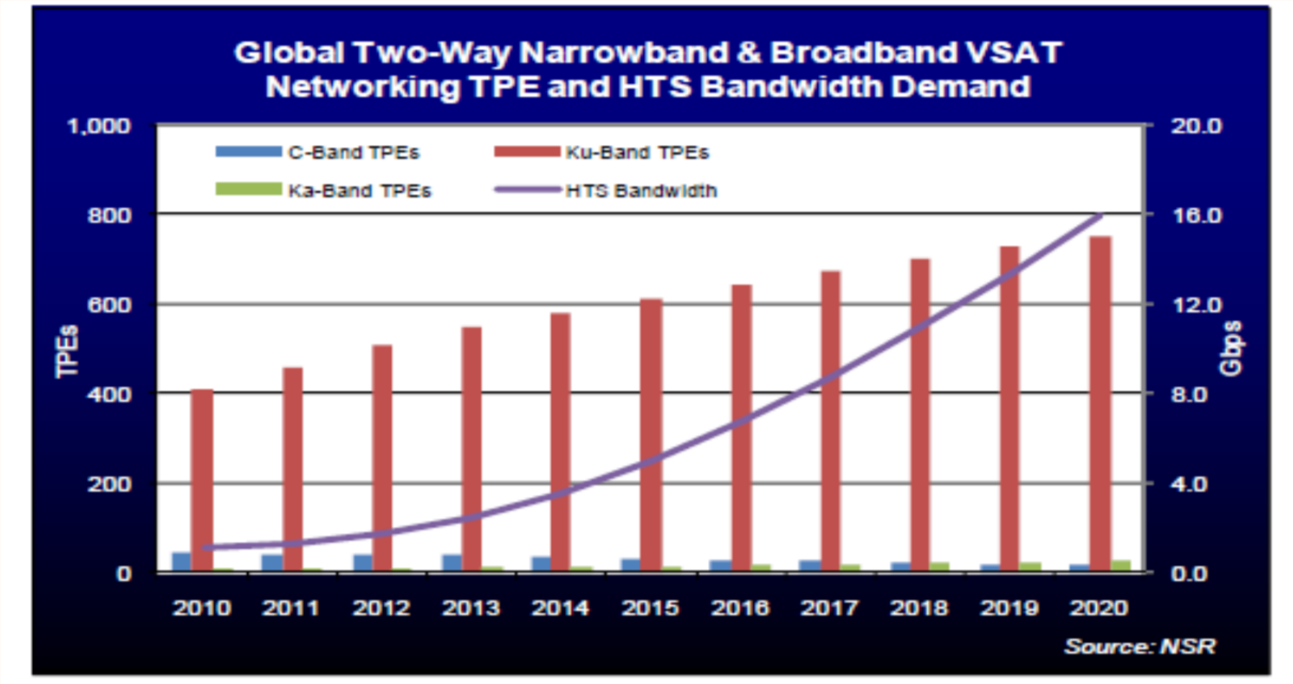
Figure 1.5 [21] shows that Ku band transponder demand shall dominate all through the period 2010 to 2020. However, the demand for Ka band HTS shall begin to show around 2013.

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.

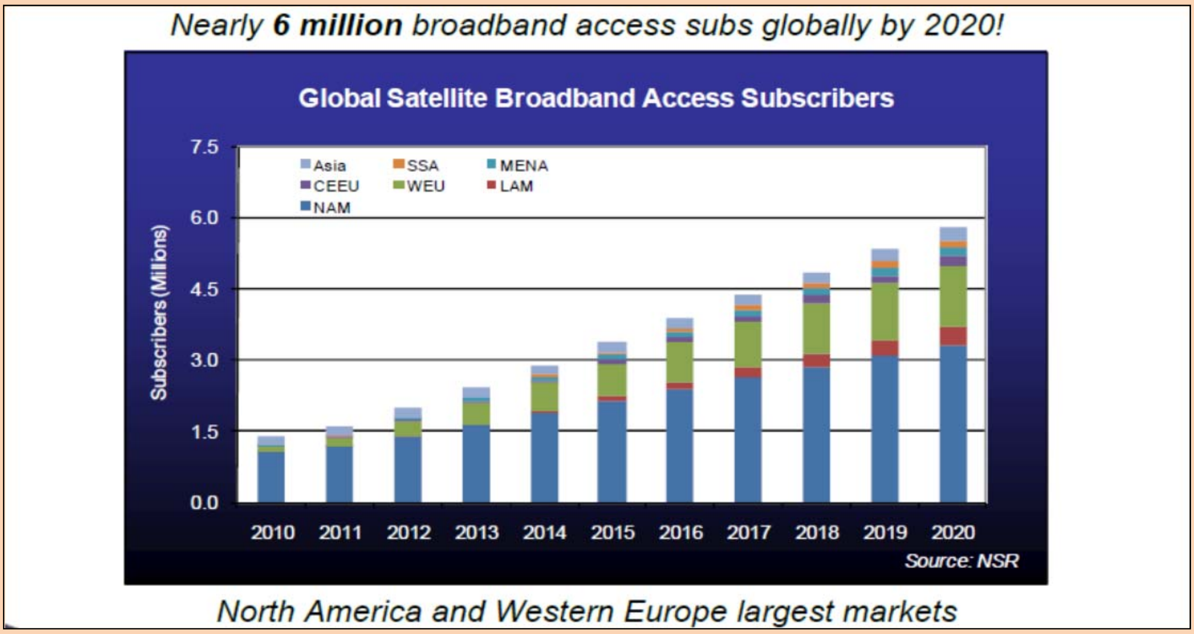
Provision of Internet is critical for innovation, economics and for social well-being**.** Broadband delivery in various geographical regions are therefore increasingly taking into consideration and including the satellite broadband options to bridge the digital divide.

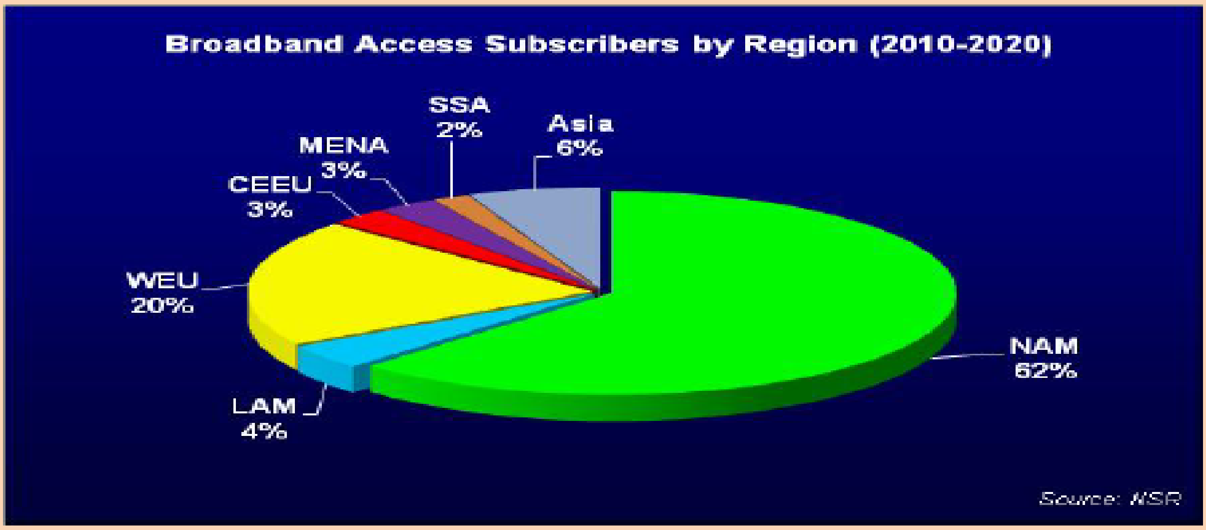
1.3.1 Regional approaches to satellite broadband services

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

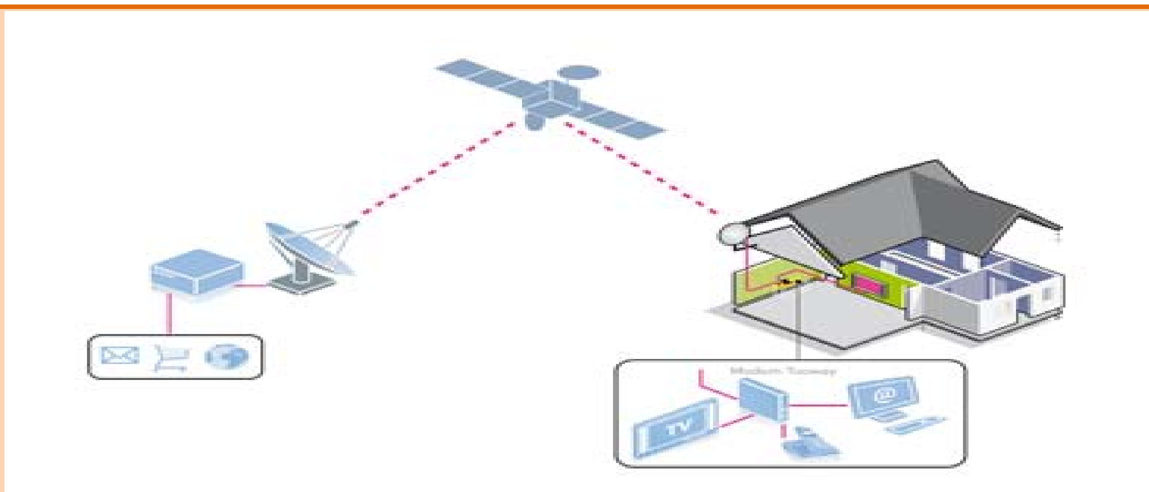
For the provision of broadband Internet access services across Europe and also a small area of the Middle East, **KA-SAT,** owned by Eutelsat[27] is an example of satellite based broadband system for IP services that deploys spot beam technology. Positioned at its geostationary orbit location at 9° East, 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/5vl9KSD8A*[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.

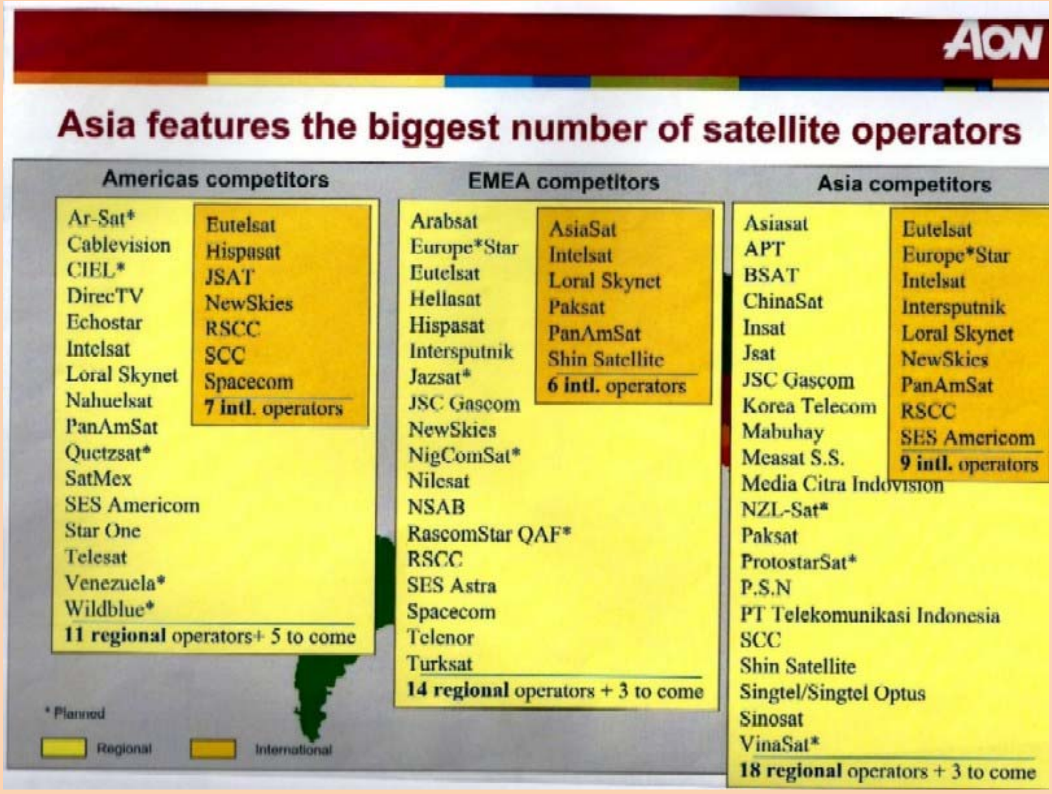
Asia & Pacific: Whereas 60% of the world population lives in Asia, out of this, 60% lives in the rural Asia with poor network penetration and telecom infrastructure [52]. Much of this can be attributed to the geographical terrain that is difficult and mountainous. This makes it very attractive for satellite 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.

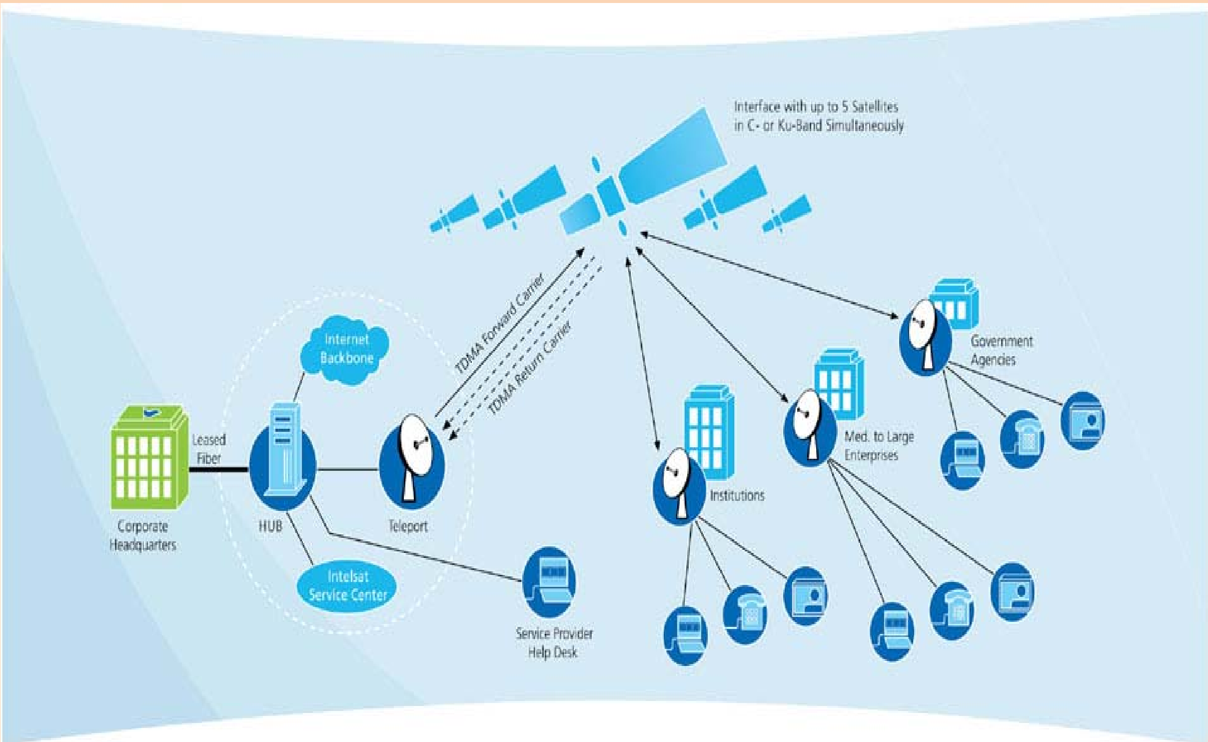
Intelsat Network Broadband [57]: As of March 2011, Intelsat operates a fleet of 52 communications satellites. Intelsat enables management of customer's network across multiple satellite and regions with the use of only one `hub station'. This arrangement supports the following applications:

> 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.

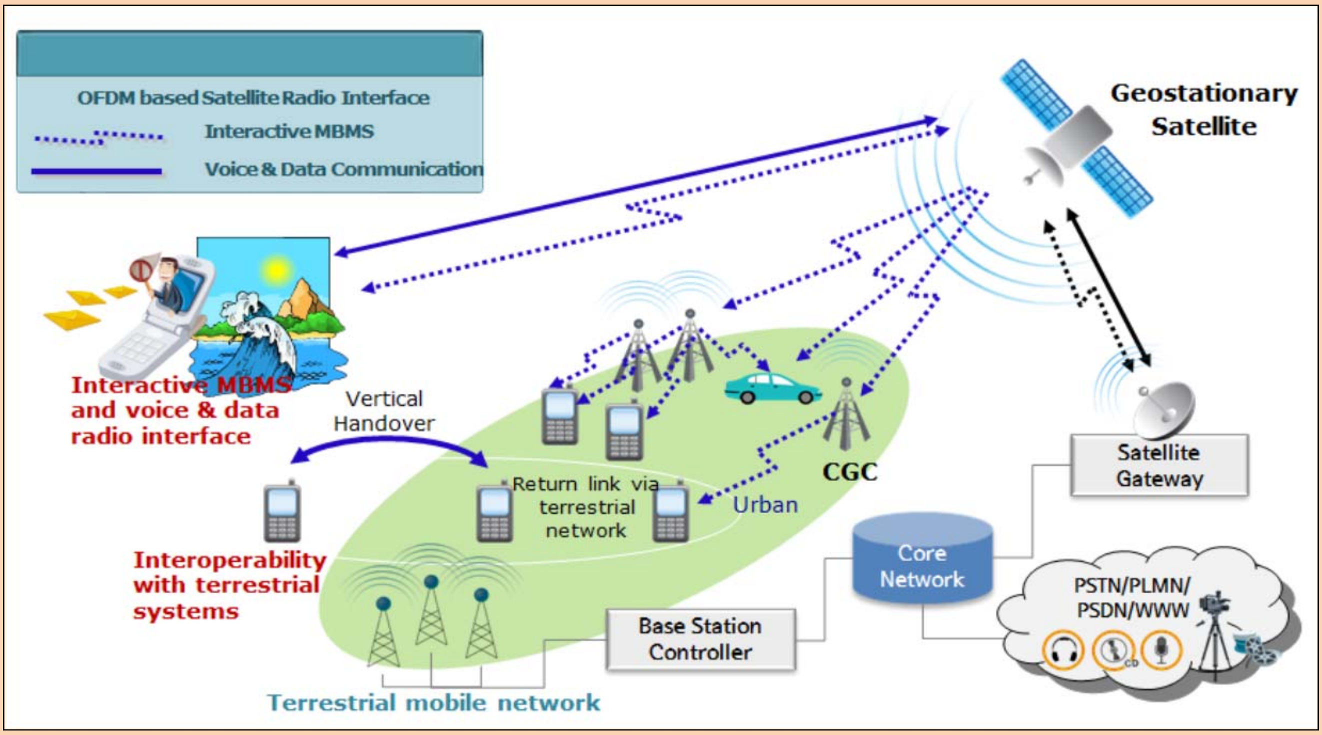
The application scenarios include:

- 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.

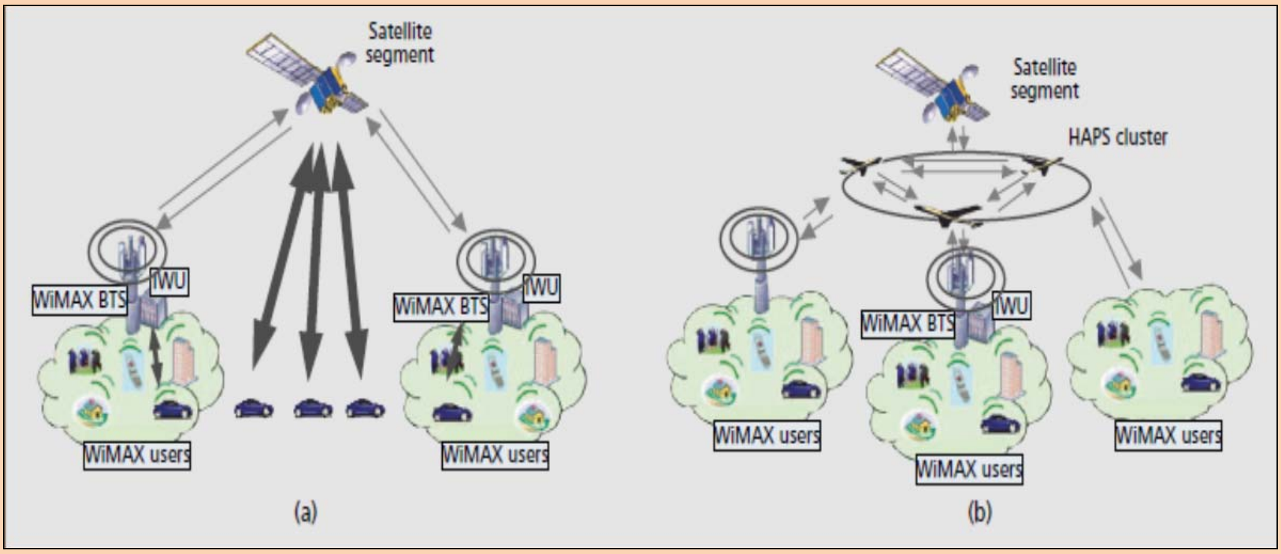
The advent of CGC (called "ATC – Ancillary Terrestrial Component" [61, 62] in North America) was a bit controversial in the US. The wireless carriers alleged that the satellite operators were simply using the "auxiliary" excuse as a way to open the door for providing a basically terrestrial network using 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

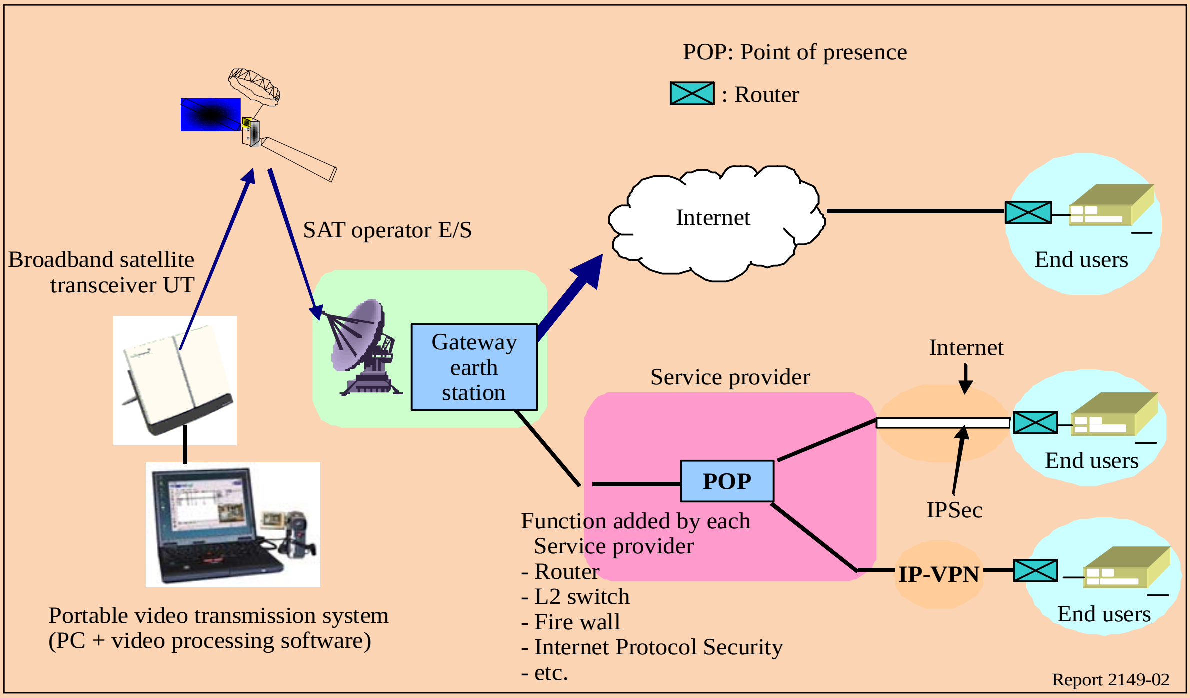
Fixed satellite and mobile satellite services (FSS & MSS) terminals have the attributes to be easily deployed and provide wide area coverage that is independent of local infrastructure, for providing immediate means of telecommunication to help in relief operations during natural disaster and emergency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

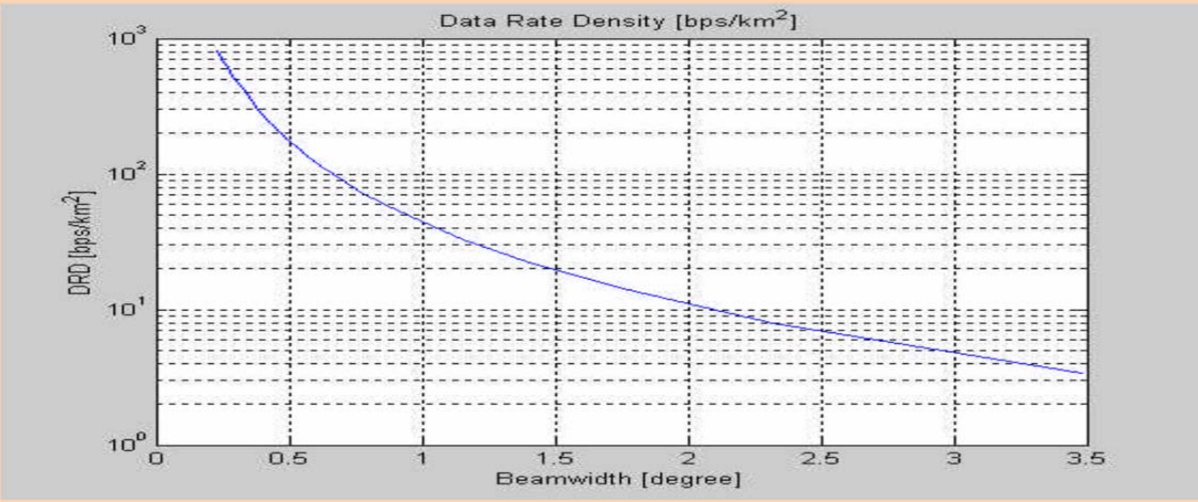
Nevertheless, satellite terminals can be deployed very quickly to bridge the digital divide, and at least offer a temporary solution in cases where a cheaper long-term solution could be provided by terrestrial infrastructure. Terrestrial broadband access cost increases at lower user density but satellite 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.

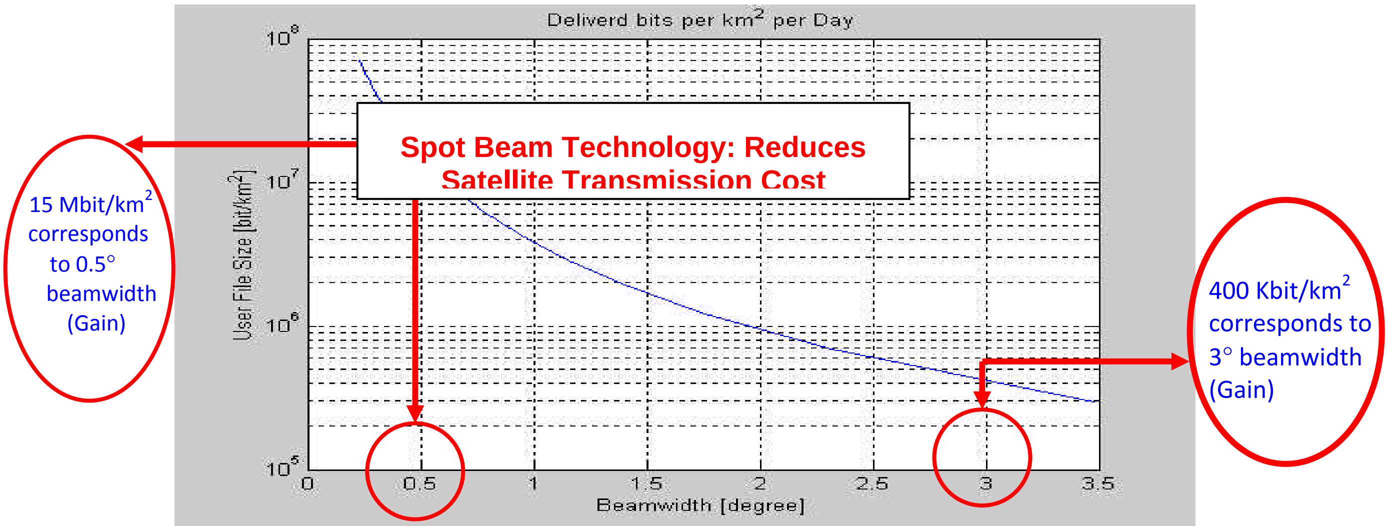
In an ideal implementation of satellite broadband, the satellite service element would see competing service providers leverage a common space platform with different ground segment (VSAT) equipment types to service consumers and enterprise level customers. The element of competition is very important 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

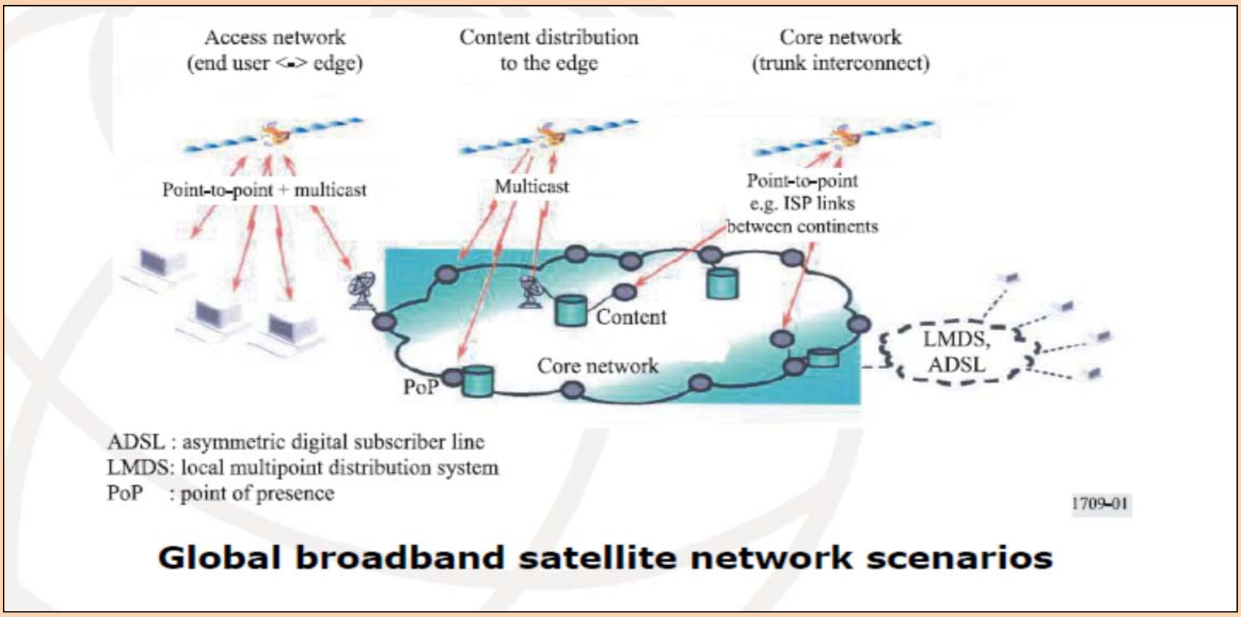
A.1.1 Generic description of the network architecture for broadband satellite networks

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

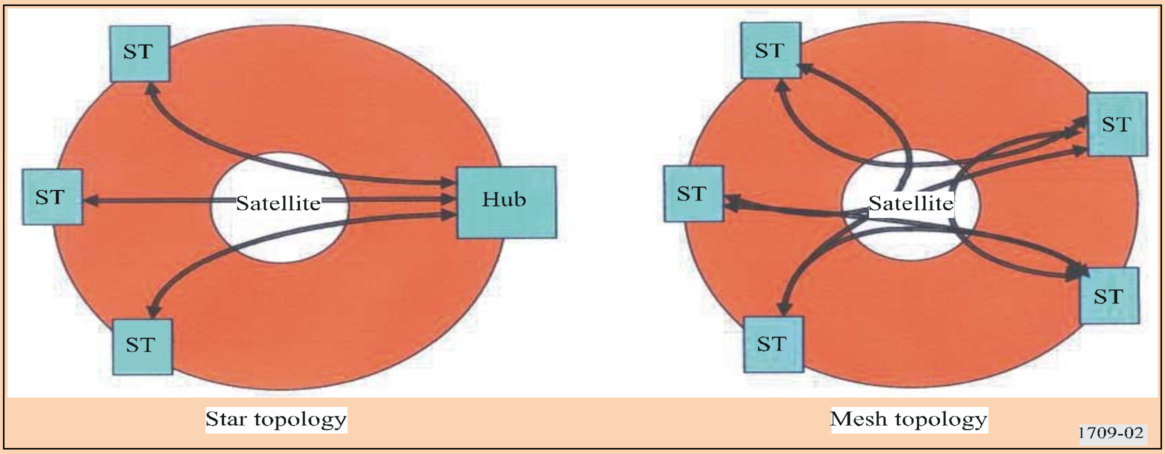
Internet access: High-speed Internet access – Electronic messaging – Multimedia applications - Distanc learning – Telemedicine.

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.

1. See, "Asia Pacific Sat Council" at: http://www.apscc.or.kr/pub/coverstory.asp

2. See " WORLD SATELLITES – One must be 'out (there)' to be 'in.' " at: http://www.abstractatus.com/english/satellites/

3 See, `IP Telephony (IPT) & Voice over IP (VoIP)' at: http://www.l1associates.com/technology2.htm

4. See RECOMMENDATION ITU-R S.1709-1 "Technical characteristics of air interfaces for global broadband satellite systems" at: http://www.itu.int/rec/R-REC-S.1709/en

5. "Broadband Internet access" at: http://en.wikipedia.org/wiki/Broadband_Internet_access

6. See http://www.wisegeek.com/what-is-satellite-broadband.htm

7. See "Comparative Approaches in the Economics of Broadband Satellite Services" by Mark Dankberg, President & CEO, Viasat, Inc and John Puetz, President, MasterWorks Communications

8. See " THE WORLD IN 2010 FACTS AND FIGURE ITU – World Telecommunication/ICT Indicators database" at: http://www.itu.int/ITU-D/ict/material/FactsFigures2010.pdf

9. See http://www.internetworldstats.com/stats.htm

10. See" ICT in Africa: Boosting Economic Growth and Poverty Reduction"- http://www.oecd.org/dataoecd/46/51/40314752.pdf

11. Improving High Latency Satellite Links (http://www.silver-peak.com/Solutions/Overcome_WAN_Limitations/satellite.htm)

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13. See "Spot beam technology" at: http://www.satelliteone.com/support-files/Spot_Beam_Short.pdf

14. See http://www.wildblue.com/

15. See http://www.viasat.com/

16. See http://www.hughesnet.com/

17. See " Tapping the Web, 22,000 Miles Up" By SUSANNA G. KIM Published: August 15, 2010, at:

http://www.nytimes.com/2010/08/16/technology/16satellite.html

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19. See " Wideband InterNetworking engineering test and Demonstration Satellite "KIZUNA" (WINDS)" at: http://www.jaxa.jp/projects/sat/winds/index_e.html

20. See "Eutelsat release on the launch of KA-SAT" at: http://www.eutelsat.com/news/compress/en/2010/html/PR5910-KA-SAT-SUCCESS/PR5910-KA-SAT-SUCCESS.html

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

22. See http://www.cost280.rl.ac.uk/documents/ws2%20proceedings/documents/pm-5-002.pdf

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

26. See "European broadband: investing in digitally driven growth" at: http://ec.europa.eu/information_society/activities/broadband/index_en.htm

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

28. See http://www.engadget.com/2011/05/31/eutelsats-ka-sat-satellite-goes-into-service-provides-broadban/

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30. See "Rascom" at: http://www.rascom.org

31. See " RascomStar-QAF" at: http://www.rascomstar.com/home.php

32. See http://www.o3bnetworks.com/Advantages/advantages.html

33. See "O3b (satellite)" at: http://en.wikipedia.org/wiki/O3b_(satellite)

34. See "O3b networks"at http://www.o3bnetworks.com/AboutUs/mission.html

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36. Technical problems' shut down Nigerian satellite: http://afp.google.com/article/ALeqM5g4S4e2LVeoER0jCP79S0gw3tjp7A

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[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.