FINAL REPORT

ITU-D STUDY GROUP 2

QUESTION 25/2

ACCESS TECHNOLOGY FOR BROADBAND TELECOMMUNICATIONS INCLUDING IMT, FOR DEVELOPING COUNTRIES

ACCESS
TECHNOLOGY
FOR DEVELOPING COUNTRIES

5TH STUDY PERIOD 2010-2014

Telecommunication Development Sector

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QUESTION 25/2:

Access technology for broadband telecommunications including IMT, for developing countries

ITU-D Study Groups

In support of the knowledge sharing and capacity building agenda of the Telecommunication Development Bureau, ITU-D Study Groups support countries in achieving their development goals. By acting as a catalyst by creating, sharing and applying knowledge in ICTs to poverty reduction and economic and social development, ITU-D Study Groups contribute to stimulating the conditions for Member States to utilize knowledge for better achieving their development goals.

Knowledge Platform

Outputs agreed on in the ITU-D Study Groups and related reference material are used as input for the implementation of policies, strategies, projects and special initiatives in the 193 ITU Member States. These activities also serve to strengthen the shared knowledge base of the membership.

Information Exchange & Knowledge Sharing Hub

Sharing of topics of common interest is carried out through face-to-face meetings, e-Forum and remote participation in an atmosphere that encourages open debate and exchange of information.

Information Repository

Reports, Guidelines, Best Practices and Recommendations are developed based on input received for review by members of the Groups. Information is gathered through surveys, contributions and case studies and is made available for easy access by the membership using content management and web publication tools.

Study Group 2

Study Group 2 was entrusted by WTDC-10 with the study of nine Questions in the areas of information and communication infrastructure and technology development, emergency telecommunications and climate-change adaptation. The work focused on studying methods and approaches that are the most suitable and successful for service provision in planning, developing, implementing, operating, maintaining and sustaining telecommunication services which optimize their value to users. This work included specific emphasis on broadband networks, mobile radiocommunication and telecommunications/ICTs for rural and remote areas, the needs of developing countries in spectrum management, the use of ICTs in mitigating the impact of climate change on developing countries, telecommunications/ICTs for natural disaster mitigation and relief, conformance and interoperability testing and e-applications, with particular focus and emphasis on applications supported by telecommunications/ICTs. The work also looked at the implementation of information and communication technology, taking into account the results of the studies carried out by ITU-T and ITU-R, and the priorities of developing countries.

Study Group 2, together with ITU-R Study Group 1, also deals with Resolution 9 (Rev. WTDC-10) on the "Participation of countries, particularly developing countries, in spectrum management".

This report has been prepared by many experts from different administrations and companies. The mention of specific companies or products does not imply any endorsement or recommendation by ITU.

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QUESTION 25/2

Access technology for broadband telecommunications including IMT, for developing countries

Executive Summary

"The number of mobile broadband subscribers around the world surpassed that of fixed broadband at the end of 2010. The extraordinary growth rate in mobile broadband adoption means that within four years, mobile broadband will compose about 80 percent of total broadband subscriptions and become the dominant means of Internet connectivity. In emerging markets, mobile broadband is expected to increase from 37 to 79 percent of all broadband subscriptions between 2010 and 2015."[1]

ITU-D Study Group 2 Question 25 has been tasked with providing developing countries with an understanding of the different technologies available for broadband access using both wired and wireless technologies for terrestrial and satellite telecommunications, including International Mobile Telecommunications (IMT). This Report covers technical issues involved in deploying broadband access technologies by identifying the factors influencing the effective deployment of such technologies, as well as their applications, with a focus on technologies and standards that are recognized or under study within ITU-R and ITU-T. This Report aims to examine future trends of wired and wireless broadband access technologies, identify methodologies for migration planning and implementation, consider trends including deployments, services offered and regulatory considerations, identify key elements to be studied in order to facilitate the deployment of systems integrating satellite and terrestrial components of IMT, and provide information on implementation impact, and provide information on IMT-Advanced. Information contained in this Report includes information directly from the two other sectors of the ITU, work conducted by ITU-D SG 2 Question 10 on Rural Technologies, as well as recent work undertaken by the UN Broadband Commission. Further information can be obtained directly from these groups.

It should be noted that there are many different definitions of the term, 'broadband'. Different countries, technologies, and international agencies use different definitions of the term. In 1990, the ITU defined Broadband wireless access (BWA) as "Wireless access in which the connection(s) capabilities are higher than the primary rate."[2] Within ITU-D Study Group 2 Question 25/2, there were several alternative proposals for a definition of broadband. However, there was no consensus on a single proposed definition, nor was it considered within the purview of the group to undertake a new definition on the part of the ITU.

1 "Ten Facts about Mobile Broadband", Darrell West. Center for Technology Innovation at Brookings. December 8, 2011.

2 Recommendation ITU-R F.1399, "Vocabulary of terms for wireless access" (2001).

1 Importance of Broadband

1.1 Social and Economic Benefits of Broadband

"Access to broadband Internet can increase productivity and contribute to economic growth, for which broadband deserves a central role in development strategies. Broadband networks (both fixed and mobile) are necessary to deliver modern communication and information services that require high rates of data transmission. Enterprise file transfer, television and high-speed Internet are examples of such services. High-speed Internet connections provide ready access to a wide range of services, such as voice, video, music, film, radio, games, and publishing.

Broadband networks enhance the efficiency and reach of existing services and provide additional capacity for unknown future applications. Indeed, broadband networks are key to the ongoing transformation of the ICT sector through the convergence of telecommunications, media and computing. The convergence process may comprise:

– Service convergence, which enables providers to use a single network to provide multiple services;

– Network convergence, which allows a service to travel over any combination of networks; and

– Corporate convergence, by means of which firms merge or collaborate across sectors.

Driven by technology and demand, convergence is resulting in major changes in market structures and business models.

There is growing evidence that broadband has a considerable economic impact for individuals, firms, and communities. Individuals increasingly use broadband to acquire knowledge and skills to increase their employment opportunities. Where broadband has been introduced in rural areas of developing countries, villagers and farmers have gained better access to crop market prices, training, and job opportunities. In developed countries and urban areas in developing countries, an increasing number of individuals are building up social networks through broadband-enabled, peer-to-peer web-based groups that facilitate economic integration and drive development. Blogs (web logs, or online diaries), wikis (websites where users can contribute and edit content), video-sharing sites, and the like allow new, decentralized, and dynamic approaches to capturing and disseminating information that enable individuals to become better prepared for the knowledge economy (Johnson, Manyika and Yee, 2005)."[3]

Broadband, in addition to positively impacting knowledge acquisition and skills for individuals is being seen as a healthy contributor to employment opportunities worldwide. In Bangladesh for example, the contribution of the ICT industry (largely encompassing broadband in particular), includes four components. The "direct" employment of the industry or workers who are directly employed by the players in the value chain, the "support" employment, which is created by outsourced work and taxes that the government spends on employment generating activities, the "indirect" category which covers other costs as well as generated profit and the "induced" employment which refers to jobs created as employees and other beneficiaries spend their earnings thereby creating extra employment. Induced employment alone has recently created 1.1 million jobs in Bangladesh[4]. In the United States, according to Deloitte, U.S. investment in broadband technology is expected to generate over $73 billion in GDP growth between 2012 and 2016 and anywhere between 371,000 and 771,000 new jobs.[5]

3 Land Mobile Handbook Volume 5 (Broadband Wireless Access Systems) (Document 25/2/4)

4 Bangladesh, Document 2/INF/36 "Statistics and Strategic Action Plan of Telecommunication/ICT Development in Bangladesh: Rural and Remote Areas"

5 "Ten Facts About Mobile Broadband", Darrell West, Center for Technology Innovation at Brookings, 8 December 2011

"Broadband offers a potential solution in the ability to deliver education in developing and developed countries alike. Broadband networks can deliver information, interactivity, shared resources and help level the playing field for everyone. Online education is easing the resource bottleneck in training teachers; UNESCO estimates suggest that as many as 10 million additional teachers will be needed globally by the 2015 MDG deadline[6].Many countries are already actively pursuing an intensive programme of teacher training online, but more needs to be done: in particular, access to broadband needs to rapidly become more affordable, particularly in the developing world. PPPs designed not only for students but also for the communities in which they live (such as ITU's Connect a School, Connect a Community initiative) can achieve a great deal in accelerating progress towards bridging the broadband divide."[7]

Investing in the education of children produces great benefits and will smooth a country's transformation to the information society. Many countries are investing in education based broadband transformation programs. These countries are using Universal Service Fund and other government sources for these projects. Each year governments are using billions of US dollars for classical education systems, including distribution of free textbooks, blackboards etc. Annual global education spending for the students is approximately **3000 billion US dollars**[8]. Lack of effective, timely usage of Universal Service Funds (USF) is also a common problem in many countries. Countries will greatly benefit by migrating from a classical education system to an ICT based Education System, not only to provide a more effective education experience, but also to ensure that all students obtain the skills necessary to succeed in a knowledge-based economy and society, which are of key importance for governments to remain globally competitive. Effective policy, aligned with desired behavior and outcomes, is critical to establish the conditions for success and to accelerate transformation.

"Using ICTs and broadband to advance universal primary education does not need to be limited to boys and girls, but can also include men and women who never had the chance to attend school and studies consistently show that literate, educated women are more likely to ensure that their children attend school. ICTs and broadband also enable inclusive education of persons with disabilities. Many schools that have been using TV and radio systems are now switching to online learning opportunities, due to their inherent interactivity. Broadband-enabled ICT applications should be seen both as a pedagogical tool and as a discipline in their own right for the development of effective educational services."[9]

"High-speed internet connections enable health workers outside major centres to receive quality training and exchange experiences and information through video-conferencing, interactive discussion forums and the use of social networking sites. Broadband services give women easier access to information on family planning, hygiene and other reproductive health issues, including visual presentation materials, information in local languages, and culturally-appropriate content. Expectant and new mothers can get better information about childbirth and the early warning signs of infection or disease for themselves and their children. Broadband applications linked to 'smart' mobile phones or portable computers linked to mobile broadband networks can enable health workers to create and access online patient records and to transmit health information to policy-makers and researchers. And there is an important and growing role for community centres with internet access to deliver essential connectivity and health information,

[6] Source: World Telecommunication/ICT Development Report 2010, available at: www.itu.int/ITU-D/ict/publications/wtdr_10.

[7] Broadband Commission, "A 2010 Leadership Imperative: The Future Built on Broadband", 2010. Page 41, available at: www.broadbandcommission.org/Reports/Report_1.pdf

[8] http://s3.amazonaws.com/zanran_storage/www.nextupresearch.com/ContentPages/2493178098.pdf

[9] Broadband Commission, "A 2010 Leadership Imperative: The Future Built on Broadband", 2010, Page 41-42, available at: www.broadbandcommission.org/Reports/Report_1.pdf

especially to women in rural and remote areas."[10] "Broadband internet can also provide powerful research and surveillance tools to tackle disease more effectively by mapping the mycobacterium tuberculosis genome, for example, or using satellites to map areas where malaria-carrying mosquitoes are likely to be found. ICT community centres can give girls and women access to undistorted and objective information on how to prevent sexually-transmissible diseases, including AIDS. Women with HiV can receive information on treatments for preventing the transmission of HiV to their unborn babies, and those caring for relatives with HiV can access support and advice. ICT community centres can also provide women with valuable information on how to combat and treat malaria, tuberculosis and other diseases."[11]

Another example of broadband services helping children to prepare for emergencies and natural disasters can be found in **Annex I** in "Let's Get Ready! Mobile Safety Project".

"Access to broadband can also support the growth of firms by lowering transaction costs and raising productivity. Realizing these performance improvements, however, depends on firms' ability to integrate their technological, business and organizational strategies. When fully absorbed, broadband drives intense, productive uses of online applications and services, making it possible to improve processes, introduce new business models, drive innovation and extend business links. A study involving business and technology decision makers in 1,200 companies in six Latin American countries — Argentina, Brazil, Chile, Colombia, Costa Rica and Mexico — showed that broadband deployment was associated with considerable improvements in business organization, including the speed and timing of business and process reengineering, process automation, data processing and diffusion of information within organizations (Momentum Research Group, 2005).

Firms in the media, export, and other information intensive sectors have benefited most from integrating broadband into their business processes. Clarke and Wallsten (2006) undertook a study of 27 developed and 66 developing countries, in which they found that a 1 percentage-point increase in the number of Internet users is correlated with a rise in exports of 4.3 percentage points. Increases of 25 percent or more in the efficiency of claims processed per day have been documented by U.S. insurance companies that have adopted wireless broadband (Sprint, 2006). Other industries that have benefited significantly from access to broadband include consulting, accounting, marketing, real estate, tourism and advertising.

Local communities around the world have realized considerable economic gains and new opportunities from broadband services. Studies from Canada, the United Kingdom, and the United States have suggested that broadband connectivity has a positive economic impact on job creation, community retention, retail sales, and tax revenues (Ford and Koutsky, 2005; Kelly, 2004; Strategic Networks Group 2003; Zilber, Schneier and Djwa, 2005). In rural areas of developing countries, communities have recently begun to launch broadband services and applications giving local populations access to new markets and services. Facilitating information exchange and value creation between buyers and sellers of agricultural products, which has improved income and livelihoods in rural areas, is one prime example of this. Previously, such opportunities were available only in the largest or wealthiest localities."[12] In Bangladesh for example, while much of the population does not have access to a direct internet connection, they use the internet through telecentres that are located in cities and rural areas. Many of these telecentres might not have fixed internet infrastructure but uses mobile broadband to run their services. These Information Centres/Touch Points have not only become the windows to the digital lifestyle for many rural people, but services like utility bill payments, mobile money transfer and cheaper calls over internet empower them to next level. These service centres provide modern broadband facilities and work to

[10] Broadband Commission, "A 2010 Leadership Imperative: The Future Built on Broadband" 2010, Page 43-44, available at: www.broadbandcommission.org/Reports/Report_1.pdf

[11] Broadband Commission, "A 2010 Leadership Imperative: The Future Built on Broadband". Broadband Commission, 2010. Page 44, available at: www.broadbandcommission.org/Reports/Report_1.pdf

[12] LMH-BWA

familiarize the rural population with modern technology[13]. An example of broadband services assisting local communities can be found in Annex 1 in “Fishing with 3G Nets”.

“Moreover, the preliminary results of a quantitative analysis being conducted by the Organisation for Economic Co-operation and Development (OECD) suggest that the expansion of broadband significantly affects labour productivity. According to this analysis, broadband prices seem to be an important driver of this in lower-income OECD countries, where cheaper broadband tends to be correlated with higher growth rates in labour productivity. For OECD countries, raising broadband penetration rates by 1 percentage point in 2009 (e.g. 24.3% instead of 23.3%) results in a labour productivity growth rate that is higher by 0.02 percentage point. Broadband penetration rates higher by 5 percentage points translate into a rise in the labour productivity growth rate of 0.07 percentage point.

A 2009 study by management consultants, Booz & Company[14] found that “10% higher broadband penetration in a specific year is correlated with 1.5% greater labour productivity growth over the following five years.” The report by Booz & Company also suggests that “countries in the top tier of broadband penetration have exhibited 2% higher GDP growth than countries in the bottom tier.” Another management consultancy, McKinsey & Company3, estimates that “a 10% increase in broadband household penetration delivers a boost to a country’s GDP that ranges from 0.1 percent to 1.4 percent.”

For developing countries in the low- and middle-income bracket, broadband is a key driver of economic growth and, according to a study by the World Bank, provides a boost of 1.38 additional percentage points to GDP growth for every 10% increase in broadband penetration — higher than any other telecommunication service (see Figure 1.1-1). And following the recent global financial crisis, many countries included the expansion of broadband networks as crucial elements in their economic stimulus plans[15].”[16]

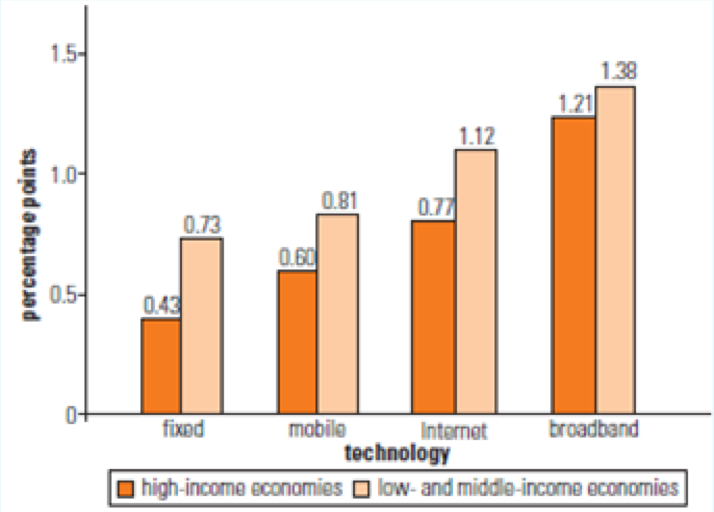
[13] Bangladesh, Document 2/INF/36 “Statistics and Strategic Action Plan of Telecommunication/ICT Development in Bangladesh: Rural and Remote Areas”

[14] Booz & Company “Digital Highways: The Role of Governments in 21st Century Infrastructure, 2009,

[15] ITU, “Confronting the crisis: ICT stimulus plans for economic growth” (2009), available at: www.itu.int/osg/csd/emerging_trends/crisis/fc01.html

[16] Broadband Commission, “Broadband: A Platform for Progress”, 2010, available at: www.broadbandcommission.org/Reports/Report_2.pdf.

Figure 1.1-1: How investing in broadband can boost economies



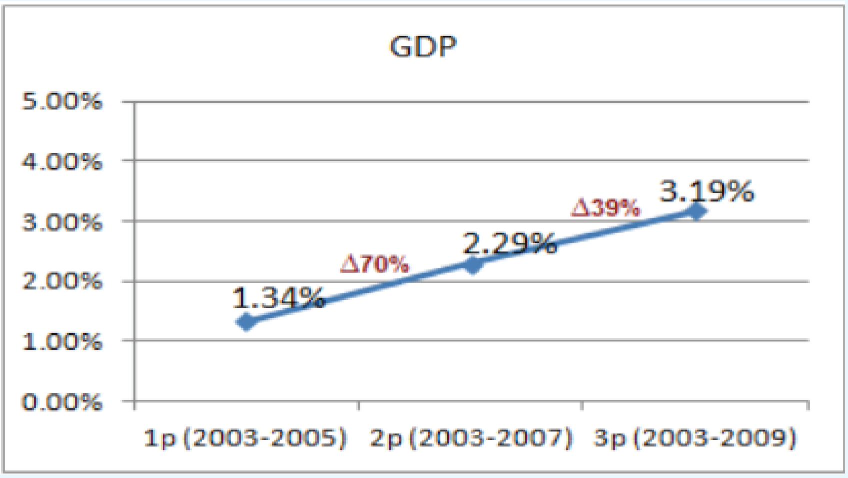
Source: World Bank, (2009)
Note: The vertical axis represents the percentage rise in economic growth per 10% rise in penetration.

More recent studies have continued to find a link between broadband access and economic growth. In November 2012, the Inter-American Development Bank (IDB) issued a report on the "Socioeconomic Impact of Broadband in Latin American and Caribbean Countries" that found that "a 10% increase in broadband penetration brought about an average increase of 3.19% in per capita GDP."[17] As shown in Figure 1.1-2 below, the findings verified that the "the greater the number of broadband subscriptions per capita a country has over time, the greater impact that an additional increase in the number of broadband subscriptions will have on that country's GDP."[18]

[17] Inter-American Development Bank, "Socioeconomic Impact of Broadband in Latin American and Caribbean Countries" November 2012, p. 9, available at: www.iadb.org/intal/intalcdi/PE/2013/11427.pdf

[18] Ibid.

Figure 1.1-2: Impact on GDP over time of a 10 Percent Increase in Broadband Penetration

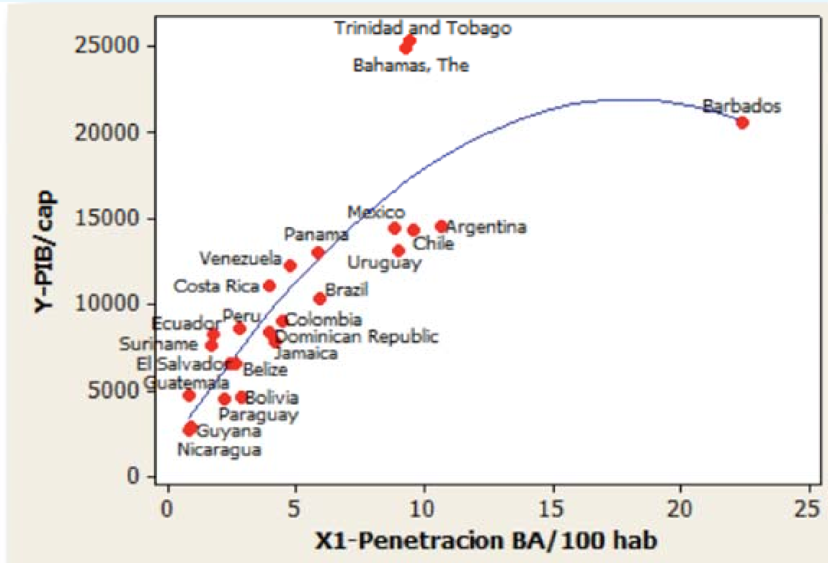


Source: IDB (2012)

The IDB further concluded that in the Latin American and Caribbean countries the relationship between broadband penetration and GDP per capita is quadratic. As shown in Figure 1.1-3 below, "when broadband penetration increases, GDP in poorer countries (those with fewer broadband subscriptions) increases more than in wealthier countries (those with more broadband subscriptions)."[19]

[19] Ibid., at 10.

Figure 1.1-3: Impact of Broadband on GDP among LAC Countries



Source: IDB (2012)

As for wireless broadband usage and its impact on GDP per capita, a recent study issued by GSM Association, Deloitte and Cisco, evaluates the econometric analysis of the relationships between 3G connections and economic growth in developed and developing markets and finds that "countries with a proportionately higher share of 3G connections enjoy an improved GDP per capita growth, compared to countries with comparable total mobile penetration but lower 3G penetration."[20] The study shows that "if countries had a 10% higher 3G penetration between 2008 and 2011, they would have experienced an increase in the average annual growth rate of GDP per capita by 0.15%." For example, the study finds that "in Indonesia, where the average penetration of 3G services was 10% over 2008-2011, 10 more 3G connections per 100 connections (a 100% increase from the actual 3G penetration level of 10%) would have increased the GDP per capita growth rate by 1.5 percentage points." [21]

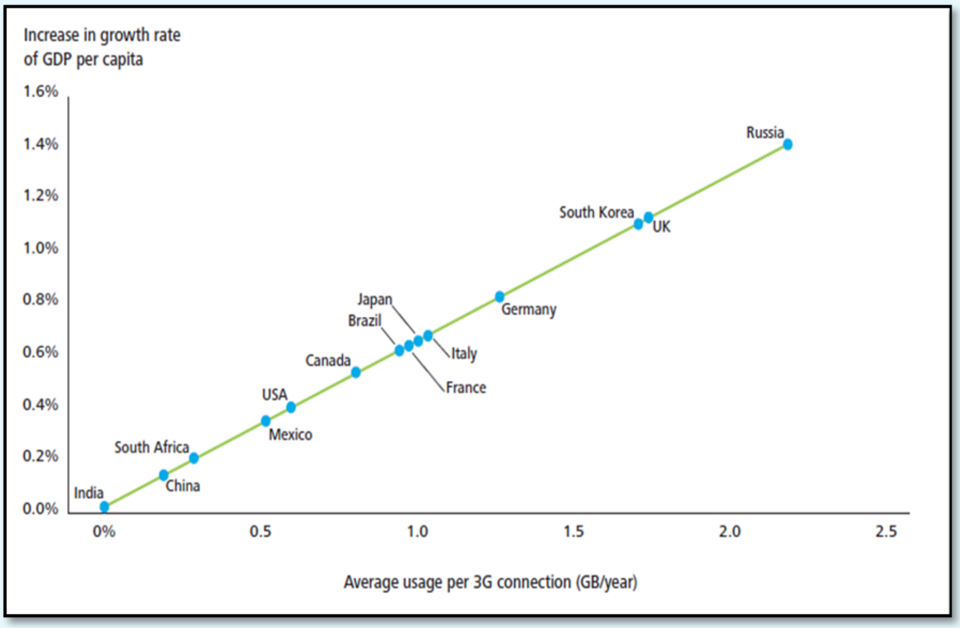
In addition, the GSM Association study also finds that there is a positive relationship between the amount of mobile data used by each 3G connection that can also increase economic growth. The study indicates that "if countries doubled their consumption of mobile data per 3G connection between 2005 to 2010, they would have experienced a growth rate of GDP 0.5% higher each year." (See Figure 1.1-4).[22]

[20] GSM Association, "What is the impact of mobile telephony on economic growth?" November, 2012, p. 5, available at: www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf.

[21] Ibid. at p. 6.

[22] The data used for this study took into account 14 countries, including Brazil, Canada, China, France, Germany, India, Italy, Japan, Korea, Mexico, Russia, South Africa, United Kingdom, and the United States. See GSMA Report p. 7-8.

Figure 1.1-4: Effect of doubling mobile data usage per 3G connection on GDP per capital growth



Source: Deloitte Analysis (GSM Association Report Nov. 2012)

"In Malaysia, the National Broadband Initiative set a target for broadband to achieve 50% household penetration by the end of 2010. Based on the statistics for 2008, the communications and multimedia industry contributed 6.1% in term of revenue to the country's GDP.[23] And in the Republic of Korea, the percentage contribution of telecommunication services and broadband to GDP more than doubled, from 2.05 to 4.99 per cent, between 1995 and 2005, the decade of broadband's expansion in the country's economy."[24]

"Since broadband networks have the potential to contribute so much to economic development, they should be widely available at affordable prices and should become an integral part of national development strategies. Currently though, few people in developing economies have access to broadband networks. In 2007, an average of less than 5 percent of the population of low-income economies was connected to broadband networks, and that was mostly in urban centres. In this light, developing countries are missing a great development opportunity."[25] Recognizing this disparity, Bangladesh, among many other countries, is striving hard to develop a vision of "connecting the underconnected" through its "Digital Bangladesh" plan which strongly depends on broadband innovations such as IMT to achieve true socio-economic development through the proper deployment of broadband technologies in Bangladesh[26].

"Broadband has been increasingly recognized as a service of general economic interest in recent years. The economic significance of broadband can be put into context by referring to similar changes in other areas of infrastructure, such as road, rail and electricity. Each of these infrastructure services transforms

[23] Malaysian Communications and Multimedia Commission "National Broadband Initiative" (2010)

[24] "Broadband: A Platform for Progress" Summary Broadband Commission 2010. Figure combined from Broadband Commission Report and BWA Handbook.

[25] LMH-BWA

[26] Bangladesh, Document 2/INF/36 "Statistics and Strategic Action Plan of Telecommunication/ICT Development in Bangladesh: Rural and Remote Areas"

economic activities for citizens, firms, and governments; enables new activities; and provides nations with the ability to gain competitive and comparative advantages. Although few of these advantages were foreseen when original investments were made, these types of infrastructure quickly became an essential part of economic lifestyles and activities. A similar assumption about the expected transformative benefits of broadband on economic and social variables has led many governments to set ambitious targets for its deployment. The World Bank study summarizes key results and implications for developing countries. The main conclusion is that broadband has a significant impact on growth and deserves a central role in country development and competitiveness strategies.

Despite its short history, broadband seems to have a higher growth impact relative to communications technologies such as fixed and mobile telephony and the Internet (Figure 1). Thus, current differences in broadband penetration among countries may generate significant long-run growth benefits for early adopters. Moreover, there are more significant and stronger growth effects of ICT for developing countries than in developed countries.

The empirical findings in the World Bank study suggest that broadband's benefits are major and robust for both developed and developing countries. Developed countries have a longer track record of broadband diffusion and may therefore stand to benefit more to date. As the number of broadband subscriptions increases and the applications supported by broadband reach a critical mass, developing economies could enjoy the benefits of broadband, as with all other communications technologies. "[27]

One of the key enablers of that stronger economic growth is the broader ecosystem of products and services that use broadband, and provide innovative services and efficiency gains. Energy efficient systems will play a key part in the future of the broadband products and services ecosystem as more people use broadband. Low cost computing can help to drive down the cost of products and services, benefiting consumers and making the economy more competitive. This will be instrumental in providing the tools for people to create new applications and services on broadband networks.

A new generation of computer chips is the central feature of smarter digital electronic products that can measure, manage and control the performance of consumer electronics and IT equipment.

At the heart of efforts to increase access to broadband is a competitive market of products designed specifically to meet the requirements of emerging markets.

"Whether the great potential of broadband to contribute to growth and competitiveness is realized will depend on whether governments understand the opportunity and ensure that supportive conditions are in place through regulatory and policy reforms, as well as strategic investments and public-private partnerships. Realizing the full benefits of broadband also requires development of new content, services, and applications, as well as increased human capacity to integrate these technologies into economic activities. Broadband clearly deserves a central role in national development strategies."[28]

1.2 Broadband Applications

"It is essential that, as broadband networks are rolled out and capacities improve, the applications using broadband are created at the same time, because improvements in demand can often drive supply. The following is a brief overview of some of the vast and quickly expanding range of services that can be delivered by broadband networks, and illustrates their impact on society.

E-commerce, for example, is an area that is increasingly familiar. According to one report[29], in 2012 more than a billion people worldwide will spend the equivalent of over a trillion US dollars on business-to-

[27] LMH-BWA

[28] LMH-BWA

[29] IDC "Number of Mobile Devices Accessing the Internet Expected to Surpass One Billion by 2013" (2009)

consumer transactions, while the value of business-to-business trade will be ten times greater. Broadband accelerates the whole process, making it faster and more convenient and attractive for sellers and buyers.

Financial transactions and banking are also fast-growing applications carried over broadband. For mobile devices, m-banking is particularly significant in developing countries, where many people would not otherwise have access to such services. It has been forecast that, by 2012, around 190 million consumers will be making mobile payments worldwide, with emerging markets growing quickest.[30]

Governments too are increasingly using broadband to provide online portals where citizens can both receive information and interact with the administration – by applying for licences, for instance. Government departments themselves become much more efficient when their systems are coordinated through broadband networks.

About 17% of the world's adults — 796 million people — still lack basic literacy skills. Nearly two thirds of these are women. The quality of education remains very low in many countries. Millions of children are emerging from primary school with reading, writing and numeracy skills that are far below expected levels. ICT, and notably the Internet, have already shown that they can significantly contribute to achieving the goal of "Education for All," which is one of the key elements in creating Knowledge Societies. The emergence of the Internet, and particularly broadband, presents an enormous opportunity to further harness ICT globally for deepening and creating knowledge through education, and for education to promote a culture of tolerance, peace-building and understanding in our increasingly interconnected world.

Healthcare is potentially one of the most important areas where broadband can make an impact. It has been estimated that at least USD 5 trillion is spent worldwide on providing healthcare[31], but cost savings of between 10% and 20% could be achieved through the use of telemedicine delivered by broadband. And if such systems are not put in place, many people could be left without adequate care: a World Health Organization report[32] revealed an estimated shortage of almost 4.3 million medical staff worldwide, with the situation being most severe in the poorest countries. Medical advice, monitoring, diagnosis and training delivered through broadband can help a great deal to overcome these gaps."[33]

Wireless technologies are being applied in the health sector in several areas of the world, especially though initiatives of public-private partnerships. An example of such a partnership can be found in Annex I in "Mobile Health Information System: Providing Access to Information for Health Care Workers".

Broadband video can be a powerful tool to provide training to professionals in all sectors. Broadband video and other applications can be applied to education at all levels, whether in schools, at home, or in other locations – no matter how remote. An example of a program bringing the benefits of education to rural and remote area is one that enables the downloading of entire course material from a university to mobile phones. This program has the potential to reach nearly 2.5 million students around the globe. At the primary school level, there is another example of a government-funded program that provides a laptop to every child and Internet access to every school. The combination will produce a generation of 'connected' children who will be able to benefit from access all the educational materials on the Internet.

[30] Gartner Research "Gartner says number of mobile payment users worldwide to increase 70% in 2009" (2009)

[31] The Boston Consulting Group (2011)

[32] World Health Organization & Global health Workforce Alliance "Scaling up, saving lives" (2008

[33] Broadband Commission, "Broadband: A Platform for Progress" Summary Broadband Commission 2011. Page 21, available at: www.broadbandcommission.org/Reports/Report_2.pdf.

"Meanwhile, digitization is making more and more information available via broadband. E-newspapers, e-books, scientific journals online and digital libraries, for example, are changing the pattern of access to valuable content in many countries, and modifying the way we read or do research."[34]

"The power of broadband also underpins the collection, sharing and analysis of vital data on the environment, gathered via satellite, for example, or direct sensor technology. This information can be used to predict natural disasters such as floods or famines.

Wireless broadband in particular also provides a platform for reliable communications in the event of natural disasters, when terrestrial communication networks are often damaged or destroyed. In addition, broadband can deliver such services as telemedicine to disaster sites."[35]

"Scientific research on a major scale is greatly assisted by broadband networks. Not only can researchers now exchange vast amounts of data of all kinds extremely rapidly, but new ways have emerged for tackling highly complex topics. Distributed or "grid" computing permits thousands of small computers to be joined together to analyse huge amounts of data and transmit the results to a central point.

More broadly, the arrival of "cloud computing" makes sharing information easier and frees individual users and businesses from having to store data and programs on their own computers. Such systems are based on broadband networks, and offer substantial savings in the costs of hardware, software, premises and personnel. One forecast by market analysts[36] suggests that at least 52 countries could benefit from cloud computing services through the addition of around USD 800 billion in net new business revenues between 2009 and 2013.

Climate change — an origin of extreme weather events — can be tackled through the energy efficiencies that broadband brings across industrial sectors. Better stock control and distribution through using networks to track radio-frequency identification (RFID) tags on goods, means fewer trucks on the road.

And when it comes to power supplies themselves, "smart grids", allow electricity companies to limit losses, prevent outages, and provide customers with real-time information they can use to manage their own energy use at home or at a business. In addition, smart grids make it easier for locally generated electricity (including from renewable sources) to be integrated, stored and shared as demand fluctuates across the grid".[37]

1.3 Gender Issues Surrounding Broadband Technology Deployment

"In many emerging economies and rural areas, women remain economically and socially marginalized and under-educated, suffering from relatively poor employment prospects. While many countries have achieved or nearly achieved primary school gender equality – the enrolment gap narrowed from 91 girls to 96 girls for every 100 boys in the developing world between 1999 and 2008 – progress still remains slow in other areas. Women are disproportionately represented in vulnerable or insecure employment. In some countries, women represent only 20 per cent of the workforce employed outside agriculture, while within agriculture, incomes remain low.[38]

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[34] Broadband Commission, "Broadband: A Platform for Progress" Summary Broadband Commission 2011, page 14, available at: www.broadbandcommission.org/Reports/Report_2.pdf.

[35] Broadband Commission ,"Broadband: A Platform for Progress" Summary Broadband Commission 2011, page 14, available at: www.broadbandcommission.org/Reports/Report_2.pdf.

[36] IDC "Aid to Recovery: the economic impact of IT, software, and the Microsoft ecosystem on the global economy"(2009)

[37] "Broadband: A Platform for Progress" Summary Broadband Commission 2010. Page 22-23, available at: www.broadbandcommission.org/Reports/Report_1.pdf.

[38] The Millennium Development Goals Report 2010, UN New York, at www.un.org/millenniumgoals

Since women are more affected by poverty than men, enabling women to create and / or enter employment is an effective strategy to combat poverty, and ICTs and broadband are key to helping women become functionally literate for greater access to skills training. The experience of the Grameen Bank in Bangladesh has shown that women with experience of even basic mobile phones are more likely to be willing to use and benefit from other ICTs for information or work opportunities. In Annex I, an example of underserved residents, most of whom are women, using mobile technology to access unique business opportunities and gain the skills needed to lift themselves out of poverty can be found in "Mobile Microfranchising & AppLab Initiatives".

ICTs and broadband are key to achieving empowerment and gender equality. They provide an excellent means of opening up opportunities in education and employment, as well as access to information, and have the potential to neutralize much of the discrimination traditionally faced by women. The flexibility provided by the use of ICTs and broadband in education and work can enable women to better fulfil their work commitments, and can help overcome issues of mobility. ICTs and broadband can also be used to influence public attitudes to gender equality, create opportunities for women as educators and activists, and enhance opportunities for networking and organizing for gender equality, as well as female participation in political processes.

ICTs and broadband are directly relevant to empowerment and gender equality in both cause and effect – increasing women's access to ICTs and broadband will help achieve these goals, and achieving gender equality will help increase women's access to ICTs and broadband. Key stakeholders must develop gender-focused or gender-neutral technology and application programmes to ensure that broadband mitigates, and does not widen, gender gaps"[39].

1.4 Access to Broadband Services for Persons with Disabilities

Accessibility is a key pillar of the work of the ITU. ITU-D has been active in addressing the issue and is a partner in a Joint ITU/G3ict Toolkit for Policy Makers Implementing the Convention on the Rights of Persons with Disabilities. The e-Accessibility Policy Toolkit for Persons with Disabilities is the definitive resource on accessibility for persons with disabilities and can be found here: http://www.e-accessibilitytoolkit.org/.

Within the ITU-D, Question 20-1/1 is tasked to address "Access to telecommunication/ICT services by persons with disabilities and with special needs". Question 20-1/1's 2010 Report, "Access to telecommunication services for people with disabilities", contains detailed guidelines and best practices for regulators to consider.

2 Broadband Policy

2.1 Regulator Strategies for Accelerating Broadband (i.e. National Broadband Plans, Universal Service Funds)

"Today, technologies are ready for affordable broadband services. Competition, government support policies and operator strategies are key factors for affordable broadband services. Delaying of right policies and regulations or doing nothing causes the billions of US Dollar economical losses in developing countries and negatively influences the life quality of citizens."[40]

[39] "A 2010 Leadership Imperative: The Future Built on Broadband". Broadband Commission, 2010.

[40] Intel Corporation, Document 2/23 "Affordable Broadband for Everyone"

"Political will and leadership at the level of Prime minister or Head of state is required: a future-oriented networked society and economy require future- oriented vision, thinking and prioritization. Broadband must be clearly embedded in national development policies that build on broadband as a development accelerator. A large number of countries have included broadband and ICT investments in their stimulus plans and are exploring new state financing packages for national broadband infrastructure.

Public authorities could play a key role in abolishing existing barriers and factors that hinder widespread adoption of broadband, as well as barriers to investment. Governments could also use tax policy to give long-term incentives to broadband investments and use e-government to create more demand. Especially important in the short term is consideration of how to meet the increasing demand for radio-frequency spectrum for mobile broadband. Special attention must be paid to increasing the availability and affordability of radio frequency spectrum as a critical enabler for wireless broadband growth. Fair competition and new services, as well as regulatory reform and fair licensing procedures, need to be taken into consideration in allocating radio frequency spectrum, under a technology-and service-neutral approach".[41] A recent study issued by the Broadband Commission on National Broadband Plans notes that in mid-2013 there were some more than 134 Plans in force in the world.[42] Two such plans are included in **Annex I** in "Argentina Connected" and "Reference Broadband Implementation Plan".

Prior to embarking on the task of creating effective broadband policies, decision-making must be coordinated with many parties including regulatory authorities, municipalities, utilities providers, and other non-telecom sectors in the economy. The overall broadband eco-system is a large one and understanding the economic functions of supply and demand is instrumental. There are several factors that influence the demand of broadband services such as broadband service prices, income levels and affordability, socio-cultural aspects and accessibility. Similarly, there are many factors that influence the supply (deployment) of broadband networks, such as cost of network deployment, technology limitations, and regulatory policies. Each of these factors influencing supply and demand must be considered during the policy making process. For example, in many cases, demand stimulation initiatives may be required from the Government. In addition, a health supply chain, reasonable business models and effective regulations are needed in all segments (access, backbone and international connectivity) in order to encourage the deployment of broadband networks and creation of policies to support it.[43]

The goal of most regulators' broadband policy is to "enable high quality, widespread, and affordable broadband. In order to achieve this global broadband objective, each country's National Broadband/ICT Plan should include broadband objectives in the following areas: (1) Deployment (network coverage); (2) Adoption (broadband subscription/service and devices); (3) Metrics and Disclosure (criteria and quality of service); (4) Universal Service Funds (subsidies); and (5) Spectrum (assignment)".[44]

Each of these aspects is addressed in the following sections:

2.1.1 Deployment

"Issue: The level of broadband infrastructure deployment in a country is measured by the percentage of people, small and medium businesses (SMBs), schools, healthcare facilities, and/or households that have access to a broadband network (regardless of whether the service is subscribed to). Generally, a two-step approach for deployment is recommended as described below.

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[41] Broadband Commission, "A 2010 Leadership Imperative: The Future Built on Broadband". Broadband Commission, 2010, available at: www.broadbandcommission.org/Reports/Report_1.pdf.

[42] Broadband Commission, "Planning for Progress – Why National Broadband Plans Matter," Broadband Commission 2013, page 7, available at www.broadbandcommission.org/documents/reportNBP2013.pdf

[43] Egypt, Document 2/INF/44 "Analysis of Factors that Influence both the Demand of Broadband Services and the Deployment of Broadband Networks"

[44] Intel Corporation, Document 2/24 "National Broadband/ICT Plans: Policy Objectives for Success"

While several broadband performance and quality factors are important to the adoption of broadband (see Adoption discussion in the next section), one factor most commonly associated with deployment is network speed. There are many different definitions of broadband speed that vary by country, technology, and international organization. The ITU, for example, defines broadband as higher than a primary rate connection (1.544/2.048 Mbps)[45].

Objective: Countries should focus on a long-term goal of high-quality broadband deployment to every household and potential use. However, in parallel, National Broadband/ICT Plans should also consider government objectives and subsidies to connect community anchor tenants such as government buildings, schools, hospitals, Internet cafés, businesses, community centers, and other public forums (see the Universal Service discussion below). Such objectives should take the form of a timeline and state the percentage of each of these sectors to be covered over time, as well as the desired performance and quality (e.g., at minimum, the actual peak period broadband speeds achieved). Once community entities are connected at a reasonable broadband speed, more emphasis should be placed on expanding the coverage area to every household.

Taking into account the current and expected levels of private deployment, these objectives should specify the percentage of the population (example: households, schools, etc.) to be covered over a set period time, as well as performance and quality objectives to be met by the deployment.

For emerging markets, depending on local circumstances, countries should ensure that most citizens are able to get at least 1-2 Mbps initially, at high quality and affordable rates, and as expeditiously as possible. Additionally, in emerging markets with little or no broadband deployment to households, the broadband performance goals could initially be the same across all platforms. However, as a country plans to deploy both wireline and wireless networks to end users in the longer-term, its National Broadband Plan should recognize that the speeds across different platforms will vary in the latter years, due to inherent coverage, service, and infrastructure differences.

As the coverage becomes more ubiquitous and well established across different types of access technologies, different speed goals should be set for different last mile broadband platforms; sample goals for five years out from that point are: Wireline: 100/20 Mbps; Fixed wireless: 20/5 Mbps; Mobile wireless: 10/2 Mbps. Also, while countries with multiple networks and acceptable initial, minimum speeds in place may set deployment goals at five year intervals to improve speed, countries with less deployment should set goals at faster intervals and focus on deployment of basic broadband service as described previously.

2.1.2 Adoption

Issue: Broadband adoption refers to the use of broadband technology and broadband-enabled devices (e.g., PCs, laptops, netbooks, PDAs, smart phones) to access the Internet. While policy makers typically focus on broadband deployment, adoption issues are equally important. The level of adoption in a country is perhaps measured most simply by the percentage of households/population using broadband on a regular basis. In some markets, pay-per-use is a prevalent form of access; therefore, the adoption goal may sometimes be broader than a measurement of monthly subscription (broadband service) accounts. Where there is little or no broadband deployment at all, a country may wish to initially emphasize the broadband adoption (usage) goal based on the usage level by government entities, schools, hospitals, Internet cafés, businesses, community centers, and other public forums. While adoption goals that include community access may be meaningful in the short-term, again administrations are encouraged to focus on adoption at the household level in parallel and as an emphasis in the long-term.

[45] ITU-T I.113 (1997) and Recommendation ITU-R F.1399 (2001)

Objective: National Broadband/ICT Plans should focus on achieving universal broadband adoption at the household level, including affordable PC/broadband programs, accompanied by digital literacy training. Simply deploying broadband networks is not sufficient to enable adoption for many citizens; ideally, countries should provide mechanisms to help low-income, less educated, and other vulnerable citizens to acquire broadband service and equipment, as well as government E-services and appropriate training to understand the relevance of broadband to their lives (see the Universal Service discussion below).

For a country that already has broadband deployment to many households, the National Broadband Plan should aim to increase household adoption at an aggressive yearly rate, based on local circumstances and growth history. For example, Year 5: increase household adoption from current X% to Y% (e.g., from current 65% to 85%). By contrast, for countries that lack any meaningful level of broadband infrastructure to households, the adoption goals should be synchronized with broadband deployment goals – expecting that both would grow rapidly on a percentage basis from the onset. Specific targets would depend on local circumstances; however, it is recommended that countries set aggressive targets for both deployment as well as adoption, along with annual progress monitoring.

2.1.3 Metrics and Disclosure

Issue: Tracking progress toward national broadband goals requires accurate, consistent, and relevant measurements and methods. These measurements can be divided into two categories: (1) country-wide top-level indicators such as number of households with broadband service available and (2) secondary-level metrics (service quality) specific to a given service offering, such as download/upload throughput, latency, and packet loss.

Top-level broadband/ICT data and indicators are necessary to measure the digital divide[46]. Such measurements evaluate access to (deployment), use of (adoption), and impact of ICTs. These indicators are primarily a tool for policy makers to assess the status of broadband and ICT in a country and craft policies to maximize the benefits of ICT[47].

The United Nations Conference on Trade and Development (UNCTAD) has established a program to develop and coordinate top-level indicators, or metrics, for measuring ICT[48]. UNCTAD's core list of 50 ICT indicators measure many aspects of ICT infrastructure and access; ICT access and use by households and individuals; ICT access and use by enterprises; sector and trade in ICT goods; and ICT in education[49].

It should be noted that these indicators, while far from perfect, are adopted by a wide variety of international bodies including all UN agencies, the World Bank, and the ITU. In short, these are a "worldwide accepted starting point," but should not limit countries using their own, expanded internal measurements.

Objective: A National Broadband Plan, at minimum, should include this recommended subset of top-level internationally recognized indicators. Again, governments should establish objectives for each of these ICT indicators, and an annual reporting program to track performance. For secondary-level metrics, the government could encourage voluntary industry-developed quality and performance metrics to track service quality improvements and/or degradations over time.

[46] UNCTAD 698

[47] UNCTAD 619

[48] UNCTAD 575 UNCTAD defines/analyzes internationally comparable ICT indicators and develops ways to collect these indicators; assists in building statistical capacity in countries; and maintains a global database on ICT indicators: UNCTAD 606

[49] UNCTAD 604

As a country's broadband market matures, the government should determine baseline broadband performance metrics [50] and facilitate meaningful, voluntary disclosure of material terms (such as actual upload/download speeds, price, packet loss, and latency). Broadband providers should give consumers meaningful data about service plans so that users can make informed service choices.

2.1.4 Universal Service Funds

Issue: Universal Service subsidies are an important tool to promote telecommunications connectivity for underserved people. Many countries have established Universal Service Funds (USF), but most of these funds are extremely underutilized, especially in developing countries. While most USFs were established with only voice service in mind, many countries, development agencies, and NGOs (non-governmental organizations) support the development and reform of USF programs to help expand and ensure benefits to consumers. Governments should establish or expand the pool for USF distributions beyond traditional voice telecommunications to include broadband/ICT adoption as well as deployment.

Objective: A National Broadband Plan should correct USF inefficiencies and refocus universal service programs to support broadband deployment and adoption. Targeted broadband/ICT subsidy programs could also be developed. Countries should establish a USF or alternatively targeted broadband/ICT funds for broadband service and equipment, as well as transition any existing USF distributions from basic telephony to broadband as quickly as possible. Ideally, countries should fund these programs with general tax revenues; if that is not possible, countries should raise USF from a comprehensive, fixed charge on end users.

A National Broadband/ICT Plan should support market-based mechanisms, such as reverse auctions, to award universal service funding on a technology-neutral and competitively-neutral basis. A National Broadband Plan should support the use of universal service to advance demand-side goals (i.e., to increase broadband adoption). In this regard, universal service and/or targeted broadband/ICT funds can be used to help fund broadband service and equipment (e.g., consumer broadband devices) for low-income households.

For developing countries, a National Broadband/ICT Plan's objectives initially may focus on using USF to expand support of broadband service and adoption to community centers, Internet kiosks, or other public places. While this may be a valuable first step, countries should set objectives for establishing a USF to support broadband service to households over the long term. As discussed in the Adoption section of this paper, countries should establish goals for ubiquitous, high-quality, affordable broadband adoption at the household level in the long-term.

Education Based Broadband Transformation

Education Based Broadband Transformation requires the collaboration and coordination between the different Ministries, along with the usage of USF and other government sources. Each administration could start by establishing a "National Education Transformation Planning Committee" in collaboration with Ministry of ICT. The committee can be composed of representatives from the Ministries of ICT, Education, Finance-Economy, Development/Planning, Science, as well as the Regulator, and the USF administrator. This committee should develop a National Education Transformation Program and implementation plan. Another key factor is to gain support at the top level of Government; from Presidents and Prime Ministers. Therefore, it is also necessary to include relevant persons from the Presidents and Prime Minister's offices in the committee. . Deployment of a National Education Transformation Program will provide a beneficial Education Based Broadband Transformation which will also significantly increase broadband and ICT penetration in the short term and accelerate reaching all citizens. Administrations could start to plan by organizing a "National Education Transformation" meeting

[50] Depending on local circumstances, it may be appropriate for the government to determine separate baseline performance metrics for each of wireline, fixed wireless, and mobile wireless.

and inviting Ministries of ICT, Education, Finance-Economy, Planning, Science, Universal Service Fund managers, and also offices of the Presidency and Prime Ministry.

National Education Transformation Planning

– Develop plan for the connection of all schools with broadband.

– Develop plan for the provision of interactive whiteboards at schools.

– Develop plan for access to PCs for all students and teachers, and their families.

– Develop plan to educate all teachers and students regarding the use of ICT.

– Develop plan for the provision of digital content for education.

– Develop plan to subsidize home broadband connectivity for low income student families.

– Develop plan for public internet access at schools (community access centres) to provide e-government, e-health, e-farming etc. services.

– Develop a Plan to integrate digital literacy training in e-gov services.

2.1.5 Spectrum

Issue: Wireless broadband in many instances can be the most efficient mechanism to achieve ubiquitous, affordable broadband access. With the onset of new, powerful broadband wireless technologies such as IMT, consumers may reap the benefits of high-quality mobile broadband, provided appropriate public policies are in place. The global demand for mobile broadband is growing at a phenomenal rate, but new spectrum appropriate for these services is scarce in many countries. Historically, it has taken countries many years to assign or re-purpose spectrum for more efficient use. With today’s demands and the rapid pace of technology advancements, it is more important than ever to streamline spectrum allocation and assignment processes to expedite benefits to consumers.

Objective: A National Broadband/ICT Plan should support technology-neutral and service-flexible spectrum policies to promote broadband investment and facilities-based competition.”[51] In developing National Broadband/ICT Plans, administrations should consider the following:

– That spectrum utilization is an appropriate objective for spectrum allocation to achieve the large socio-economic benefits of broadband coverage.

– That their spectrum allocation method should provide incentives to operators to expedite network deployment.

– That infrastructure rationalization and resources sharing schemes can improve the economics of network deployment (ROI).

– That alignment with regionally or globally harmonized spectrum promotes the economies of scale needed to drive down equipment costs.

The ITU-R publishes Recommendations on frequency arrangements for wireless broadband technologies, including Recommendation ITU-R M.1036, “Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR)(03/2012)”, which encourage the use of harmonized spectrum.

[51] Intel Corporation, Document 2/24 “National Broadband/ICT Plans: Policy Objectives for Success” with minor editorial changes

2.2 Best Practice Guidelines for Regulators for the Promotion of Low-Cost Broadband

The Broadband Commission concluded that the following measures were critical to successfully deploying a national broadband infrastructure:

– "Infrastructure policy should take account of rapid technical advances and be focused on larger goals, not directed towards a specific technology mix. Legacy infrastructure (or lack thereof) constitutes both a constraint and an opportunity.

– Infrastructure goals are separate from questions of public ownership of facilities and the role of competition in spurring private investment.

– Pricing or other barriers that restrict access to networks or infrastructure must be removed as far as possible. Interconnection among networks must be robust, cheap and efficient.

– Preserving flexibility and innovation at the network's edges is essential. It must be possible to attach new applications and access devices, such as smartphones — which is much easier and cheaper than replacing core infrastructure

– The physical network is distinct from the services and functions that travel across it, and, in the interest of competition and technical progress, too close an association between infrastructure and a particular service should be avoided.

– Fibre-optic networks are likely to be preferred as backbone wired infrastructure, but these must be complemented by rapidly-evolving wireless infrastructure that will provide more bandwidth more economically as technology develops.

– The sharing of infrastructure should be facilitated and encouraged, and policy-makers should consider how best to ensure synergies among applications and services. This means adopting an integrated, trans-sectoral approach.

Some of the options open to regulators[52] are as follows:

– Seek to maximize investment flows by liberalizing markets and permitting foreign ownership. This includes allowing broadband providers to offer a full range of services and applications, such as the "multiple play" of voice, Internet access and video/multimedia programming.

– Build an adaptive regulatory framework by adopting a technology neutral approach, and an administratively simplified and flexible licensing regime providing for easy market entry of new players, such as through general authorizations and multiservice/unified licences.

– Create a regulatory framework that encourages a full range of potential broadband providers. Moving beyond large-scale national network operators, regulators can empower, for example, universities and government offices, local communities and smaller entrepreneurs to deploy broadband access networks. This may include tailoring regulatory frameworks to each group of potential broadband providers:

  • A regulatory framework tailored to small broadband providers will enable and encourage local community providers to harness the potential of broadband technologies and enable greater broadband access in rural areas;

  • Competitive large-scale operators can be encouraged to extend their networks to rural areas through infrastructure-sharing arrangements that guarantee open access to all competitive operators;

[52] See "GSR Best Practice Guidelines" 2003-2009, on various regulatory topics, available at: www.itu.int/ITU-D/treg/bestpractices.html

- Competitive large-scale operators can be given incentives to deploy networks in return for appropriate rewards;
- Regulators could seek to encourage the deployment of broadband access networks by providing direct, targeted subsidies from universal access funds or indirect financial benefits (such as tax exemptions) to a full range of broadband providers.

– Shift regulatory attention from retail to wholesale markets; i.e. by ensuring that alternative operators have access to dominant players' infrastructure (through passive sharing such as duct sharing, local loop and sub-loop unbundling, bitstream access, network and facility sharing, etc.) to offer competitive converged services, therefore avoiding unnecessary duplication of infrastructure and reducing costs.

– Create an asymmetric regulatory regime to prevent the dominant operator from constraining the development of competition in the broadband access market.

– Work with other government agencies or ministries to develop initiatives stimulating demand for services and applications within the framework of broader strategic goals, such as connecting public institutions (especially public administrations, schools, libraries and hospitals), businesses and residential users with broadband, promoting economic development, digital inclusion, social cohesion and equality of opportunity.

– Encourage the deployment of wireless broadband access networks by freeing up the requisite spectrum, while taking account of the range of demand. This strategy can be augmented by a technology-neutral approach to spectrum assignments.

– Encourage the build-out of fibre backbone networks to boost the capability of both wire-line and wireless broadband technologies. These steps include forging synergies with transport and energy infrastructure projects and providing incentives for 2G mobile operators to replace their microwave links with fibre networks. It also means making it possible for all owners of such communication resources to lease unused capacity to others for commercial deployment.

– Link broadband access development strategies to efforts to help people have access to personal computers or other devices. Build government-sponsored Internet kiosks and access terminals, especially in areas where broadband networks are to be deployed.

As regulators consider and implement new strategies, they will have to remain flexible."[53]

Broadband policies should seek to equally encourage all technologies. The following best practices are recommended to regulators and policy makers to help foster satellite solutions for broadband deployment:

– Broadband Plans – Include satellites technologies in national broadband plans (spectrum access, financing, build-out, etc.).

– Spectrum Access – Harmonize FSS allocations, including Ka-band, in national frequency tables with ITU Tables of Allocations.

– Co-primary sharing – Follow ITU Radio Regulations regarding sharing between satellite systems and terrestrial wireless systems.

– Licensing – Streamline satellite operator and national service provider licensing for broadband services and allow for 'open skies' access to capacity.

– Satellite Equipment – Expedite new broadband-capable satellite equipment approvals: type approvals, homologation, import/export fees and processes.

[53] Broadband Commission, "Broadband: A Platform for Progress" Summary Broadband Commission 2010, available at: www.broadbandcommission.org/Reports/Report_1.pdf

– Spectrum Fees – Consider lower fee approach, taking into account the social, economic development and other needs being served; keep passed-down costs low for ultimate end-users of higher bandwidth services to help meet broadband deployment policy objectives.

2.3 Operator Strategies for Promoting Broadband Deployment

"Minimization of infrastructure costs is a concern for operators in developed as well as developing countries. However, due to lower penetration rates and ARPUs in developing countries this constraint is heavier in these countries. Thus, from the standpoint of the operators there is a need for a regulatory environment that minimizes implementation and roll-out costs (such as sustainable coverage obligations, low licence fees, choice between alternative technologies allowing a cost efficient network deployment, possibility to use lower frequency bands, infrastructure sharing). Furthermore, since in most developing countries mobile networks provide more extensive coverage than fixed networks, administrations in these countries may wish to support the usage of such networks for fixed/data applications."[54]

Table 2.3-1 - Special needs of operators

Item	Operator needs and rationale[55]
Costs	Costs should be minimized as much as possible because the vast majority of the population has little discretionary budget for telecommunications/entertainment. Recovery of evolution/migration capital expenditure (CAPEX) and operating (OPEX) costs
Fixed wireless access	Some operators may provide fixed wireless access for IMT services in urban areas
Coverage and deployment obligations	Target coverage/service penetration and roll-out schedule set by regulators in some cases. The goal for coverage for IMT systems, which will be realized over time, should be consistent with existing pre-IMT-2000 systems. Roll-out obligations must be set keeping in view the business case of the operator and the user's interest
Transition time	Time frame for transition from existing "mobile"/"fixed" towards IMT. Operators should have maximum flexibility in determining and finalizing the transition
Mass application	Applications such as tele-education, telemedicine, e-government may require IMT technologies
Government support	Role of government subsidy for infrastructure and/or advanced applications (not for infrastructure but for affordability of services by all including universal service obligations)
Value depreciation	Possible obsolescence of new infrastructure investments while waiting for IMT demand
IMT bands	Access to appropriate frequency bands and adequate spectrum is required. Use of frequencies below 1 GHz and allocation of future frequency bands as per WRC/WARC decisions may be advantageous in providing cost-efficient coverage. Use of harmonized IMT bands decreases equipment costs and facilitates worldwide roaming

[54] Rev.1 of Supplement 1 to Handbook on Migration to IMT-2000 Systems (Document 25/2/2)

[55] Rev.1 of Supplement 1 to Handbook on Migration to IMT-2000 Systems (Document 25/2/2) with editorial change from IMT-2000 to the broader term, IMT

Item	Operator needs and rationale[55]
Technical and administrative conditions	Conditions for use of spectrum (licensing/roaming/coverage/other operator obligations)
Infrastructure sharing	Sharing of (radio/network) resources for rapid rollout and coverage (VNO – virtual network operator) can be encouraged to facilitate speedy deployment of new technologies and lower the costs to operators
Satellite component	Usage of satellite component of IMT-2000
Market analysis and business cases	How to develop market analysis/business case? (population literacy, disposable income, . . .)
Services and applications	- Low entry fees would reduce the entry cost of service provider - Use of IMT for access to education in remote villages, rural economic development, access to Internet at affordable price
Availability of equipment from multiple vendors	- Existence of multiple vendors increases competition with positive price effects for operators - Dependency of operators on vendors is reduced - Multivendor systems require standardization by a broad community and leads to open standards

*See also Case Studies listed in **Annex I**.*

3 Broadband Technologies

3.1 Deployment Considerations: Wireline vs. Wireless[56]

As wireless technology represents an increasing portion of the global communications infrastructure, it is important to understand overall broadband trends and the roles of wireless and wireline technologies. Sometimes wireless and wireline technologies compete with each other, but in most instances they are complementary. For example, backhaul transport and core infrastructure for wireless networks are usually based on wireline approaches, whether optical or copper. This applies as readily to Wi-Fi networks as it does to cellular networks.

Given that the inherent capacity of one fiber optical link exceeds the capacity of the entire available radio frequency (RF) spectrum, data flow over wireless links will never represent more than a small percentage of the total global communications traffic. Nevertheless, wireless technology is playing a profound role in networking and communications, because it provides two fundamental capabilities: mobility and access. Mobility refers to untethered communication whether stationery or in motion. Access refers to communication services, whether voice or data, easily provided across geographic areas, with wireless, this is often more easily accomplished than with wireline approaches, especially in greenfield situations where there is little existing communications infrastructure. Thus, given these characteristics, mobile communications volume may be less than wireline, but its overall contribution to communications in the world and its social, political and economic impact, is just as significant.

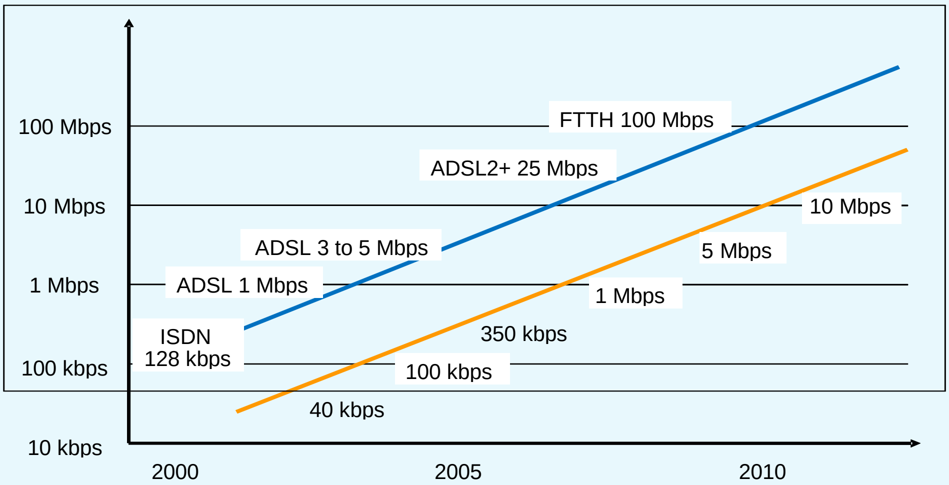
The overwhelming global success of mobile telephony, and now the growing adoption of mobile data, conclusively demonstrate the desire for mobile-oriented communications. Portio Research predicted in April 2012 that worldwide mobile data revenue would increase at a compound annual growth rate of 13.2 percent to reach $539.9 billion the end of 2015.[57] However, the question of using wireless technology, for

[56] The text in Section 3.1 is largely taken from the LMH Handbook Vol. 5 on BWA Systems (Document 25/2/4) with editorial changes.

[57] "Portio Research Mobile Factbook" 2012, Portio Research, April 2012.

access is more complex. One must consider the performance and capacity of wireless technologies relative to wireline approaches, what wireline infrastructure may already be available, and ongoing developments with wireline technology. In particular, wireline networks have always had greater capacity, and historically have delivered faster throughput rates. Figure 3.1-1 shows advances in typical user throughput rates, and a consistent 10x advantage of wireline technologies over wireless technologies.

Figure 3.1-1: Wireline and wireless advances in typical user throughput rates

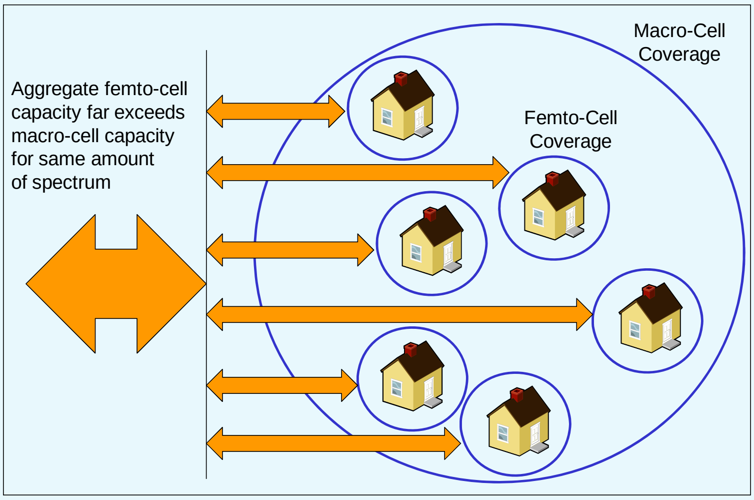


Mobile broadband combines compelling high-speed data services with mobility. Thus, the opportunities are limitless when considering the many diverse markets mobile broadband can successfully address. In developing countries, there is no doubt that mobile broadband technology will cater to both enterprises and their high-end mobile workers and consumers, for whom mobile broadband can be a cost-effective option, competing with digital subscriber line (DSL), for home use. In some cases, there may be no option to obtain broadband service via DSL at all, making mobile broadband the only viable connectivity choice.

Users' desire to be connected anytime, anywhere will be a primary source of demand. While user demand for social networking and search information services, as well as Internet businesses, increases the demand for mobile-broadband capabilities among individuals, the majority of early adopters of mobile broadband have been enterprises, since better connectivity can improve business efficiency. As a result, enterprise broadband-connectivity adoption is taking on the same "look and feel" as early mobile-phone service adoption. For example, in the early 1990s, doctors, lawyers, salespeople, and executives already had home phones, office desk phones, and even receptionists. It was the productivity increases associated with being connected to a cellular network, however, that accelerated mobile broadband growth throughout the world. Overall, whether in business or in our personal lives, the world of voice and data is quickly becoming one that must be *untethered, but always connected*.

Although it is true that most BWA systems are now offering throughputs of about 2 Mbit/s – which is comparable to what many users experience with a basic DSL or cable-modem service – the overall capacity of wireless systems is generally lower than it is with wireline systems. This is especially true when wireless is compared to optical fiber, which some operators are now deploying to residences. With wireline operators looking to provide 20 to 100 Mbit/s to either homes or businesses via next-generation cable-modem services, very high-speed DSL (VDSL), or fiber – especially for services such as high-definition IP Television (IPTV) – the question becomes, is it possible to match these rates using wireless approaches? While the answer is "yes" from a purely technical perspective, it is "no" from a practical point of view. It is only possible to achieve these rates by using large amounts of spectrum, generally more than is available for current BWA systems, and by using relatively small cell sizes. Otherwise, it simply will not be possible to deliver the hundreds of gigabytes per month that users will soon be consuming – notably due to increased interest in video content – over their broadband connections with wide-area wireless networks. Consider that current high definition (HD) television content that demands 6 to 9 Mbit/s of continuous connectivity, meaning that one subscriber could essentially consume the entire capacity of a cell sector. A possible wireless approach to address such high-data consumption is with hierarchical cell approaches, such as femto cells as shown in Figure 3.1-2. This presupposes, however, an existing wireline Internet connection (e.g., DSL).

Figure 3.1-2: Femto cells used to expand capacity



What is often the case today is using wireless technology for access only when there are no good wireline alternatives. Hence, the interest developing countries have in broadband-wireless technologies. What changes the dynamics of the business model in these areas is that operators can cost-effectively deploy voice (which is inherently low bandwidth) and lower-speed data services, more quickly and less expensively than running copper or fiber lines. Deploying at lower capacity – as measured by lower bits per second (bit/s) per square kilometer – means larger cell sizes, and thus fewer cell sites and much lower deployment costs.

Table 3.1-1 summarizes the strengths and weaknesses of wireless versus wireline broadband approaches.

Table 3.1-1: Strengths and weakness of broadband approaches

	Strength	Weakness
Cellular mobile broadband	Constant connectivity. Broadband capability across wide areas. Good access solution for areas lacking wireline infrastructure. Capacity/coverage enhancement options via femto cells.	Lower capacity than wireline approaches. Future evolution to serve high-bandwidth applications such as IP TV.
Wireline broadband	High capacity broadband at very high data rates. Evolution to extremely high throughput rates.	Expensive to deploy new networks, especially in developing economies lacking infrastructure.

This is not a static situation, however. In the longer term, a number of developments could make high-capacity broadband-wireless systems more competitive with wireline approaches. Among these developments are mesh capabilities to reduce deployment costs, higher spectral efficiency, low-cost commoditized base stations, and future spectrum allocations for mobile-broadband systems. However, any such future success is somewhat speculative and dependent on many developments including technology and broadband application evolution.

There are new broadband access technologies enabled by wireless devices using the Cognitive Radio System (CRS) techniques through Dynamic Spectrum Access (DSA) for determining available frequencies. There are underway commercial deployments and trials in some countries, utilizing these techniques in the unused TV bands ("TV white spaces") where the local regulations allow it. An example of one commercial pilot is included in **Annex I**.

This technical solution is being studied at several study groups in ITU-R and their outputs will need to be considered, alongside other relevant research, when evaluating the technical, economical and regulatory aspects of its implementation, especially in developing countries.

Cellular mobile broadband technologies clearly address user needs; hence, their success. The cellular mobile broadband roadmap, which anticipate continual performance and capacity improvements, provide the technical means to deliver on proven business models. As the applications for mobile broadband continue to expand, cellular technologies will continue to provide a competitive platform for tomorrow's new business opportunities."[58]

An example of one administration's analysis of the various broadband access technologies is included in **Annex I** in "Evaluating different access technology options". Other case studies submitted to this Study Question show that administrations tend to support technologies that fit the needs of their citizens. These technologies include IMT, satellite, fiber, etc. **Annex I** contains examples from these case studies.

3.2 Technical Measures for Effective Use of Wireless Telecommunication

In the case of wireless telecommunication, unlike wired telecommunication, ensuring adequate capacity is a key issue. Thus, the main concern for wireless telecommunication operators will be acquiring sufficient spectrum to meet the capacity demand. However, the spectrum available for wireless telecommunications is limited. Thus, we have to consider other measures to ensure that the available spectrum is used more effectively.

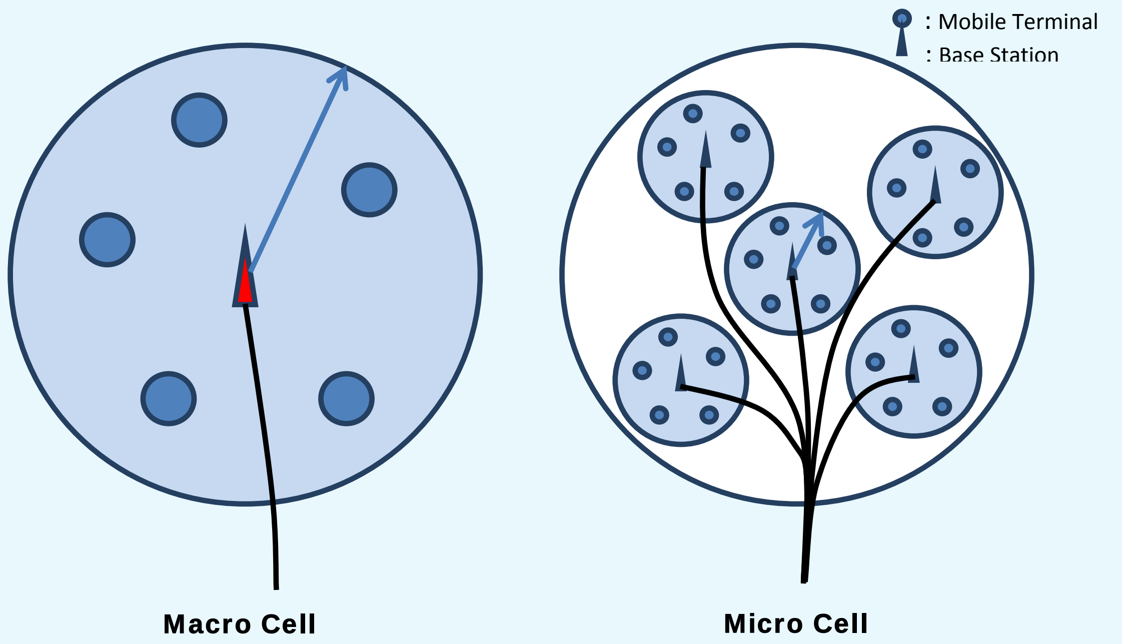
- **Applying using smaller cell sizes**

Macro cell base stations generally cover wide areas with one station. On the other hand, the number of active users under a Macro cell base station in the covered area is often less than the number of users that would be served in the same area through the use of multiple Micro cells (See Figure 3.2-1). In other words, the efficiency of frequency use in a Macro cell is less than that in a Micro cell.

In the case of a Micro cell, output power from the base station is weaker and radio signals do not reach far. That means that the reuse of the same frequency is possible while minimizing interference.

[58] LMH Handbook Vol. 5 on BWA Systems (Document 25/2/4)

Figure 3.2-1: Efficiency comparison between Macro Cell and Micro Cell



However, operators have some flexibility in their network designs that allows them to use a macro cell coverage radius that is lower than the maximum available for a given base station. In other words, operators can vary cell sizes in order to meet capacity demands. This allows them to pack cells more closely together and use micro cells where even smaller radii are required.

Table 3.2-1: Various types of cell size

Cell size	Macro Cell	Micro Cell	Pico Cell	Femto Cell
Range of cell size	From hundreds of meters to several kilometres	From tens of meters to several hundred meters	From several meters to tens of meters	Several meters
Typical usage	Outdoor	Outdoor / Indoor	Mainly inside a house, basement, upper stories of tall building	Usually inside a house / room, office

- **Other measures to the rapid increase of wireless traffic**

– Adoption of charging depending on volume of the traffic

– Restriction on (extremely) heavy user

– Data Offload

To effectively provide wireless high speed data, operators sometimes encourage users to take advantage of smaller base stations such as Femtocells, or Wi-Fi access points, where the efficiency of frequency use is very high. Traffic is then routed to the wired telecommunication system, which does not need to worry about interference. Such an approach is referred to as “Data Offload”.

More information on techniques to address the increase in wireless traffic can be found in Annex 5, "Various measures to respond to increased mobile broadband traffic" of Report ITU-R M.2243, "Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications".

3.3 Wireline Broadband Access Technologies [59]

The Wireline Broadband Network – ISDN

Integrated Services Digital Network (ISDN) was the first attempt at a completely digital telephone/telecommunications network (as opposed to using modems over switched analogue circuits). ISDN provides one or two 64 kb/s digital service channels and a 16 kb/s digital signal channel to each subscriber. It was designed to carry voice, data, images, video, in digital format, with a standard network and device interface over, essentially, the legacy PSTN. ITU-T standards describing this application date from 1980 and are in the ITU-T I-series of Recommendations, in particular Recommendations ITU-T I.120 and I.210.

In 1988 Recommendation ITU-T I.121 was published which described an enhanced ISDN service created by multiplexing multiple 64 kb/s channels and managed using Asynchronous Transfer Mode (ATM). Even though ISDN found several important niche applications such as video conferencing and audio recording, it has never prospered as a consumer broadband access technology, Germany – with 25 million ISDN channels at one point in time – being the notable exception.

The Wireline Broadband Network – DSL

The poor adoption of ISDN as a wireline broadband access technology is attributed to several factors, including delayed standardization, failure to keep pace with advances in applications like video and interactivity, complexity of consumer solutions and limited marketing by the network operators. However the fatal blow to ISDN deployment was the rapid development and commercialization of Digital Subscriber Line (DSL – originally "Digital Subscriber Loop") as a broadband wireline technology.

DSL carries digital broadband signals on the PSTN using higher frequencies than those used for voice traffic. Thus, unlike with modems, the customer can use the telephone and computer simultaneously and keep legacy interfaces and equipment (e.g., analogue telephone). For example, in the most common consumer realization of DSL, Asymmetric DSL (ADSL), the broadband signals are carried on frequencies between 25 and 1104 kHz.

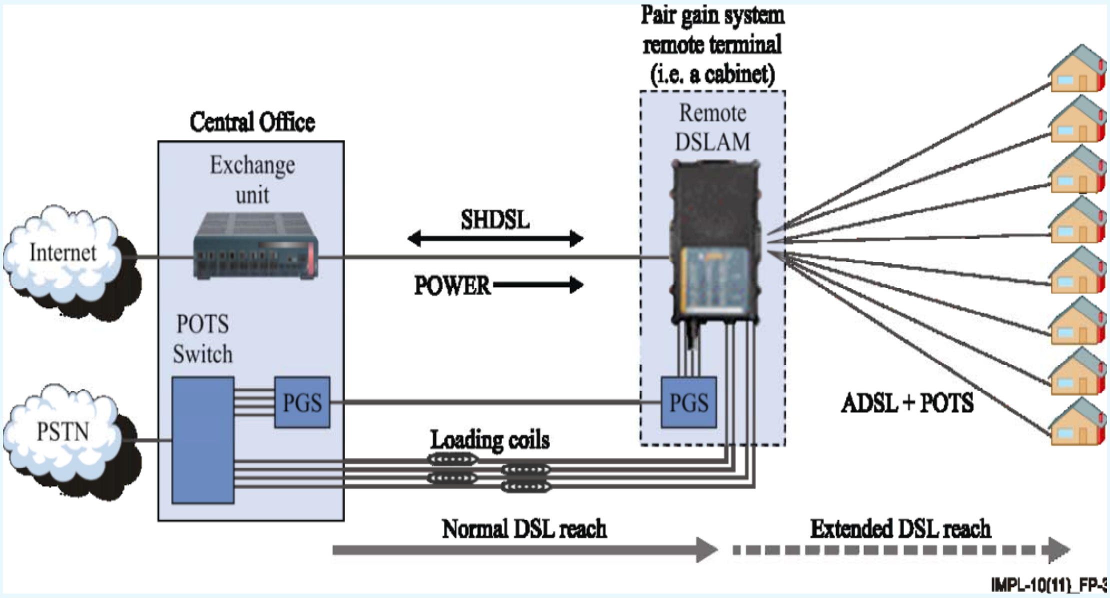
Note – Within this Technical paper, the term "broadband" is used when qualifying a system that requires transmission channels capable of supporting rates greater than the primary rate.

Several varieties of DSL have been developed to meet different applications, such as business (Symmetric, or SDSL), academia (Symmetric-High Speed, or SHDSL) and video (Very high speed DSL, or VDSL). The performance differences are accomplished by changing the power levels and spectrum characteristics, advanced modulation techniques, channel bonding and noise management. Advanced versions of ADSL and VDSL such as ADSL2, VDSL2 and ADSL2+ are also available.

DSL's advantage of using the legacy PSTN physical plant is offset by several factors. The subscriber's data rate, or speed, reduces as the distance from the network operator's DSL modem (DSLAM, DSL Access Multiplexer) to the subscriber's DSL modem increases. A common solution is to place the DSLAM in the network in a remote terminal (RT), thus reducing the loop length to the subscriber. An example of this configuration is shown for SHDSL in Figure 3.3-1.

[59] Excepted from ITU-T SG/15 publication: "Wireline broadband access networks and home networking", www.itu.int/pub/T-ITU-HOME-2011

Figure 3.3-1: Remote SHDSL DSLAM configuration



DSL performance on the PSTN is also limited by the quality of the physical plant. Old cables damaged by age, fatigue, corrosion, or even poor handling and installation practice, can reduce DSL capability. Even the presence of lighter gauge wires (which can range from 0.4 mm to 0.9 mm) or the mix of different wire diameters reduces capability and impairs DSL service.

Table 3.3-1: Access network wireline data transmission standards

Modem	Data rate*	Application	Recommendation
ITU-T V.90	56 kbit/s	Data and Internet access	ITU-T V.90
ISDN BRI	144 kbit/s	2B (2 x 64 kbit/s) + D (16 kbit/s)	ITU-T I.432.x series
HDSL	2,048 kbit/s	1.5 – 2.0 Mbit/s symmetrical service on two-three pairs	ITU-T G.991.1
SHDSL	768 kbit/s	HDSL on a single pair	ITU-T G.991.2
ADSL	6 Mbit/s / 640 kbit/s	Access to Internet and multimedia databases, video distribution	ITU-T G.992.1
ADSL2	8 Mbit/s / 800 kbit/s		ITU-T G.992.3
ADSL2+	16 Mbit/s / 800 kbit/s		ITU-T G.992.5
VDSL	52 Mbit/s / 2.3 Mbit/s	Internet Access + HDTV	ITU-T G.993.1
VDSL2	100 Mbit/s		ITU-T G.993.2
VDSL2 vectoring		Internet Access + HDTV over longer loops with more users	ITU-T G.993.5

* *Downstream (network to subscriber) / upstream (subscriber to network). Single values are symmetric. DSL speeds are "up to" the values in the table.*

Finally, DSL performance is affected by the number of subscribers served within a distribution area, as well as the coexistence of different services in the same cable. Noise from TWP carrying DSL degrades service on other pairs in the distribution cable. The remedies are noise cancellation and spectrum selection techniques common in advanced DSL technologies like the more recent VDSL2 vectoring specifications. These techniques and the use of channel (pair) bonding extend the theoretical bandwidth delivered to consumers over copper pairs to around 1 Gbit/s, depending on the distance.

The ITU-T has published DSL standards since the late 1990's. They are summarized in Table 3.3-1, along with telephone modem and ISDN standards.

The Wireline Broadband Network – DOCSIS

Through the 1960's and 1970's, demand for video services compelled and financed the construction of CATV networks to the point where their subscriber access was competitive with the PSTN. By the 1990's many of these smaller systems consolidated into large "Multi-Service Operators" (MSOs) who identified digital communications as a growth opportunity and a source of revenue for return on their network investments. The Data Over Cable Service Interface Specification (DOCSIS) was published in 1997. It defines the addition of high-speed data communications to an existing CATV system. Using DOCSIS, MSOs offered competing data communications on their video network, and with the development of Voice Over Internet Protocol (VoIP) offer POTS-like service. The latest version of the standard, DOCSIS 3.0, bonds up to 8 channels from the network to the terminal, to deliver up to 343 Mbit/s to the optical node. MSOs offer subscriber access speeds as high as 100 Mbit/s using this technology.

The use of the CATV network to offer digital services by DOCSIS is outside the scope of this Technical paper. However ITU-T standards describing this application are in the ITU-T J-series of Recommendations.

The Wireline Broadband Network – FTTx

The effective response from telephone operating companies has been to replace the PSTN with fibre optics. Optical fibre is capable of delivering bandwidth intensive integrated voice, data and video services in the access network to distances beyond 20 km, e.g. more than 4 times the distances allowed with TWP cables through the DSL systems.

A fibre optic wireline broadband network can have several configurations, such as Fibre-to-the-Home (FTTH), Fibre-to-the-Building (FTTB), Fibre-to-the-Curb (FTTC) and Fibre-to-the-Node (FTTN). In each case the optical network is terminated at an Optical Network Unit (ONU – also known as an Optical Network Terminal, or ONT).

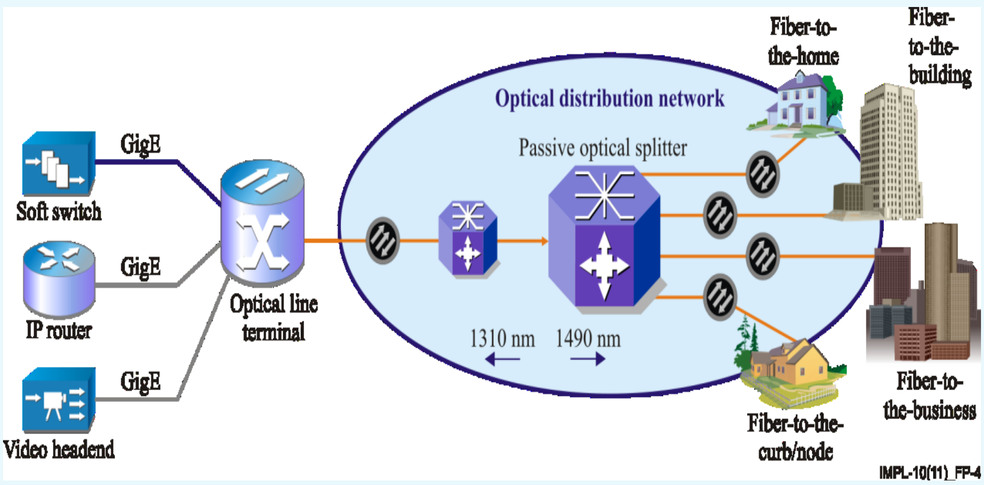
The versions of FTTx are differentiated by the location of the ONU. For FTTH, the ONU is located on the subscriber's premises and serves as the demarcation between the operator's and customer's facilities. For FTTB and FTTC, the ONU serves as a common interface for several subscribers (e.g., the basement of an apartment building or a telephone pole), with the service delivered over the customers' existing TWP drop cables. For FTTN, the ONU is located in an active network node serving dozens to hundreds of subscribers from which service is delivered by existing TWP local loops.

In fact these configurations represent various degrees of fibre deployment within the access network and are complementary with other broadband technologies (wireline and wireless). For example, remote terminals (RTs) used to reduce subscriber loop lengths and improve DSL availability are often connected ("backhauled") to the telephone exchange by fibre optics – especially as those RTs convert to Internet Protocol (IP). VDSL is often used to provide service from the ONU in FTTB and FTTC deployments and wireless broadband access is commonly "backhauled" by fibre optics, especially "4G" services like Long Term Evolution (LTE).

There are two common architectures for FTTx: "point-to-point" (PtP) and the Passive optical network (PON). In a PtP configuration, enterprise local area network (LAN) architecture is applied to the telephone access network, with a dedicated optical fibre connection (one or two fibres) from the ONU to the telephone exchange. In a PON network, several ONU – typically up to 32 – share a single fibre connection to the network which is typically split at a passive network node. An example is shown in Figure 3.3-2.

A future configuration of PON, Wavelength Division Multiplexing (WDM) PON, replaces the splitter with a grating so that each subscriber can be served with a dedicated channel, i.e., wavelength.

Figure 3.3-2: Passive optical network (PON) architecture



ITU-T has been writing standards for FTTx since the 1990's. They are in the ITU-T G.98x-series of Recommendations, Optical line systems for local and access networks. PtP standards describe 100 Mbit/s and 1 Gbit/s bi-directional service. PON systems have developed from bandwidth based on the ISDN primary rates to a few Mbit/s up to 10 Gbit/s service from the telephone exchange to the network. Several informative Supplements and Implementers' Guides have also been published. A summary of key ITU-T FTTx standards is shown in Table 3.3-2.

Table 3.3-2: Summary of ITU-T FTTx wireline broadband standards

ITU-T G.982	Optical access networks to support services up to the ISDN primary rate or equivalent bit rates
ITU-T G.983.x	Broadband optical access systems based on Passive optical networks (PON)
ITU-T G.984.x	Gigabit-capable passive optical networks (GPON)
ITU-T G.985	100 Mbit/s point-to-point Ethernet-based optical access system
ITU-T G.986	1 Gbit/s point-to-point Ethernet-based optical access system
ITU-T G.987.x	10-Gigabit-capable passive optical network (XG-PON) systems
ITU-T G.988	ONU management and control interface specification (OMCI)

Home networking

As the performance of the broadband wireline network to the home has increased, so has the need for performance of the network within the home. Within the home individual equipment capability has improved enormously: large screen high definition televisions (HDTV); multiple personal computers (PCs), each with more computing power than industrial models a generation ago; personal entertainment devices that have shrunk large game consoles to the size of a matchbox. Now there is great opportunity to network them all. Plus, futurists forecast networking common appliances (refrigerators, thermostats), security systems, energy usage and exotic applications like opening and closing blinds and curtains in the morning and evening.

However several challenges confront this utopian vision of the fully networked home. Unless home networks can use existing physical plant (e.g., the home's electrical, telephone or coaxial cable network), constructing a wireline home network will be expensive in any home, and prohibitive on a societal basis. Also, the digital competency of the general public is different than that of trained telephone company installation teams. For every enthusiast installing a complex home network, there is a frustrated consumer unable to plug two cables together.

The ITU-T recently began to address this problem by drafting the ITU-T G.99xx-series of Recommendations providing transceiver standards for using common, existing home wiring as a broadband home network. Key ITU-T Recommendations serving as home network standards are summarized in Table 3.3-3.

Table 3.3-3: ITU-T Recommendations specifying home networking standards

ITU-T G.9901, ITU-T G.9902, ITU-T G.9903, ITU-T G.9904	Home networking transceivers for operation over powerlines
ITU-T G.9951, ITU-T G.9952, ITU-T G.9953	Home networking transceivers for operation over phoneline
ITU-T G.9954	Home networking transceivers for operation over phone line and coaxial cables
ITU-T G.996x	Home networking transceivers for operation over phoneline, coaxial cables and power lines
ITU-T G.9972	Coexistence mechanism for wireline home networking transceivers (phone line, coaxial cable and powerline)
ITU-T G.9970	Generic home network transport architecture
ITU-T G.9971	Requirements of transport functions in IP home networks

Recognizing the need for strong leadership and coordination during the development of standards for wireline broadband access networks and home networking, the ITU-T designated ITU-T Study Group 15 as the "Lead Study Group on Access Network Transport" (ANT). Thus ITU-T SG 15 has developed and published this Technical paper to assist all interested parties – administrations, network operators, vendors and subscribers – in the existence and use of ITU-T Recommendations specifying wireline broadband access networks and home networking standards.

Refer to **Annex III** for ITU documents that may provide useful references on wireline systems.

3.4 Wireless Broadband Access Technologies, Including IMT

"A number of BWA systems and applications, based on different standards, are available and the suitability of each depends on usage (fixed vs. nomadic/mobile), and performance and geographic requirements, among others. In countries where wired infrastructure is not well established, BWA systems can be more easily deployed to deliver services to population bases in dense urban environments as well as those in more remote areas. Some users may only require broadband Internet access for short-ranges whereas others users may require broadband access over longer distances. Moreover, these same users may require that their BWA applications be nomadic, mobile, fixed or a combination of all three. In sum, there are a number of multi-access solutions and the choice of which to implement will depend on the interplay of requirements, the use of various technologies to meet these requirements, the availability of spectrum (licensed vs. unlicensed), and the scale of network required for the delivery of BWA applications and services (local vs. metropolitan area networks)."[60]

Recommendation ITU-R M.1801 contains "Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz". These standards support a wide range of applications in urban, suburban and rural areas for both generic broadband internet data and real-time data, including applications such as voice and videoconferencing. The following standards are included in Recommendation ITU-R M.1801:

- (Annex 1) ARIB HiSWANa
- (Annex 1) ETSI BRAN HiperLAN 2
- (Annex 1) IEEE 802.11-2012 Subclause 17 (Formerly 802.11a)
- (Annex 1) IEEE 802.11-2012 Subclause 18 (Formerly 802.11b)
- (Annex 1) IEEE 802.11-2012 Subclause 19 (Formerly 802.11g)
- (Annex 1) IEEE 802.11-2012 As amended by IEEE 802.11n (Subclause 20)
- (Annex 2) IMT-2000 CDMA Direct Spread
- (Annex 2) IMT-2000 CDMA Multi-Carrier
- (Annex 2) IMT-2000 CDMA TDD
- (Annex 2) IMT-2000 FDMA/TDMA
- (Annex 2) IMT-2000 OFDMA TDD WMAN
- (Annex 2) IMT-2000 TDMA Single-Carrier
- (Annex 3) LTE-Advanced
- (Annex 4) IEEE 802.16 WirelessMAN/ETSI HiperMAN
- (Annex 5) ATIS-0700004.2005 high capacity-spatial division multiple access (HC-SDMA)
- (Annex 6) eXtended Global Platform : XGP
- (Annex 7) IEEE 802.20
- (Annex 8) YD/T 1956-2009 Air interface of SCDMA broadband wireless access system standard.

Recommendations ITU-R M.1457 and ITU-R M.2012 provide, respectively, the detailed specifications of the terrestrial radio interfaces of International Mobile Telcommunications-2000 (IMT-2000) and International Mobile Telecommunications-Advanced (IMT-Advanced). These recommendations provide specific information regarding the air interfaces that are used in all modern commercial mobile telephony

[60] LMH-BWA

and mobile broadband networks. Recommendation ITU-R M.1457 contains overviews and detailed specifications of each of the IMT-2000 radio interfaces:

– (Section 5.1) IMT-2000 CDMA Direct Spread
– (Section 5.2) IMT-2000 CDMA Multi-Carrier
– (Section 5.3) IMT-2000 CDMA TDD
– (Section 5.4) IMT-2000 TDMA Single-Carrier
– (Section 5.5) IMT-2000 FDMA/TDMA
– (Section 5.6) IMT-2000 OFDMA TDD WMAN

Recommendation ITU-R M.2012 contains “Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced”. The Recommendation includes both overviews and detailed specifications of the two IMT-Advanced radio interfaces:

– (Annex 1) Specification of the LTE-Advanced radio interface technology
– (Annex 2) Specification of the WirelessMAN-Advanced radio interface technology

Recommendation ITU-R M.1450 contains “Characteristics of broadband radio local area networks” and includes technical parameters, and information on RLAN standards and operational characteristics. Basic characteristics of broadband RLANs and general guidance for their system design are also addressed in Recommendation ITU-R M.1450.The Recommendation contains each broadband RLAN standard and information in the annexes can be used for general information on RLANs, including characteristics. Information is also provided on how to obtain complete standards described in the Recommendation.

The following standards are included in Recommendation ITU-R M.1450:

– IEEE Std 802.11-2012 Clause 17, commonly known as 802.11b
– IEEE Std 802.11-2012 Clause 18, commonly known as 802.11a
– IEEE Std 802.11-2012 Clause 19, commonly known as 802.11i
– IEEE Std 802.11-2012 Clause 20, commonly known as 802.11n
– IEEE 802.11ac
– IEEE Std 802.11ad-2012
– ESTI BRAN HIPERLAN2
– ARIB HiSWANa

The annexes in Recommendation ITU-R M.1450 contain the following information:

– Annex 1 – Obtaining additional information on RLAN standards
– Annex 2 – Basic characteristics of broadband RLANs and general guidance for deployment
    - Mobility
    - Operational environment and considerations of interface
    - System architecture including fixed applications
    - Interface mitigation techniques under frequency sharing environments
    - General characteristics

3.5 Satellite Broadband Access Technologies and Solutions

3.5.1 Overview

Broadband access is an important indicator for economic development. Increasingly, governments have developed goals and strategies to ensure access to all citizens, but have been challenged to meet objectives in rural and remote areas. Many countries' broadband goals may not be achieved without a mix of broadband technologies, including cable, fiber, wireless – and satellite. Terrestrial infrastructure is often concentrated in urban centers, with limited coverage for rural and remote areas, preventing segments of the population from benefiting from the information society. Ongoing advancements in satellite networks, ground equipment and applications have made satellite technologies an increasingly cost effective solution – and a critical component of telecommunications and broadband access strategies and national broadband plans, particularly to ensure coverage in remote and rural areas.

Satellite-based Internet and broadband services provide an opportunity to extend connectivity to even the most remote areas where terrestrial-based (wired or wireless) services are unavailable or expensive to deploy. With increased demand and the development of rural or universal access broadband strategies, there has been an increase in demand for satellite-based solutions for rural and remote areas, including through government-led projects or public-private partnerships which aim to increase access. This section provides an overview of some of the available and emerging satellite based broadband access solutions – many of which are currently deployed in developing country markets.

Some satellite based access technologies are aimed primarily at provision of broadband to a fixed location, others provide broadband to mobile terminals, which may be used on the move, or from a temporary fixed location.

3.5.2 Satellite Broadband Capabilities and Characteristics

Satellite services are increasingly being implemented as an internet and broadband access solution in both developed and developing country markets. Satellite-based services offer many advantages, particularly for remote and rural areas where terrestrial infrastructure is limited, such as:

– ubiquitous coverage to all corners of the globe;

– cost-effective and easy-to-install solutions, even for remote and rural areas;

– no significant ground infrastructure investment required;

– sustains large end-user populations;

– capable of large network deployments;

– fixed and mobile applications; and

– reliable and redundant services in the case of a disaster or emergency situation.

Ready to Deploy – Globally

Given their unique regional and global coverage capabilities, satellites are able to deliver immediate internet and broadband connectivity even to remote areas using existing satellite resources. This gives the flexibility and capacity to extend the service footprint based on market demand, instantly and easily covering rural areas. Importantly, particularly for developing regions, end-user and community connectivity is possible without huge capital investments or extensive build-out programs. Once a satellite system is operational, connectivity can be further extended to user locations with easy-to-deploy and install ground terminals. As users increase, economies of scale enable cheaper equipment, making satellite an even more competitive solution since build out is not sensitive to distance or location as with fiber.

Moreover, high-density, small-dish services, which can be enabled by higher PFD levels, offer the opportunity for even more cost-effective connectivity. As next generation satellite networks are launched, capacity is increasing and higher speed, lower latency options make satellite even more attractive as a solution.

3.5.3 Satellite Constellation Characteristics

Satellite system can be in either a geostationary orbit (GSO) or non-geostationary orbit (NGSO), each with its particular characteristics.

3.5.3.1 GSO

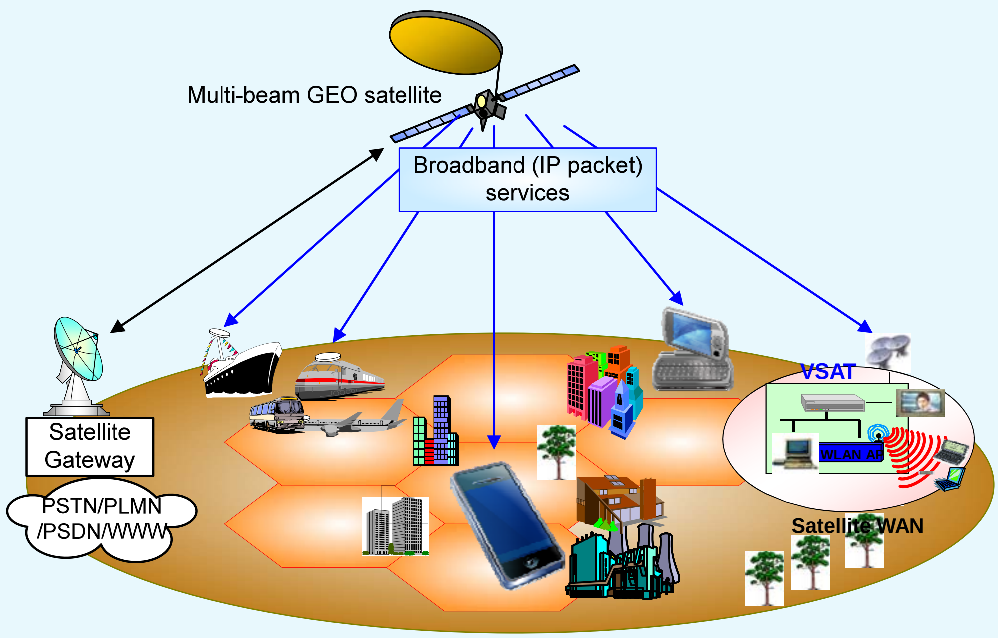
A geostationary orbit (GSO) satellite communication system can provide broadband services to fixed or mobile user terminals. With the use of large satellite antenna(s), broadband services can be provided to small user terminals taking advantage of the large satellite antenna gain. A GEO satellite system with multi-beam antennas has a larger capacity than a system with a single global beam over the same service area. [61]

S.1 illustrates a multi-beam satellite system providing broadband (IP packet) services. Services for mobile users are linked to a terrestrial core network through a fixed earth station (FES) and satellite. The FES is a gateway that links user services to the terrestrial network. When the satellite has on-board processing (OBP) capability, it can perform adaptive resource allocation. [62]

[61] S. Egami, “A Power-Sharing Multiple-beam Mobile Satellite in Ka Band”, IEEE Journal on Selected Areas in Communications, Vol. 17, No. 2, p. 145-152, February 1999.

[62] K. Lim, S. Kim, and H.-J. Lee, “Adaptive Radio Resource Allocation for a Mobile Packet Service in Multibeam Satellite Systems”, ETRI Journal, Vol. 27, No. 1, p. 43-52, February 2005.

Figure 3.5.3.1-1: Multi-beam satellite system providing broadband (IP packet) services



State of the art

Broadband satellite could be a viable way to achieve broadband penetration for those in communities that are underserved and where it would be prohibitively expensive to build terrestrial infrastructure. [63] Currently, most satellite Internet services are provided at data rates that are lower than the minimum data rates set forth in various national regulations. [64] However, there are many advanced technologies that could be applied in the provision of satellite Internet services and qualify them as broadband services. To access government subsidies for the provision of Internet broadband services, satellite companies will have to meet the minimum data rates as defined in each national strategy.

High-throughput satellites (HTS) are being developed by several companies worldwide that could meet the minimum data rates defined for broadband. For example, in the US, developers of HTS are expected to provide download data rates to the user of 2-10 Mbit/s and 5-25 Mbit/s, respectively. [65] However, these HTS will operate in GEO and, as a result, are more susceptible to latency than low earth orbit (LEO) and medium earth orbit (MEO) satellites. Too much latency could hinder the use of interactive real-time applications. However, the latency issue is less relevant for applications that require best-effort network performance, such as e-mail and Internet browsing. To attempt to overcome the latency issue, one

[63] Sastri L. Kota, Kaveh Pahlavan, Pentti Leppanen, Broadband satellite communications for internet access, Kluwer Academic Publishers, Norwell, MA, October 2003.

[64] ITU, "Birth of broadband – frequently asked questions", June 2007. www.itu.int/osg/spu/publications/birthofbroadband/faq.html; FCC, "Wireline Competition Bureau presentation of the section 706 report and broadband data gathering order", March, 2008.; Industry Canada, "Broadband Canada: Connecting Rural Canadians – FAQ", October, 2009. www.ic.gc.ca/eic/site/719.nsf/eng/h_00004.html#BPQ5

[65] FCC, "Connecting America: the national broadband plan", March 2010, www.broadband.gov/download-plan/

company is currently developing a satellite broadband Internet service provided by MEO satellites. [66] This development includes the deployment of several MEO satellites – at 1/5 the distance of GEO satellites – that use flexible spot beams to provide Internet broadband services to developing nations. By reducing the distance of satellites from the earth, the latency of round-trip delay will be less.

Broadband satellite systems using Ku and Ka bands

The increasing demand for broadband services can be effectively handled by a satellite system using high frequency bands such as the Ku and Ka bands. In particular, to provide high-speed Internet and television (TV) services to maritime and air vehicles, a satellite system may be the only possible option. In this case, an active array antenna that is mounted on a moving vehicle is used to track a satellite and provide seamless connections.

For Ka-band broadband satellite systems, the volume of traffic on the forward link, which provides connections from the satellite gateway to the user terminals, is much greater than that on the return link, which provides connections from the user terminals to the satellite gateway. Recommendation ITU-R S.1709contains three air interface standards, which may be used to implement broadband satellite networks. [67]

Broadband satellite systems using L-band (1.5/1.6 GHz)

Frequency bands allocated to the MSS around 1.5/1.6 are used by NGSO and GSO MSS networks. Current services available to users range from low data rate (e.g. voice and SCADA68) to broadband rates for GSO MSS systems of around 500 kbit/s. Data rates may increase in the future. A range of terminals are available, including terminals with tracking antennas intended for use on ships and aircraft, and small handheld and portable terminals.

Some of the services currently offered use radio interfaces which are among the family of satellite component of IMT-2000, described in Recommendation ITU-R M.1850.

3.5.3.2 NGSO

Satellite systems that use non-geostationary satellite orbits (NGSO) usually have a lower orbital altitude than geostationary satellites (GSO), which operate at approximately 36,000 km altitude. One type of NGSO satellite system uses a Medium-Earth Orbit ("MEO"), which follows circular orbits around the Equator. Other NGSO satellite system operate in low-Earth orbits (LEOs), sometimes in circular but inclined orbits that provide better coverage to higher latitudes, such as the Scandinavian countries. While still other MEO systems employ elliptical orbits that are closer to the earth at one point in their orbit and farther at the opposite point.

MEO satellite design provides several major advantages:

High Availability: Fiber is not always available, especially for landlocked nations, and rural and remote areas of a country. In addition, GSO coverage may not be complete over certain countries or regions (such as the Pacific Ocean island nations).

– Affordable Cost: MEO design can create substantial savings compared to either GSO capacity or to building and maintaining thousands of kilometers of fiber infrastructure or hundreds of radio towers to interconnect cities and towns. Rural areas with several small to medium size towns will

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[66] O3b Networks, 2010, www.o3bnetworks.com/

[67] ITU-R, "Technical characteristics of air interfaces for global broadband satellite systems", Recommendation ITU-R S.1709-1, 2007.

[68] SCADA stands for supervisory control and data acquisition.

be able to obtain low latency, high rate internet connectivity with very little capital expenditures ahead of initiating service.

– High Throughput: Throughput is measured in the steady state flow of megabits per second (Mbps) and is important for downloading large files, watching video, or other bandwidth intensive utilization. Proposed NGSO systems provide scalable bandwidth and spot beams which can be steered to any location ahead of fiber, moved as demographics change, or moved as the market demands, providing added flexibility in rolling out broadband and mobile voice services nationwide.

– Low Latency: Latency is the round trip time that each packet takes between a computer and the server. Latency dictates how fast web pages load and how well collaborative online applications function. Compared to GSO satellites with approximately 500-600ms latency, the MEO altitude of e.g. 8000km enables round trip customer-gateway latencies of <150ms, very close to that experienced in a pure terrestrial fiber-based network, and critical to the provision of the real-time, interactive applications. Furthermore, because cellular backhaul today is made up primarily of voice traffic, such a MEO system low latency enables high quality voice and is a very good solution for backhaul. If digital infrastructure is to be a true economic engine in the future, network operators must consider low latency, in addition to high throughput, as a key driver in successful broadband network implementation.

– Strong Public Benefits: As telecom and mobile operators consider how to build out their networks to reach their service obligations in the rural and remote parts of their countries, governments are also evaluating their role in accelerating deployment of broadband technology to their most needy populations. MEO satellite's beam flexibility provides governments with an important tool in the fulfillment of their national broadband plans on the ambitious schedules many have announced. In addition, MEO satellite capacity can serve as an easily deployable high-speed communications backbone for disaster recovery efforts, and can provide critical redundancy to long haul fiber cables (either within a country or for submarine cables serving a country).

A connected world enables new levels of understanding, sharing of ideas and has a pronounced impact on economic growth, knowledge development, and efficient government. This connected world however requires modern and resilient communications infrastructure.

Middle range transmission media

MEO ("medium Earth orbit") satellite systems are ideally suited to providing "middle mile" trunking and backhaul capacity for national telecom operators, mobile operators, ISPs, large enterprises and government agencies. Because a MEO satellite system is much closer to the Earth than a geostationary satellite, there is a far lower latency in the signals, which is essential for many types of today's IP-based and broadband services.

With low latency combined with wide bandwidth and high throughput, a MEO satellite system can be the much-needed middle mile in remote and rural areas where traditional terrestrial and geostationary satellite technologies have not or cannot provide the necessary broadband capacity.

3.5.4 System and Deployment Options and Considerations

Within the past few years, satellites have been instrumental in bringing broadband services to users located in areas where terrestrial infrastructure such as xDSL or cable cannot reach, and offering a layer of redundancy for terrestrial links in the case of a disaster or other outage.

3.5.4.1 VSAT

Countries throughout the developing world are experiencing tremendous growth in VSAT deployments, as e-governance initiatives, corporate networks and rural demand for broadband, television and mobile phone and mobile broadband services also increase. Corporate or organizational VSAT networks have become increasingly vital, as companies and their metropolitan and rural workforces depend on reliable and scalable connectivity for everything from email, Internet and Intranet access. Such networks are also critical in providing redundancy or back up connectivity for critical networks in the case of a disaster or other outage.

Moreover, direct-to-Home satellite broadband is a growing service option for developing countries. Service providers seeking alternative solutions for internet access in rural and remote locations have found satellite broadband to be a compelling solution – and one that is proven and easy to deploy.

3.5.4.2 Community Access Points

The combination of VSAT and Wireless is an effective solution for many rural applications. Rural populations are often clustered in or around villages with most of the populations within a range of 1 to 5 km. A single VSAT can provide service to an entire village using a wireless local loop solution for the last mile connection. Wireless has the added advantage of spanning rivers or other obstacles and provides a more reliable connection when cable theft is a problem.

One possible solution involves an integrated system of a VSAT, a wireless local loop base station and a solar power system all mounted on a 10 meter post. Such a solution is easy to install, helps overcome obstructions from buildings, addresses power source concerns and is very secure.

The combination of a satellite VSAT connection to the Internet plus WiFi for local access by multiple users can provide the lower per-subscriber costs that the market requires, particularly in rural and remote areas. The satellite connection brings the Internet stream to the village, and WiFi access points extend that connectivity to homes, schools, and public buildings. Users can share both equipment and connection costs through subscription or other joint payment plans.

The keys factors to reducing costs are:

– Use low cost equipment – Off the shelf, open standard equipment (DSL/WiFi/Cable modem) leverages mass production. Integrating satellite equipment that is based on widely-accepted global standards dramatically reduces equipment cost.

– Maximize Subscribers per Gateway – A larger pool of subscribers reduces the equipment cost per subscriber. A larger subscriber base is also more efficient in sharing a single connection. The key issue is to extend the range of standard WiFi equipment to allow a single VSAT to service an entire village.

Such solutions integrate interactive satellite broadband service with the existing last mile infrastructure, such as copper line, TV cable or wireless network. A single central satellite antenna is installed at an aggregation point – i.e. street cabinet in the community, cable TV head-end, or WiFi mast. The broadband connection to the end users is then supplied via the existing last mile infrastructure or the WiFi access, providing all households with internet access at a speed of up to 8 Mbit/s. End users do not have to install a satellite antenna at home, but pay only for a DSL connection and a standard broadband equipment.

3.5.4.3 Spectrum Considerations

Frequency bands used can impact the size of the dish required and its capabilities:

– L-band (1.5/1.6 GHz) is used by NGSO and GSO MSS systems. For GSO MSS systems large antennas (e.g. 10-20 m diameter) are used on the satellite platform to provide large number of small spot beams on the Earth surface. This allows use of small mobile terminals (e.g. laptop sized) to provide broadband connectivity. Due to the limited spectrum available in this range, data rates are limited (currently around 500 kbit/s). L-band frequencies are virtually unaffected by propagation impairments. Applications include internet access for remote workers such as those in mining, relief agency workers and journalists.

– C-band (4/6 GHz) transmissions require larger dishes because of the longer wavelength of transmissions in this frequency range. Transmissions in the C-band are less affected by rain fade and other weather conditions compared to higher frequencies because of the highly favorable propagation characteristics of this spectrum. Applications include GSM backhaul, public switched networks, corporate networks, and Internet trunking.

– Ku-band (11-12/14 GHz) has a shorter wavelength allowing for smaller dishes than C-band. However, the higher frequencies make Ku-band more susceptible to atmospheric conditions like rain fade. Applications include VSAT, rural telephony and broadband, satellite news gathering, backhaul links, videoconferencing and multi-media.

– Ka-band (20/30 GHz) has even shorter wavelengths than Ku-band, allowing for even smaller dish size; however transmissions are also even more susceptible to poor weather conditions. High-bandwidth interactive services are possible including high-speed Internet, videoconferencing, and multi-media applications.

Services provided via C-band have been an essential element of the global telecommunications infrastructure. C-band fixed satellite services offer higher reliability and availability than Ku and Ka band networks under rain-fade conditions, and permit broad regional coverage using global beams. For these reasons C-band is generally the frequency band of choice for connecting remote areas of developing countries with wide territories and/or suffering frequent adverse weather conditions.

3.5.4.4 Mitigating Interference

Countries considering deployment of satellite communications in support of a broader broadband deployment strategy should take steps to ensure that satellite and terrestrial networks are able to operate in an interference-free environment. The ITU-R has studied the impact of sharing between satellite and terrestrial networks regarding IMT deployment and offers guidance on effective deployments.

For example, to provide secure satellite backhaul for IMT networks in countries most susceptible to rain fade (tropic areas around the equator) or support satellite broadband deployments, spectrum below 4200 MHz allocated for Fixed Satellite Service (FSS) should be protected from harmful interference from other services. Relevant ITU reports include:

– Report ITU-R S.2199 “Studies on compatibility of broadband wireless access (BWA) systems and fixed-satellite service (FSS) networks in the 3 400-4 200 MHz band”

– ITU-R Report M.2109 – sharing studies between IMT Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 and 4 500-4 800 MHz frequency bands

Such considerations are particularly essential for those satellite broadband networks supporting critical services such as e-government or emergency communications applications.

Refer to Annex III for a list of ITU-R Recommendations that may provide a useful reference for satellite systems.

3.6 Backhaul for Broadband Access [69]

One of the key components of any data service is the backhaul, routing traffic from cells sites into the core network.

Backhaul can be done via wired or wireless solutions. The following sections include overviews of backhaul solutions via terrestrial wireless, satellite backhaul, and fiber, including submarine cable.

3.6.1 Terrestrial Wireless Backhaul

A number of technologies can be used to connect cell sites to the core network, in particular:

[69] Section 4.5 is extracted from “Mobile Backhaul – The Wireless Solution”, a White Paper by Transfinite Systems Ltd., available at: www.transfinite.com/papers/backhaul.pdf, with minor editorial changes.

– Point to point (PtP): this is what traditionally has been used, with narrow pencil like beams connecting two points, one of which is the cell site

– Point to multi-point (PtMP): in this approach at one end a broader beam is used so that it covers a relatively wide area within which there could be several cell sites

– Multi-point to multi-point or mesh: here cells sites communicate to potentially multiple other cell sites with traffic routed between them

Wireless backhaul can operate in frequency division duplex (FDD) mode with a pair of frequencies, one for each direction, or time division duplex (TDD) mode, sharing capacity between uplink / downlink directions.

The most effective technological solution will depend upon the backhaul requirements, which will include:

– The number of sites to connect

– Their location and accessibility

– Existing communication facilities at each site

– Traffic profiles (mean, peak, burstyness etc)

– Scalability over deployment lifetime

– Reliability and resilience

Furthermore there will of course be budgetary constraints and comparative equipment costs.

The solution is likely to evolve as requirements and technology changes and could include a combination of PtP, PtMP and mesh technologies.

A number of tasks will have to be undertaken:

– Selection of suitable architectures and topologies

– Selection of frequency bands

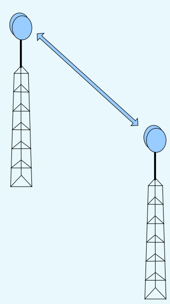
– Access to suitable spectrum

– Frequency planning and interference analysis

3.6.1.1 Selecting the Architecture

Each of the wireless backhaul types has strengths and weaknesses.

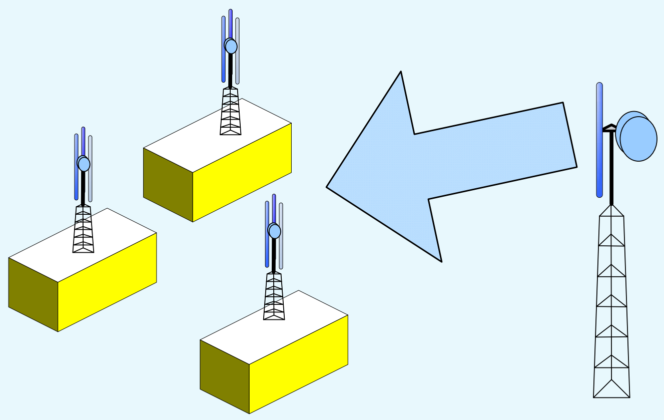
Figure 3.6.1.1-1: PtP Links



These use highly directional antenna to provide capacity between two fixed locations. They are very spectrally efficient and can provide very high data rates (up to a Gbps) and QoS (such as 99.999% availability).

Equipment is readily available from multiple manufacturers providing a range of features to improve link stability and performance (e.g. low noise, higher modulations, adaptive modulation, and adaptive power control). Spectrum is also readily available in a number of frequency bands and links can be deployed quickly with low CAPEX. A disadvantage is that every cell site will require at least one antenna and there can be difficulties in installing PtP equipment on pico-cells and those using street-furniture such as lamp-posts. To get to the core network it might be necessary to daisy chain links together, in particular as in urban areas there is less likely to be line of sight between sites.

Figure 3.6.1.1-2: PtMP Links



One problem with PtP links is that every time a new cell site is installed it needs a dedicated antenna at some other site to connect with. In addition the capacity of the link is sized by the need to service the cell's peak data rate which will result in unused capacity for most of the time.

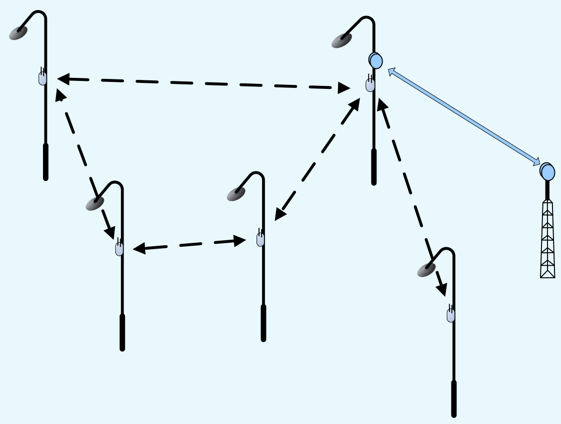
A PtMP system gets round this by having a sectorial antenna at a central point that can cover a wide area within which there could be many cell sites. As more cells are introduced there is no need to modify the hub station as the existing antenna can be re-used. Furthermore capacity is shared between all sites so that the bandwidth required can be sized by the peak demand over all cells, which for bursty traffic such as web browsing is significantly less than the aggregate of the peak demand of each cell.

One problem with PtMP systems is that the central station's antenna's wide beam is less spectrum-efficient than using multiple highly directional antennas. Some radio planning tools can have problems managing both PtP and PtMP operating co-frequency. For this reason not all regulators make available spectrum licence product that permit site by site licensing, which therefore requires purchase of a spectrum block in an auction.

When cells get very small it becomes important to have compact equipment boxes – for example those attached to street furniture such as street lights. These might have little space for a directional antenna and can have difficulties maintaining the tight pointing accuracy required for parabolic dish antennas and often in urban areas having line of sight to the central station.

For these scenarios some organisations have considered looking at mesh style backhaul.

Figure 3.6.1.1-3: Mesh Networks



Where there are many small cells located below roof tops, for example on street lights, it can be difficult to get the line of sight needed for backhaul links.

Also as there are so many sites to deploy it becomes important to keep the cost of installation as low as possible. One solution is for each site to talk to another as nodes in a mesh, preferably auto-configuring the radio component. Traffic aggregates through the mesh until reaching an access node which could be fibre or a point to point link. Each site operates as a node within a network, routing traffic from other sites in a way that brings resilience and also permits new sites to be introduced automatically.

One problem with mesh networks is that the traffic builds up and the links nearest the access node can become congested. Furthermore there can be difficulties in some planning tools in introducing low gain mesh networks into the spectrum planning. For this reason again some regulators restrict the use of this sort of technology to the lightly licensed bands. These bands can become congested which leads to reduced QoS.

3.6.1.2 Licensing Models

A wide range of frequency bands is available for use by wireless backhaul, often depending upon the architecture used.

A number of different regulatory models can be used to provide access to spectrum including:

Licence exempt: examples would be the 2.4 GHz WiFi band and the 5.1 GHz RLAN bands where equipment can be purchased and switched on without requiring a licence

Lightly licensed bands: in some countries there is a simple registration process for bands such as upper 5 GHz, 60 GHz and 70 / 80 GHz. The regulator does not undertake any compatibility or planning tasks but the list of registered systems can be used by users to self-manage the band. For example there is often an assumption that in the case of interference the priority goes to the organisation that registered the earliest.

Site licensing: this is the traditional way to provide PtP backhaul and involves the regulator or approved third party undertaking spectrum management tasks including planning and interference analysis. There are a wide range of bands available including but not limited to 1.4, 6, 7, 12, 14, 18, 23, 25, 28, 32, 36 and 42 GHz.

Block licensing: in this case the regulator makes available, usually via auction, entire blocks of spectrum which the user (e.g. operator) can manage themselves.

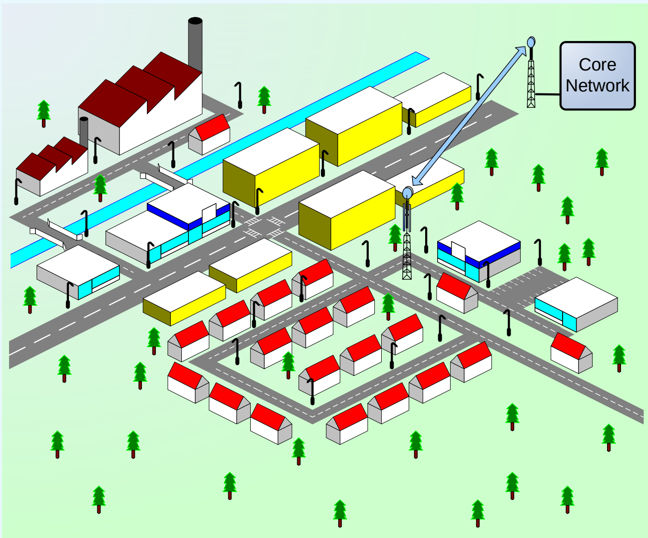
In this case there are generic constraints (frequency, geography, maximum EIRP, block edge masks etc) that must be met but apart from that there is flexibility in its usage. The frequency bands available will depend upon the national regulator but in the UK they are the 10, 28, 32 and 40 GHz bands.

3.6.1.3 Example Scenario

It can be necessary to combine all of these technologies and licensing models to provide an integrated cost effective backhaul solution.

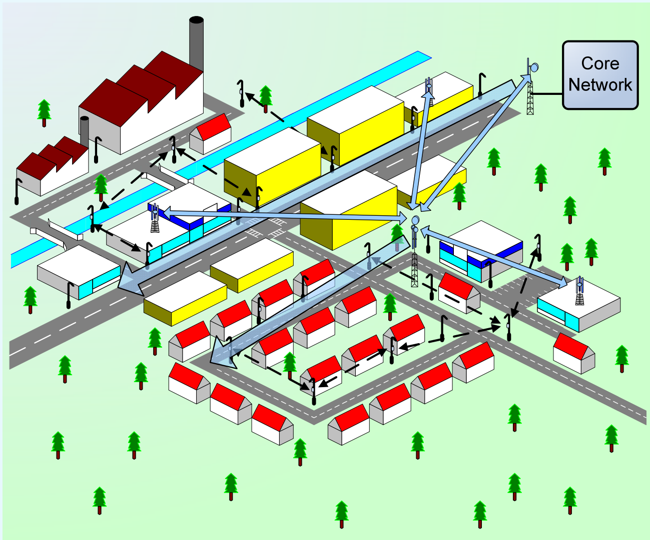
Consider the example scenario below. Initially when the network is driven by voice traffic or low data rate messaging it could be sufficient to have a single base station using a PtP link for backhaul:

Figure 3.6.1.3-1: Example Scenario 1



As traffic levels increase a more comprehensive solution is needed:

Figure 3.6.1.3-2: Example Scenario 2



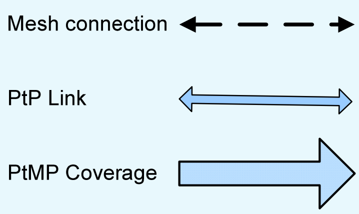
Coverage is now provided by:

– 3 base stations mounted on roof tops

– 15 pico cells attached to street lights

This example shows how a combination of PtP, PtMP and mesh links can be used to provide backhaul, as identified in the figure using the key below:

Figure 3.6.1.3-3: Key to Example Scenarios



Refer to Annex III for a list of ITU-R Recommendations that may provide a useful reference for wireless backhaul.

3.6.2 Satellite Backhaul Solutions

Satellite-based GSM backhaul has played an increasingly important role in extending the reach and coverage of mobile telephony and mobile broadband networks throughout the globe, particularly in developing markets. Advancements in technologies have led to more cost-effective and robust satellite solutions, making them an integral component of mobile network deployment, particularly in rural and remote areas. As governments seek to ensure mobile connectivity for all citizens, satellite backhaul will continue to play a role in providing connectivity to regions where terrestrial-based technologies alone are not an economically viable solution.

Satellite communication forms a key element in the design of cellular infrastructure by providing affordable, reliable broadband backhaul links to the core network. Mobile switching centres and base-station controllers can be connected via satellite, overcoming any barriers of distance, terrain or terrestrial infrastructure and expanding network coverage.

Fixed satellite services can:

– Provide backhaul to support coverage in areas unreachable by terrestrial connections

– Expand network reach quickly with affordable mobile backhaul

– Scale networks as business grows or to provide for temporary hot spots such as concerts, exhibitions or sporting events;

– Diversify networks, including offering redundancy in the case of a disaster

– Moving vehicles or isolated environments without any other means to connect services, such as ships and aircraft or oil and gas platforms.

Benefits of Satellite Backhaul

Using satellite backhaul to extend broadband services offers benefits in terms of coverage, cost, security and redundancy. Geostationary Earth Orbit (GEO) satellites can provide backhaul services for a large region with only a minimum expenditure on infrastructure. Satellite backhaul solutions enable operators to position base stations where they would provide the most benefit to citizens, with little reference to the location of terrestrial infrastructure. Because fiber build out costs are highly sensitive to distance from the core network and location, the lowest cost solution for backhaul supporting base stations located in rural or remote areas may be satellite.

The use of satellite backhaul also provides redundancy of connectivity. Damage to the fiber backbone network could lead to terrestrial base stations being cut off from key networks, while the extra diversity that satellite backhaul provides will ensure that connectivity remains un-interrupted, even if there is serious damage to terrestrial infrastructure.

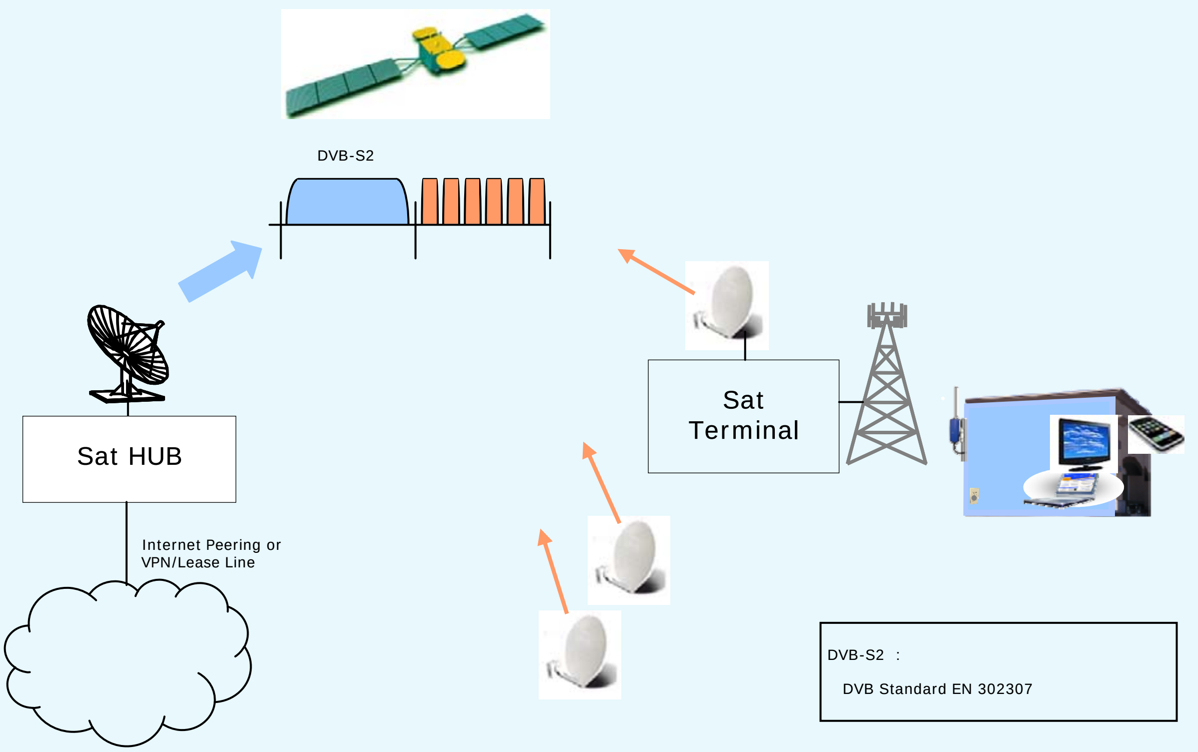
As countries increasingly seek to deploy LTE networks, satellite systems have already been demonstrated through high-throughput satellite backhaul to support these higher bandwidth transmissions.

Medium-Earth Orbit (“MEO”) Satellite Backhaul

Because a MEO satellite system is much closer to the Earth than a geostationary satellite system (as much as 4 times closer), there is far lower latency in the signals. This is desirable for cellular backhaul and many types of today’s IP-based and broadband services. MEO satellites are smaller than geostationary satellites, and therefore less expensive to build and launch. MEO satellites have dynamic, steerable, spot beams that can easily target remote or isolated areas for backhaul, and be moved to other areas as needed.

Example of Satellite Backhauling Network

Figure 3.6.2-1: Example of Satellite Backhauling Network Scenario



As mobile penetration rates in populated areas become more dense, mobile operators in developing markets are increasingly using satellite-delivered GSM backhaul to expand their reach further and further into rural markets. Satellite is the only economically viable way to bring capacity to connect the un- and under-connected. With the recent auctions of IMT licenses, and the roll-out of high through-put data services across the networks, backhaul demand is likely to see exponential growth.

3.6.3 Fiber Backhaul

See Section 3.3 above as well as the references in Annex III.

3.6.4 Submarine Cable Backhaul

Submarine cables provide vital international telecommunication links between countries across the world. Submarine cables terminate in the country through cable landing stations.

Regulations on non-discriminatory access to cable landing station

Salient points that one administration has included in their Regulations in order to insure equitable access are as below:

1. The owner of cable landing station (OCLS) shall provide access to any eligible International Telecommunication Entity, on fair and non-discriminatory terms and conditions, at its cable landing stations.
2. OCLS shall submit a 'Cable landing Station Reference Interconnect Offer (CLS RIO)' to Regulator, in a specified format, containing the terms and conditions of Access Facilities and Co-location facilities including landing facilities for sub-marine cables at its cable landing stations for its approval.
3. On getting approval from Regulator, OCLSs shall publish the CLS-RIO on their web-sites.
4. Access Facilitation Charges (AFC) are the charges, which are payable by International Long Distance Operators (ILDO)/ Internet Service Providers (ISP) to the owner of the cable landing station to access the acquired international bandwidth in a submarine cable. To further insure stability in the relationship between the OCLS and the ILDO/ISP, regulators can provide estimated Access Facilitation Charges and specified Access Facilitation Charges for Submarine Cable Landing Stations.

I Annexes

Annex I: Country Experiences

Annex II: Definition of Question 25/2

Annex III: Other ITU Sector Relevant Recommendations and Reports

II Acronyms/Glossary

III References

Annex I: Country Experiences

Country/Entity	Source Document	Technology	Hyperlink to documents on Case Study website
BDT	25/2/5	WiMAX/Microwave Backhaul	Case study on project in Burundi is not available in case study library
Democratic Republic of Congo/ARPTC	25/2/6	WiMAX/WiFi/VSat/GSM/CDMA/Fiber Optic Cable	Case study from D.R. Congo is not available in case study library
Rwanda/Rwanda Utilities Regulatory Agency	25/2/7	WiMAX/WCDMA	Case study from Rwanda is not available in case study library
Egypt/NTRA	25/2/40 and 2/312	A variety of access technologies	Evaluating different access technology options
Japan/KDDI	25/2/43	WiMAX	Mobile WiMAX in Japan
Qualcomm Inc. (United States) (Project in South Africa)	25/2/50	IMT	Mobile Health Information System: Providing Access to Information for Health Care Workers
Qualcomm Inc. (United States) (Project in Indonesia)	25/2/51	IMT	Mobile Microfranchising & AppLab Initiatives
Argentine Republic	25/2/52	Satellite, Terrestrial Broadcast, Fiber	Argentina Conectada (Argentina Connected)
Qualcomm Inc. (United States) (Project in Brazil)	2/339	IMT	Fishing the 3G Nets
Qualcomm Inc. (United States) (Project in P.R. China)	2/340	IMT	Let's Get Ready! Mobile Safety Project
China Telecommunications Corporation (P.R. China)	2/321		Introduction of China Telecom's fiber Cities Broadband Development Experience
Intel Corporation (United States)	2/333		Reference Broadband Implementation Plan
Microsoft Corporation (United States)	2/338		Mawingu: Providing broadband access using TV White Spaces in Kenya

Annex II: Definition of Question 25/2

Question 25/2: Access technology for broadband telecommunications including IMT, for developing countries

1 Statement of the situation

ITU-D Study Group 2 will provide developing countries with an understanding of the different technologies available for broadband access using both wired and wireless technologies for terrestrial and satellite telecommunications, including International Mobile Telecommunications (IMT). Study Group 2 will continue to cover the technical issues involved in deploying broadband access technologies, including the integration of such access network solutions in existing and future network infrastructures, provide guidelines for broadband access development, taking into account the fact that the standardization of broadband access technologies is a priority in the strategic plan of ITU, and respond to the initiatives of all developing countries (as proposed by the six WTDC regional preparatory meetings (RPMs).

2 Question for study

Identify the factors influencing the effective deployment of broadband wireline, wireless and satellite access technologies and their applications, with a focus on technologies and/or standards recognized or under study by the other two ITU Sectors.

a. Examine wired and wireless broadband access technologies and their future trends;

b. Identify methodologies for migration planning and implementation of broadband wired and wireless technologies, taking into account existing networks, as appropriate;

c. Consider trends of broadband access technologies; deployments, services offered and regulatory considerations;

d. Continue to identify ways and means of implementing IMT, using terrestrial links and satellites;

e. Identify key elements to be studied in order to facilitate the possible deployment of systems integrating satellite and the terrestrial component of IMT (see Recommendation 206 (WRC-07);

f. Provide information on the specific impact of the implementation of broadband wired and wireless means, including IMT, on underserved populations, including persons with disabilities;

g. Provide information on IMT-Advanced systems based on the advice of Working Party 5D of ITU-R Study Group 5.

3 Expected output

a. Yearly progress report on the above study items including a matrix of different broadband access technologies, both wired and wireless, terrestrial and satellite, with yearly updates;

b. Analysis of the factors influencing the effective deployment of broadband access core technologies;

c. A set of guidelines for broadband access deployment that could be delivered inter alia through training seminars in accordance with the BDT Programme 4;

d. .A handbook on IMT deployment in developing countries to replace the Handbook on Deployment of IMT-2000 systems (2003). This handbook will be the result of study group collaboration between ITU-R Study Groups 4 and 5, ITU-T Study Group 13 and the Rapporteur's Group dealing with this Question as part of ITU-D Study Group 2;

e. Draft Recommendation(s), as appropriate and if justified.

4 Timing

The interim report on this Question is expected by 2012. The final report is expected in 2013 at the end of the ITU-D study period.

5 Proposers

Arab States, United States.

6 Sources of input

1) Results of related technical progress in relevant ITU-R and ITU-T Study Groups, in particular Working Parties 5D (Question 77) and 5A of Study Group 5 and Working Parties 4A, 4B and 4C of Study Group 4, and in ITU-T in particular Study Group 15 (Question 1) and Study Group 13 (Question 15).

2) ITU publications on both broadband and IMT.

3) Relevant reports of national and/or regional organizations in developing and developed countries.

4) Contributions on experiences with the implementation of relevant networks in developed and developing countries.

4*bis*) Contributions of Sector Members on the development of broadband access technologies for wired, wireless and satellite.

1) Relevant inputs from service providers and manufacturers.

7 Target audience

a. Target audience

Target audience	Developed countries	Developing countries ([1])
Telecom policy-makers	Yes	Yes
Telecom regulators	Yes	Yes
Service providers/operators	Yes	Yes
Manufacturers	Yes	Yes
[1] This includes least developed countries (LDCs), small island developing states (SIDSs), landlocked developing countries (LLDCs), and countries with economies in transition.		

b. Proposed methods for implementation of the results

The work of the Rapporteur's Group will be conducted and publicized through the ITU-D website as well as through the publication of documents and appropriate liaison statements.

8 Proposed methods for handling the Question

The Question will be handled by a Rapporteur's Group of ITU-D Study Group 2.

9 Coordination

In order to coordinate effectively and avoid duplication of activities, the study should take into consideration:

– outputs from the relevant ITU-T and ITU-R Study Groups;

– the relevant outputs from ITU-D Questions;

– inputs from the relevant BDT programme(s);

– inputs from those involved in the implementation of the study of IMT systems.

10 Relevant programme

Programme 1 will be the relevant programme.

11 Other relevant information

Resolution 43 as revised by WTDC-10 should be taken into consideration.

Annex III: Other ITU Sector Relevant Recommendations and Reports

Wireline Broadband Access Technologies

– "Access Network Transport Standards Overview", is produced by ITU-T WP1/15, under Question 1/15, as the Lead Study Group on Access Network Transport (ANT) activities. The Standards Overview contains ANT scenarios, and Annex 2 of the Overview contains a detailed list of Standards and Recommendations from ITU and various Standardization Bodies.

– "Wireline broadband access networks and home networking" is produced by ITU-T SG15. It is an ITU-T Technical Paper in Series G: Transmission Systems and Media Digital Systems and Networks. It was published in December 2011.

Wireless Broadband Access Technologies[, including IMT]

– Recommendation ITU-R M.687, "International Mobile Telecommunications-2000 (IMT-2000)"

– Recommendation ITU-R M.819, "International Mobile Telecommunications-2000 (IMT-2000) for developing countries"

– Recommendation ITU-R M.1036, "Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations (RR)(03/2012)"

– Recommendation ITU-R M.1224, "Vocabulary of terms for International Mobile Telecommunications (IMT)"

– Recommendation ITU-R M.1450, "Characteristics of broadband radio local area networks"

– Recommendation ITU-R M.1457, "Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)"

– Recommendation ITU-R M.1579, "Global circulation of IMT-2000 terrestrial terminals"

– Recommendation ITU-R M.1580, "Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT 2000"

– Recommendation ITU-R M.1581,"Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT 2000"

– Recommendation ITU-R M.1645, "Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000"

– Recommendation ITU-R M.1768, "Methodology for calculation of spectrum requirements for the future development of IMT-2000 and systems beyond IMT-2000"

– Recommendation ITU-R M.1801, "Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz"

– Recommendation ITU-R M.1822, "Framework for services supported by IMT"

– Recommendation ITU-R M.1850, "Detailed specifications of the radio interfaces for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)"

– Recommendation ITU-R M.2012, "Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)"

– Report ITU-R M.2038: Technology trends (as they relate to IMT-2000 and systems beyond IMT-2000)"

– Report ITU-R M.2039, "Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses"Report ITU-R M.2072, "World mobile telecommunication market forecast"

– Report ITU-R M.2078, "Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced"

– Report ITU-R M.2079, "Technical and operational information for identifying spectrum for the terrestrial component of future development of IMT-2000 and IMT-Advanced"

– Report ITU-R M.2242, "Cognitive radio systems specific for IMT systems"

– Report ITU-R M.2243, "Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications"

Satellite Broadband Access Technologies and Solutions

Tables S.2 and S.3 below list the ITU-R Recommendations and Reports related to broadband satellite systems and technologies.

Table S.2
List of ITU-R Recommendations and Reports related to satellite broadband systems and technologies

ITU-R No.	Title
Rec. S.1709-1	Technical characteristics of air interfaces for global broadband satellite systems
Rec. S.1782	Possibilities for global broadband Internet access by fixed-satellite service systems
Rec. S.1783	Technical and operational features characterizing high-density applications in the fixed-satellite service
Rec. S.1806	Availability objectives for hypothetical reference digital paths in the fixed-satellite service operating below 15 GHz
Rec. BO.1724-1	Interactive satellite broadcasting systems (television, sound and data)
Rec. S.1001-2	Use of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations.
Rep. S.2151	Use and examples of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations
Rec. M.1854-1	Use of mobile-satellite service in disaster response and relief
Rep. M.2149	Use and examples of mobile-satellite service systems for relief operation in the event of natural disasters and similar emergencies
Rec. SNG.1710	Satellite news gathering carriers universal access procedures

Table S.3
List of ITU-R Recommendations and Reports related to performance enhancement techniques to provide satellite broadband access services

ITU-R No.	Title
Rec. S.1061-1	Utilization of fade countermeasure strategies and techniques in the fixed-satellite service
Rec. S.1711-1	Performance enhancements of transmission control protocol over satellite networks
Rep. S.2148	Transmission control protocol (TCP) over satellite networks
Rec. S.1878	Multi-carrier based transmission techniques for satellite systems
Rep. S.2173	Multi-carrier based transmission techniques for satellite systems
Rec. S.1897	Cross-layer QoS provisioning in IP-based hybrid satellite-terrestrial networks
Rep. S. 2222	Cross-layer QoS for IP-based hybrid satellite-terrestrial networks

Terrestrial Wireless Backhaul

General technical information:

– Rec. ITU-R F.1101, Characteristics of digital fixed wireless systems below about 17 GHz

– Rec. ITU-R F.1102, *Characteristics of fixed wireless systems operating in frequency bands above about 17 GHz*

More detailed information relevant to fixed backhaul systems:

– Rec. ITU-R F.746, Radio-frequency arrangements for fixed service systems

– Rec. ITU-R F.752, Diversity techniques for point-to-point fixed wireless systems

– Rec. ITU-R F.755, Point-to-multipoint systems in the fixed service

– Rec. ITU-R F.1093, Effects of multipath propagation on the design and operation of line-of-sight digital fixed wireless systems

– Rec. ITU-R F.1668, Error performance objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections

– Rec. ITU-R F.1703, Availability objectives for real digital fixed wireless links used in 27 500 km *hypothetical reference paths and connections.*

II Acronyms/Glossary

ADSL	Asymmetric Digital Subscriber Line
ADSL2	Advanced version of ADSL
ADSL2+	Advanced version of ADSL
ANT	Access Network Transport
ARPU	Average Revenue Per User
ATM	Asynchronous Transfer Mode
BWA	Broadband Wireless Access
CAPEX	Capital Expenditure
CATV	Community Antenna Television
CDMA	Code Division Multiple Access
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital Subscriber Line
DVB	Digital Video Broadcasting
EIRP	Equivalent Isotropic Radiated Power
EPON	Ethernet Passive Optical Network
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
FTTC	Fibre to the Curb
FTTB	Fibre to the Building
FTTC	Fibre to the Curb
FTTH	Fibre to the Home
FTTN	Fibre to the Node
FTTx	Fiber to the X, i.e. any of the above
FWA	Fixed Wireless Access
GDP	Gross Domestic Product
GEO	Geostationary Earth Orbit
GPON	Gigabit-capable passive optical networks
GSO	Geostationary Orbit Satellite
HDSL	High-bit Rate Digital Subscriber Line
HDTV	High Definition Television
IEEE	Institute of Electrical and Electronics Engineers
ICT	Information and Communication Technologies
IMT	IMT-2000 and IMT-Advanced
IMT-2000	International Mobile Telecommunications (Recommendation ITU-R M.1457)
IMT-Advanced	International Mobile Telecommunications-Advanced (Recommendation ITU-R M.2012)

ISP	Internet Service Provider
IP	Internet Protocol
ISDN	Integrated Services Digital Network
iTV	Interactive Television
LAN	Local Area Network
LEO	Low Earth Orbit
LMH-BWA	Land Mobile (including Wireless Access) – Volume 5: Deployment of Broadband Wireless Access Systems
LTE	Long Term Evolution
MEOs	Medium Earth Orbit Satellites
NGSO	Non-Geostationary Orbit
OFDMA	Orthogonal Frequency Division Multiplexing Access
OMCI	ONU management and control interface specification
ONU	Optical Network Unit
OPEX	Operating Expenditures
PtMP	Point-to-Multipoint
PtP	Point-to-Point
PC	Personal Computer
PDAs	Personal Digital Assistants
PON	Passive Optical Network
PPPs	Public-Private Partnerships
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RF	Radio Frequency
RLAN	Radio Local Area Network
RT	Remote Terminal
SHDSL	Symmetric High Speed DSL
TDD	Time Division Duplex
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
USF	Universal Service Fund
VoIP	Voice-over-Internet Protocol
VDSL	Very High-Speed DSL
VDSL2	Advanced version of VDSL

VSAT	Very Small Aperture Terminal
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access
WCS	Wireless Communication Services
WDM	Wavelength Division Multiplex
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WMAN	Wireless Metropolitan Access Network
XG-PON	10-Gigabit-capable passive optical networks

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4. "A 2010 Leadership Imperative: The Future Built on Broadband", Broadband Commission, 2010

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7. Rev.1 of Supplement 1 to Handbook on Migration to IMT-2000 Systems (Document 25/2/2)

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