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BACKGROUND PAPER

BUILDING DIGITAL BRIDGES WITH EMERGING TECHNOLOGIES

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This background paper has been prepared by Taylor Reynolds (taylor.reynolds@itu.int) and Ayanna Samuels (asamuels@mit.edu) of the Strategy and Policy Unit of the International Telecommunication Union. The paper was commissioned and produced under the Digital Bridges Initiative, a joint project of the International Telecommunication Union (ITU) and the Ministry of Information and Communication of the Republic of Korea (MIC). This series of case studies forms a part of the background research for the Digital Bridges Symposium, co-held by the ITU and the Korea Agency for Digital Opportunity and Promotion (KADO). All materials relating to this case study and the Digital Bridges Symposium in general can be found at http://www.itu.int/digitalbridges.

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1 Introduction

In July 2004, a team of network engineers built a fixed wireless network spanning hundreds of miles throughout the rural areas of a large country. The network provided high-speed broadband access across many areas that had no accessible fixed-line infrastructure. This wireless broadband network delivered 14 Mbit/s of connectivity along winding roads, often under very mountainous conditions. While the development of such a network is noteworthy, this particular network was literally picked up and moved to a different area of the country each day, highlighting the advances in wireless technology and deployment ability. This mobile network was not located in a developing economy but rather formed a wireless connection to France Telecom's network during the Tour de France.

As the Tour de France portable network has shown, technologies exist that can quickly and effectively expand access to remote regions with very little fixed infrastructure costs. If this is the case, what are the issues that seem to be holding back providers in developing economies from adopting these same technologies to offer voice/Internet services to users? The answers are complex and touch upon all areas of economic development, from education to regulation, income to infrastructure.

While the digital divide is a complex problem, part of the solution can be found improving the transfer of information about new, advanced wireless technologies to developing economies. Policy makers and operators in many parts of the world are still struggling to follow what some have claimed is an outdated network architecture model of focusing on expanding fixed line connections.

Wireless technologies used for entertainment and convenience in the developed world could have much more profound effects in the developing world. While checking e-mail in a distant city from the back of a taxi surely makes business travel more effective in richer economies, being able to send and receive messages at all in a remote, rural community could produce a much greater improvement in social welfare for the same infrastructure investment.

This paper will approach one small aspect of the digital divide, how emerging information and communication technologies in the developed world can be adapted to provide ICT access in developing and rural areas.

2 Digital divide background

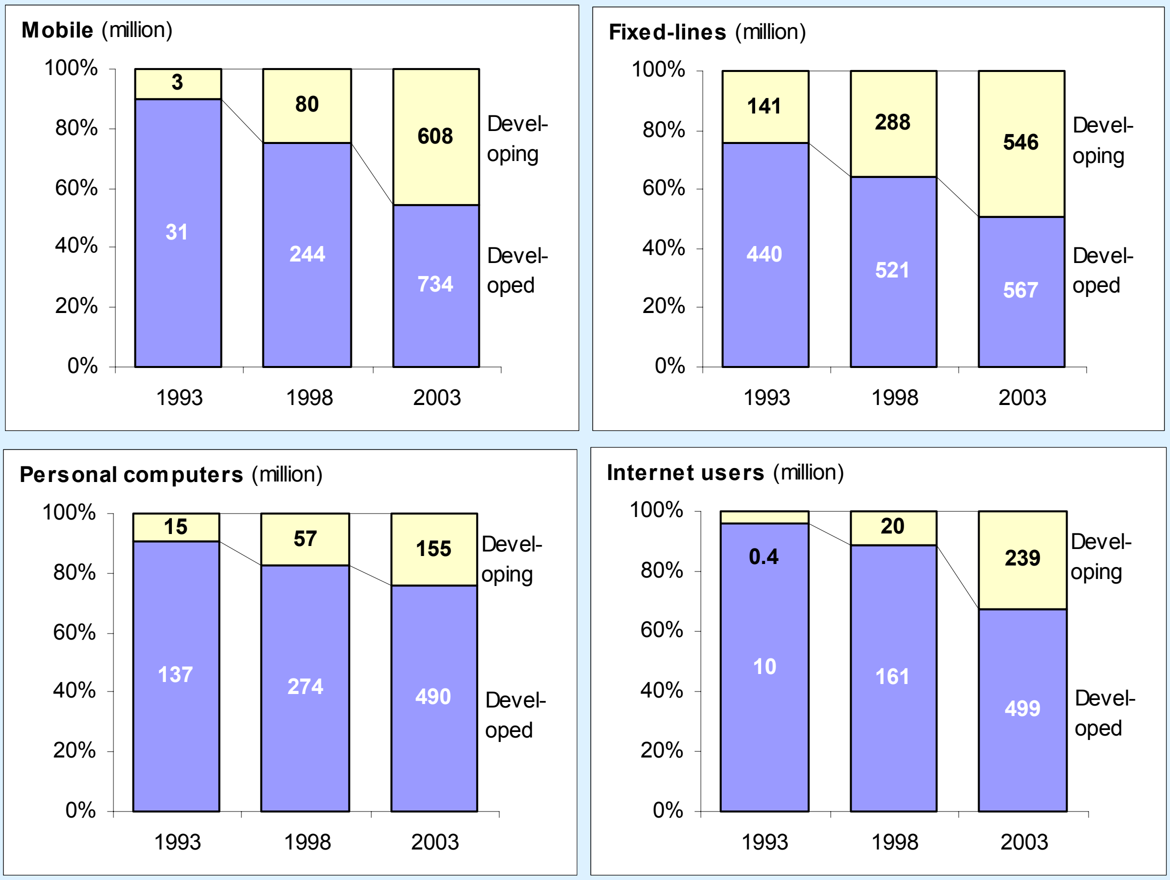
The digital divide problem is multifaceted and affects every continent and region of the world. However, the problems are particularly serious in several regions, namely Africa, South Asia, and island developing states where users have very little access to ICTs. In most economies there is not simply one problem that must be addressed. Instead various factors contribute to the lack of connectivity. These include a lack of infrastructure and investment, adverse geographical conditions, regulatory and policy provisions that are not conducive to promoting public-private partnerships, skills shortages and lack of relevant content and applications. In addition many small domestic markets have not been perceived to be capable of supporting efficient competition to the incumbent operators. Finally, as long-distance calling patterns have changed, many economies have suffered from falling settlement payments from international voice traffic that help support domestic telecommunication infrastructure investment.

World leaders and policy makers understand that ICT access and skills are becoming more important in economies throughout the world, improving efficiency and welfare. Therefore, any changes in the digital divide will have implications on longer-term development and national income. Policy makers around the world are facing challenges of how to increase access to ICTs and prevent the widening of the digital divide at both national and international levels. With this in mind, the ITU has organized the World Summit on the Information Society (WSIS), the first phase of which was held in Geneva from 10 to 12 December 2003 in order to coordinate international efforts to address the digital divide.[1] While the challenges may appear daunting, the WSIS Plan of Action sets out objectives to improve infrastructure, training and skills, and other pre-requisites to help increase connectivity in the developing world and other less-connected areas.

By some measures, the substantial effort to reduce the digital divide has been a success. People around the world, especially in developing economies, have better access to ICTs that they did a mere 10 years ago. Advances in technology and insightful policy have helped people communicate better.(see Figure 2.1).

Figure 2.1: The shrinking digital divide

Percentage shares among developed and developing economies of fixed lines, mobile phones, personal computers and Internet users in 1993, 1998 and 2003



Source: ITU.

While there have been gains in increasing access to ICTs, the digital divide has become a moving target for policy makers because the classification of "digital divide" is constantly shifting. Originally the digital divide referred to unequal access to Internet connections over a dial-up connection at 56 kbit/s. Now just a few years later, the digital divide problem has shifted to lack of *fast,* broadband access to the Internet (at speeds of 256 kbit/s and greater) and the applications higher-speed connections can provide.

In a generic sense, the digital divide can be simply defined as much better access to ICTs for some people than others. The different speeds only play a part because they are directly tied to the *types* of applications people can use with a connection (see Figure 2.2). For example, voice telephony over the Internet (often referred to as VoIP) can be provided with as little as 9 kbit/s of connectivity (roughly one sixth the speed of a standard dial-up connection). Conversely, near-CD quality audio streams require a minimum of 96 to 128 kbit/s of bandwidth for good sound reproduction. This represents two times the speed of a standard dial-up connection (56 kbit/s) and roughly half the speed of the lowest speed broadband service (256 kbit/s).

What seems to be making the problem worse is that as the technology changes, developing and rural areas are often slower to adopt newer technologies as they struggle to increase access to earlier technologies. An example is that while many economies in the world are still struggling to put in simple copper wires, leading broadband countries Japan and Korea are pushing fibre optic cabling to homes. This leaves the developing economies and rural areas further and further behind as later adopters (see Box 2.1).

Box 2.1: The never-ending catch-up cycle for developing economies

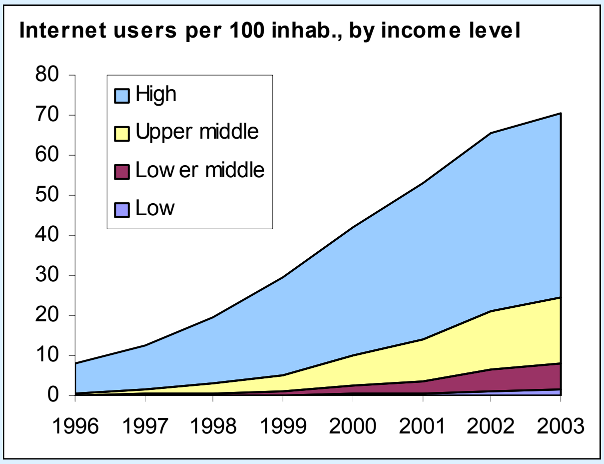
Just as developing economies start making progress bridging the digital divide in one ICT, new technologies appear and the cycle repeats.

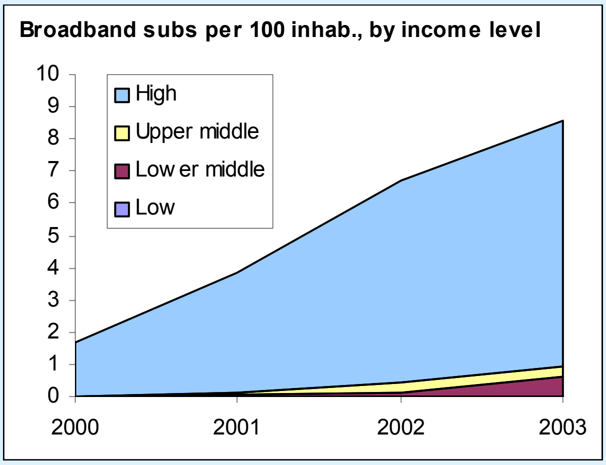
In mid 1990’s the Internet was a new communication medium whose benefits were touted as the ultimate information tool for users. The Internet was the technology that was supposed to open libraries worth of materials to users at the click of a mouse. Some of the initial excited soon gave way to new fears about how people in developing economies would be able to make use of this new, incredible information tool. This was the emergence of the “digital divide” and policy makers went to great lengths to figure out how to prevent new classes of “haves” and “have-nots” in their economies and between nations.

The attention given to the digital divide has been successful in increasing awareness of what the Internet can do for people. There is still much work to be done but initiatives such as community access centres and ICT training are helping increase the number of people with Internet access in the developing world.

However, just the numbers are starting to look more promising throughout the developing world for basic Internet access (left figure), a new technology, broadband, has appeared in markets around the world and is allowing users much “*better”* access than simple dial-up connections (right figure).

This puts policy makers and operators in a difficult position. They must decide if their goals to provide universal access to data continue to focus on dial-up connections or if efforts should be shifted to build networks more suitable for broadband access.


Internet users per 100 inhab., by income level


Broadband subs per 100 inhab., by income level

Source: ITU World Telecommunication Indicators Database

Worldwide, one of the most important Internet applications is still e-mail and will continue to be so for some time. Since e-mail is time *insensitive,* there is very little lag in text messages sent from a dial-up or high-speed broadband connection. Many then believe that the digital divide focus should rest on bringing a first round of connectivity to users throughout the world that will allow simple, e-mail access. However, others argue that rather than focusing on e-mail over copper dial-up lines, any new infrastructure in the developing world should include the ability to receive different types of streaming multimedia. This is especially important in areas of the world where literacy rates and computer skills are low.

The digital divide bandwidth paradox:

Text-based communication often requires users to have a more advanced skill set than multimedia communication. However, the least developed economies where users have the greatest need of multimedia-based ICTs are also the economies characterised by a lack of even basic ICT infrastructure, leaving text-based communication often as the only viable option (see Box 2.2). Areas characterized by high illiteracy face extreme difficulties accessing text-based ICTs, even when programs are available in local languages.

This poses a unique set of challenges for policy makers and operators throughout the developing world. They must find a way to connect rural villages with enough bandwidth for video and voice but at costs that are still affordable to users. This background paper will examine some of the best candidate technologies for providing cheap, but fast access capable of delivering multimedia services to underserved areas.

Box 2.2: Video e-mail allows Indians to keep in touch with distant relatives

Demand for video e-mail is strong in areas with low literacy rates

In India, there is a significant amount of migration of rural people to the urban cities and towns and often to distant lands such Singapore, Malaysia and countries of the Middle East. However, communicating with relatives remaining in the villages and remote areas poses difficulties.

Rural India is largely illiterate with the literacy rate at 49.4 percent compared to the urban populace, where the literacy rate is 70 percent. A deeper analysis of the working class reveals an even bleaker scenario, wherein 68 percent of rural males and 90 percent of rural females are either illiterate or have been educated only up to the primary level.

For these people, any mode of quick and cost-effective communication is highly welcome. In this context, even a 60 second video-mail is of great value and people are willing to pay up to even US¢ 50 for this.

The services are especially appealing in rural areas because it allows relatives to keep in contact with one another when voice telephony may not be available.

Source: Indian case study available at: http://www.itu.int/digitalbridges/docs/casestudies/India.pdf.

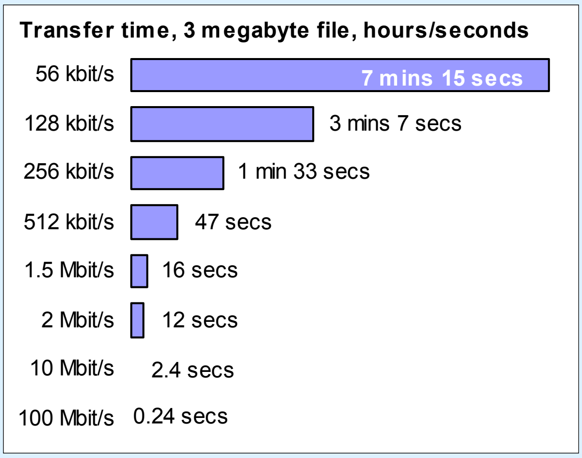
Bandwidth needs

Before delving into the technologies that can help bridge the digital divide it is important to understand what types of connectivity are required to give people sufficient access to ICTs. In Japan, ADSL offers have topped 47 Mbit/s while broadband speeds in many other areas of the world are hovering between 512 kbit/s and 1 Mbit/s. Data surfers over mobile phones in richer economies can expect typical connection speeds between 64 kbit/s and 512 kbit/s.

In an ideal information society, all users would have access to fast data streams. However, many developing economies have not yet reached a level of development that can support extensive broadband rollouts and high-speed connectivity. It is therefore prudent to look into the minimum speeds required for several basic, but very important technologies used for digital communication throughout the world (see Figure 2.2).

Figure 2.2: Speed matters

Download time of a 3-megabyte file for various Internet connections



File type	Megabytes
Movie (1.5 hour - DVD)	4'000
Movie (1.5 hour - DivX)	650
3 minute music file (Wav file, raw)	35
Digital photograph (4 megapixels, uncompressed)	11
ITU Internet for a Mobile Generation (PDF, 240 pages)	4
3 minute music file (MP3 - 128 kbit encoding)	3
Digital photograph (4 megapixels, JPEG 10:1)	1

Note: (Left) The times listed use the theoretical maximum line speeds and do not take into account any transmission control overhead. As a rule of thumb, overhead will decrease transfer rates by around 13 per cent. Network congestion will also slow transfer speeds further still.

(Right) The digital file sizes are only approximations as issues like video resolution and sound quality have an enormous impact on overall file sizes.

Source: ITU

In India, research has shown that it is a financial strain for users to support even a dedicated 33 kbit/s connection that they must all share in a village. However, 33 kbit/s connections are currently used to provide video streaming (at low quality levels) that are used for video conferencing and e-learning. Recent studies have shown that even doubling the bit rate to 64 kbit/s would be a boon for villages around the country[2]

A 64 kbit/s connection is slightly faster than a standard dial-up connection but could support 5-6 computers in a village, likely in kiosks or cybercafés. However, as the number of users in the village increases, the amount of connectivity required would also jump. In a short time many villages in India will require connections ranging from 100 – 150 kbit/s, sustained. The next step would be to 1 Mbit/s, which happens to correspond to rates promised by emerging long-range wireless technologies.

3 Introduction to technologies

3.1 Wired

Wireless technologies may dominate in voice telephony but the broadband world is still the domain of fixed-line connections. Indeed, wired connections form the bulk of high-speed backbone connections that permeate the Internet and should also play a key role in industrial policy of regions and economies.

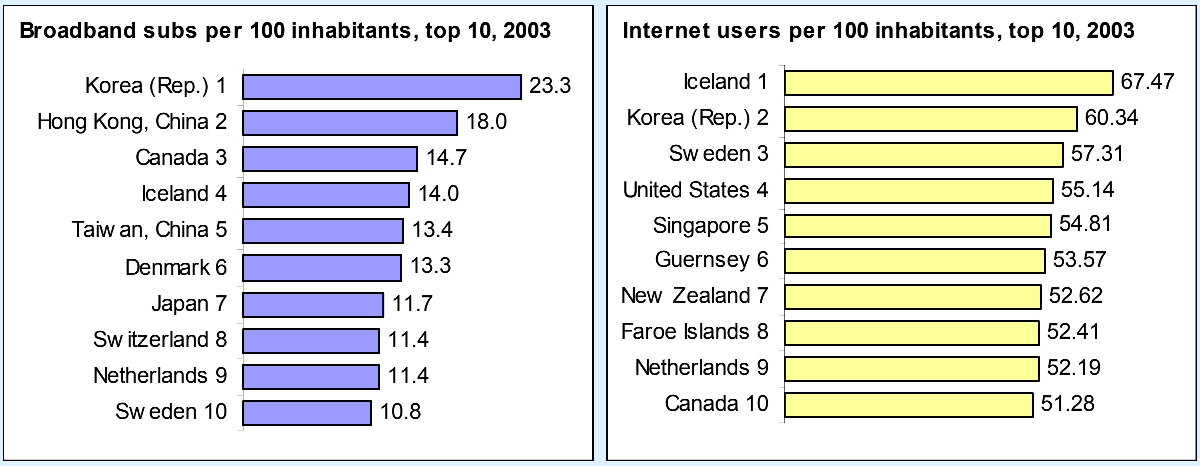
Until now, high-speed broadband has been mainly a "wired" phenomenon. Broadband delivered over wireless technologies made up less than five per cent of the world's broadband subscribers in 2003. Around 60 per cent of broadband subscribers access the Internet over the existing telephone network via xDSL lines. The other nearly 35 per cent use cable modem technologies. While these ratios are slowly changing with the evolution of wireless broadband, fixed-line connections will continue to play an important role in delivering connectivity.

Wired connections also form the vast majority of backbone connections connecting cities. Economies that planned early for wired backbone infrastructure are now benefiting from fast wired connections that can be extended to the last several kilometres via wireless technologies. Extensive fibre networks in Korea and India for example are helping shorten the distance required for wireless connections and making bridging the digital divide a much easier task.

In the early 1990's the Republic of Korea decided that a fibre optic backbone throughout the country would be vital to Korea's competitiveness for years to come. Korea's Ministry of Information and Communication (MIC) devised a way to ensure that fibre lines would criss-cross the country. In the early 1990's the Korean government contracted with KT, which was still a state-owned enterprise, to install fibre optic links to villages and cities around the country as a way to interconnect post offices and government buildings. KT was given the mandate to lay the private lines for the government but was also allowed to lay its own fibre strands next to those being put in place for the government. While KT was allowed to put in its own lines, it was required to lease capacity on those lines at a rate mandated by MIC. The resulting rollout was extensive and has helped propel Korea into the leading broadband position worldwide (see Figure 3.1).

Figure 3.1: Excellent Internet access in Korea and Iceland

Korea and Iceland top the list in connectivity to users, much of it via fibre-optic lines



Source: ITU World Telecommunication Indicators Database

It is not just developed economies that have benefited from extensive fibre rollouts. Backbone connectivity has also been a priority in India with stakeholders including the Department of Telecommunications, the

Government of India and Bharat Sanchar Nigam Limited (BSNL) – the state-owned incumbent, laying fibre to almost all *taluka* (country) headquarters and towns in the last 15 years. The fibre optic cables in the ground have a bandwidth capacity of over 10 Gbit/s, with technology advancements promising much higher data rates over the same strands in the future. Since almost 85 per cent of Indian villages lie within a 15-20 kilometre radius of these taluka towns, a wireless system with a radius of coverage of about 20 kilometres would be able to connect most of these villages[3].

An interesting commonality between the Indian and the Korean examples is a push by the government to connect villages with high-speed fibre-optic lines. Usually the initial justification for such infrastructure is to connect schools, government buildings and post offices. However, any accounting of the true social value of the network must include the massive externalities of fibre to the town and the corresponding services it can provide to end-users.

Some analysts have argued that governments should leave backbone infrastructure solely to markets. However, the economies that seem to be reaping the early benefits of broadband are those where governments have taken an active role promoting investment and creating an environment favourable to infrastructure rollout (See Box 3.1).

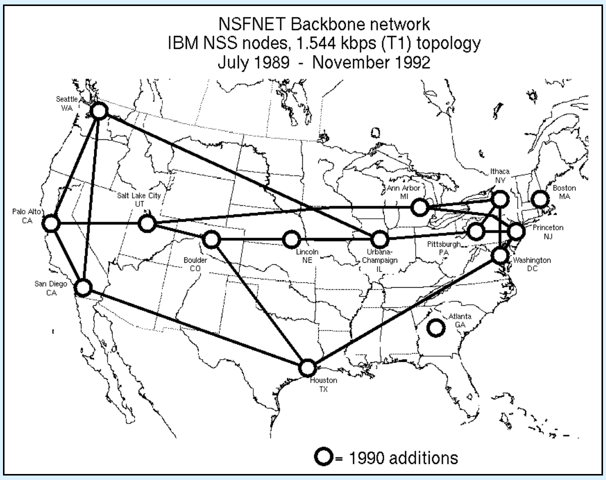
Box 3.1: Building the Internet backbone through public investment

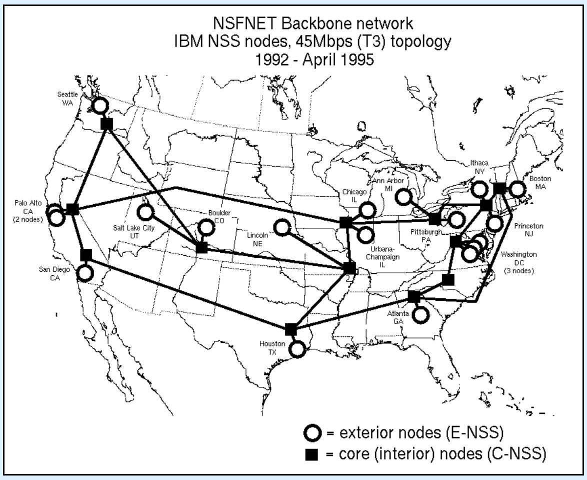
How the United States' National Science Foundation took a leading role in building out the first Internet backbone

Much of the early backbone investment for the Internet was done by a branch of the United States government, the National Science Foundation (NSF). During the 1990's the NSF made it a priority to subsidize very fast backbone connections between research universities in the United States. The work on the NSFNet backbone network started in the 1980s and by 1988 there were 13 backbone nodes crossing the country and linking research centres at 1.5 Mbit/s (T1) speeds. As the needs of the network grew, so did the bandwidth of the backbone to 45 Mbit/s (T3).

Once the backbone infrastructure was in place, the NSF put together a program that gave universities a USD 20'000 grant to help connect to the nearest existing NSFNet point of presence (POP). The NSF was also interested in increasing international connectivity and provided grants to connect foreign research and educational networks to the backbone, finally linking 28 research and educational networks in a total of 26 countries.

The resulting network became the first global Internet backbone for a total infrastructure cost of less than USD 100 million to US taxpayers. Policy makers in developing economies can take several lessons from the experience and apply them on a smaller scale in their economies. Pushing backbone infrastructure as deep as economically possible is one of the best ways to ensure that emerging wireless technologies can reach as many potential users as possible.


NSFNET Backbone network
IBM NSS nodes, 1.544 kbps (T1) topology
July 1989 - November 1992


NSFNET Backbone network
IBM NSS nodes, 45Mbps (T3) topology
1992 - April 1995

Source: http://www.worldpaper.com/2004/july/july3.html , images: http://moat.nlanr.net/ INFRA/NSFNET.html

India and Korea are just two countries that have pushed backbone fibre infrastructure deep into outlying regions and many other economies are looking at or proceeding with similar plans.

Japan's NTT is on the forefront of running fibre-optic lines to homes as a way to prepare for a communication network of the future. With the support of the government, NTT has made fibre-to-the-home (FTTH) installations a key part of its long-term vision of a ubiquitous network and now Japan's FTTH rollout is probably the most extensive in the world.

On the other side of the world in Iceland, the city-owned Reykjavik Energy has a plan to have all 65,000 homes in Reykjavik connected via a fibre-optic network in five years[4]. This ambition plan would give Iceland's world-leading Internet penetration a speed jolt (see Figure 3.1, right).

Fibre will play a key role in bridging the digital divide and fibre investments should extend as deep as economically feasible. Groups planning any new infrastructure investments in fixed lines should strongly consider using fibre instead of copper since installation costs are similar but fibre's capacity is so much higher than a similar copper line (see Figure 3.2).

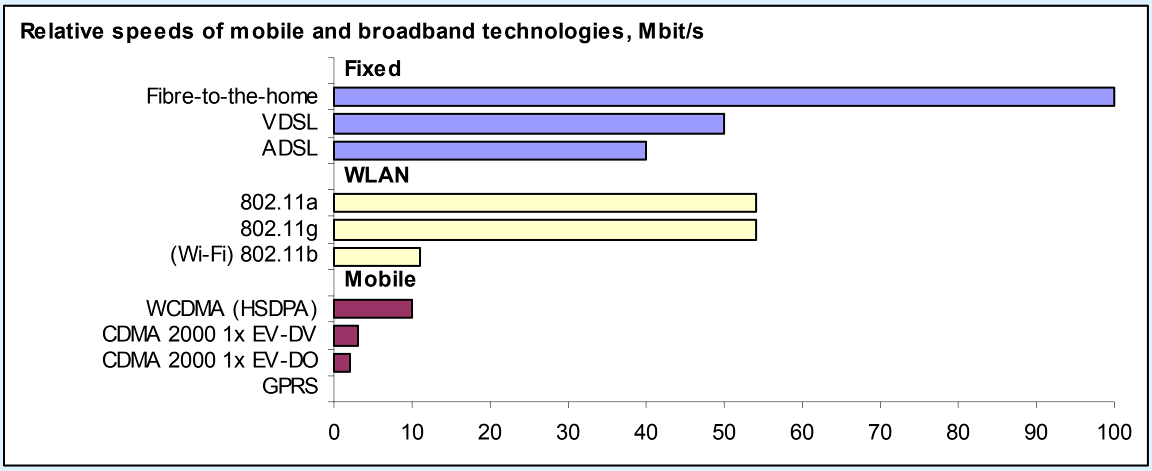
Policy makers must look at ways to ensure that fibre extends are far as economically possible in their economies. Fibre-to-the-home is not an option for all but the most advanced ICT economies but fibre-to-the-town or region should make much more economic sense. Since fibre forms the backbone for most types of telecommunication (e.g. fixed line and mobile telephone, Internet, etc), any efforts to extend the reach of fibre will make future telecommunication easier.

One way policy makers can help stimulate ICT development in their economies is to consider initiatives that would push fibre connectivity to schools. Universities could be the first connected with tertiary, secondary and primary schools following if economically feasible. Connecting schools first has two important effects on ICT development. First, students will have access to ICTs in the classroom, helping them develop into future consumers capable of using and paying for more technical and advanced communication services. Second, schools would serve as distance points-of-presence from which wireless connectivity could be launched further into rural areas. Finally schools, as public institutions, could also be used as community access centres to the public after school hours.

Policy makers in developing economies should compare the relative costs of fibre and long-range wireless implementations and build fibre connectivity whenever economically feasible. Then, wireless technologies can serve as a temporary bridge until a later date when fibre connectivity would be economically possible. Most communication networks include a mixture of fibre, copper and wireless segments and the key work for policy makers is to calculate the best balance.

Figure 3.2: Relative speeds of mobile and broadband technologies

Wired connections are show in blue and are among the fastest connections available. WLAN technologies are shown in yellow and offer high-speed connectivity, but within a very small area of mobility. IMT-2000 (3G) technologies are given in maroon and offer the lowest speeds but with the highest degree of mobility.



Source: ITU.

3.2 Wireless

New advances in wireless technologies are expanding the reach of ICTs at prices that are approaching affordability in developing nations around the world. A new wave of standards has allowed for mass production of wireless equipment, bringing costs down while raising the level of interoperability.

Operators in developing economies have found wireless to be an excellent way to branch out from the last "wired" segment of their networks to end-users and distance community access centres. On the other hand, developing economies have embraced wireless as a technology for unleashing mobile communication to areas traditionally out of the reach of wires. As current and emerging technologies arrive in markets, policy makers will need to decide how and when to implement these technologies.

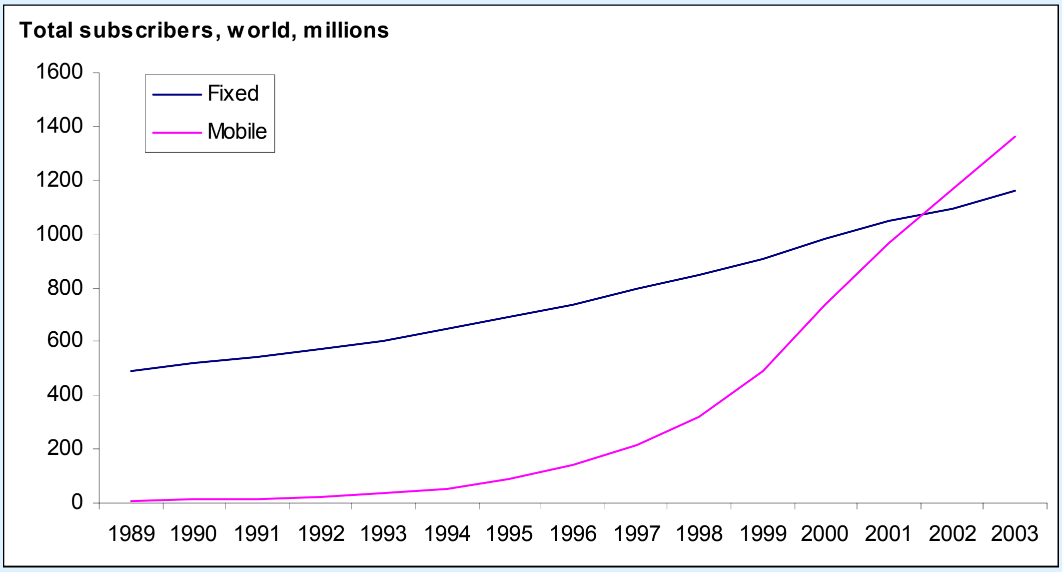
No one technology will offer the best connectivity in all situations. Finding the right mixture of technologies and applying them to a given geographic and economic situation will remain a difficult, but achievable task for policy makers. This section will look into a range of new wireless technologies and give examples of either how they are currently being adapted to bridge the digital divide, or in the case of emerging technologies, where the possibilities for the technology lie.

3.2.1 IMT-2000 / Third-generation mobile technologies

The number of mobile phone users in the world overtook the total number of fixed line subscribers in 2002 (see Figure 3.3). With this tremendous growth of mobile communications comes the possibility that the world's vast mobile networks can offer one of the most promising methods of delivering effective and inexpensive data connectivity throughout rural and developing areas of the world.

Figure 3.3: Mobile overtakes fixed

In 2002, the number of total mobile subscribers in the world outnumbered fixed-line subscribers.



Source: ITU World Telecommunication Indicators Database

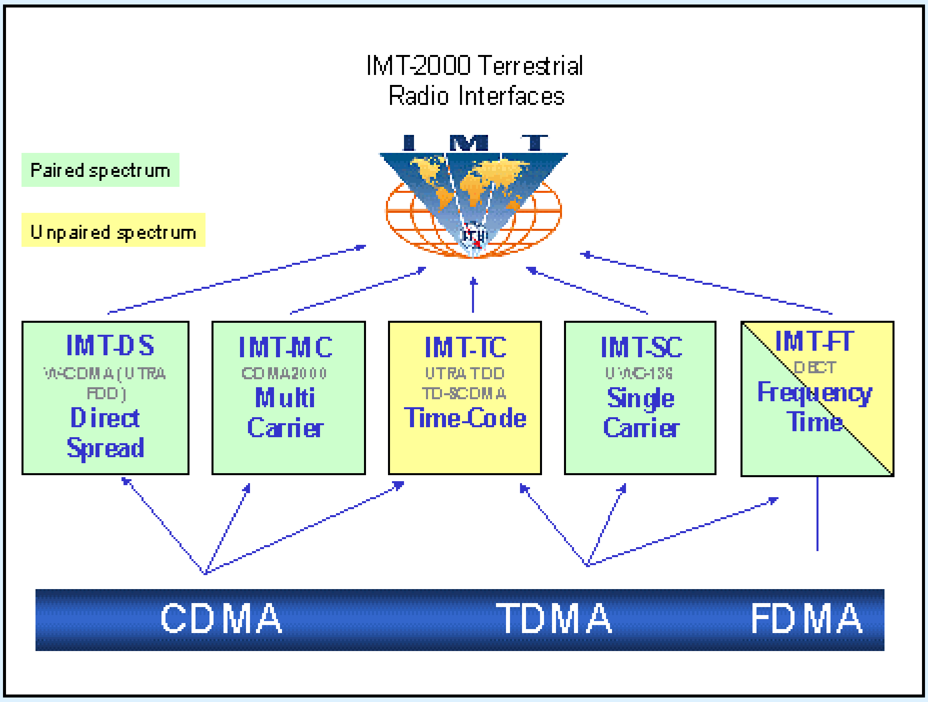
Most of the world still uses 2G and 2.5G networks to make voice calls. However, the data speeds for 2G networks are simply too slow to allow efficient Internet connectivity on the networks. Since the networks were originally designed for mobile phone connectivity, users in a given cell must “share” a limited amount of bandwidth. For example, 2.5G technologies provide a 100 kbit/s *shared* connection in a sector. If more than one computer or mobile phone is using the data network the speeds will fall far below rates for dial-up connections[5].

In addition, a wide range of inoperable mobile standards has made the development of harmonized equipment impossible. With these two issues in mind, the ITU started work on a new, global standard for third generation mobile communication. This work culminated in the development of the IMT-2000 “International Mobile Telecommunications-2000” standard.

IMT-2000 (known as 3G) mobile services are making fast inroads in Asia and slowly gaining momentum in other areas of the world. The data services are usually sold to mobile phone subscribers as a way to check e-mail, browse simple web pages, and look up information on the go—essentially making a mobile subscriber’s life more convenient.

These same technologies can also be adapted to use in rural and developing areas for basic connectivity with remarkable ease. Rather than targeting users with mobile phones, wireless cards in desktop computers use the mobile networks to send and receive data from fixed locations. While data speeds are lower than other types of connections, they can provide a stable connection to the Internet. It is clear then why IMT-2000 technologies look to be a promising method of introducing Internet connectivity in underserved areas.

Figure 3.4: IMT-2000



Source: ITU.

While the goal of the IMT-2000 project was to harmonize third-generation mobile networks with one standard, in reality, three different approaches to 3G evolved (see Figure 3.4) IMT-2000 encompasses three different access technologies (CDMA, TDMA, and FDMA) through five different radio interfaces. Most deployments have centred around two main interfaces, CDMA-2000 and W-CDMA (also known in Europe as UMTS). CDMA-2000 and W-CDMA networks have been the choice for mobile operators to deliver third-generation voice, but other radio interfaces are starting to be used for dedicated data delivery in both developed and developing areas. These technologies will be briefly introduced below.

W-CDMA (Wideband CDMA), IMT-DS

The overwhelming early choice for mobile operators has been a move from GSM networks to W-CDMA, which promises high data rates and improved voice quality for mobile phone users. However, W-CDMA networks have been slow to appear in the market due to the costs of building entirely new infrastructure to support them. GSM networks in use around the world cannot be upgraded to W-CDMA. Equipment has also been slow to reach the market and fall in price because the number of functioning W-CDMA markets is extremely low. Operators in many economies spent so much in bidding wars to obtain 3G licenses that they have very little financial ability to roll out new infrastructure.

W-CDMA is able to provide voice and data at theoretical rates of 2 Mbit/s in close, stationary environments and 384 kbit/s over longer ranges by using a 5 Mhz-wide carrier signal.[6] A new iteration of the original W-CDMA specification called High Speed Downlink Packet Access (HSDPA), has increased the data download rate on W-CDMA networks to a theoretical data transfer rate of 14 Mbit/s at close range although the longer-range applications are the most promising for rural connectivity.[7]

CDMA 2000, IMT-MC

CDMA-2000 technologies have been the surprise winner throughout the world in terms of IMT-2000 rollouts and are gaining popularity as both mobile phone networks and longer-range data networks in developing economies (see Box 3.2). CDMA-2000 has proven very popular and costs have remained low because second-generation CDMA IS-95 networks could be easily, and inexpensively, upgraded to CDMA 2000 1x networks. This has allowed for operators with existing CDMA networks to quickly move to 3G.

The CDMA-2000 standard has also been evolving to allow for faster data traffic. CDMA-2000 1x EV-DO (Evolution-data only) allows for much faster data-only speeds (700 kbit/s – 2 Mbit/s). The Republic of Korea has the world's most extensive CDMA-2000 1x EV-DO network and is doing commercial trials of the second iteration of the standard, CDMA-2000 1x EV-DV (Evolution-Data and Voice). EV-DV should allow speeds up to 3.1 Mbit/s to users.

Box 3.2: CDMA technologies for rural Internet access in Brazil

School 45 kilometres away from the nearest base station connected via CDMA.

Anatel and Lucent Technologies are looking into ways CDMA450 can help bridge the digital divide in Brazil through Anatel's Digital Inclusion and Universal Internet Access project. The goal of the project was to see how CDMA450 could be used to deliver high-speed Internet and voice access to the outlying regions of Brasilia that had never before had access to high-speed data or even voice services. During the trials, 3000 people in Brasilia's outlying cities including Santa Marina, Candangolândia, Taquatinga and Sobradinho accessed the new network for the first time.

CDMA450 is CDMA2000® 1X and 1xEV-DO wireless technologies that have been adapted to work in the 450 MHz range of spectrum. This range of spectrum is important for long-distance transmissions because at such a low frequency there is no line-of-sight requirement.

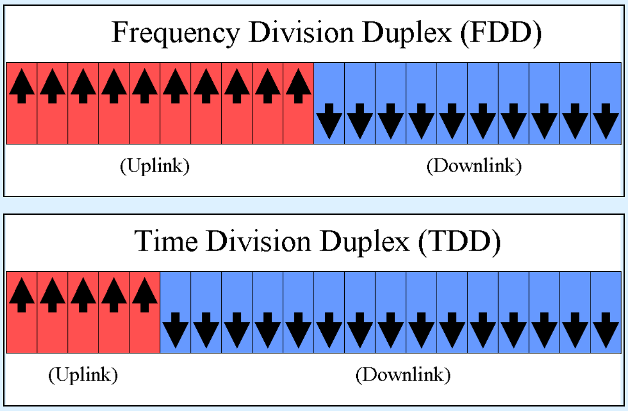
As part of the test run, Lucent engineers were able to reach speeds of 820 kilobits per second (kbps) to the Lago Oeste Teaching Center, a rural school with 1,200 students that never had Internet access or online educational content and is located a full 45 kilometers away from a Lucent base station.

While the initial project was simply a test, the results were promising for reaching remote villages via long-range IMT-2000 technologies.

Source: http://www.cdg.org/news/latest_news.asp?hnYY=2004&hnMM=06#060804_ind_c.html

Of the five radio interfaces for IMT-2000, W-CDMA and CDMA-2000 have proven the most popular, although they are not necessarily optimal networks for dedicated data access. W-CDMA and CDMA-2000 both use Frequency Division Duplex, which separates the uplink and downlink on different frequencies. For example, when a voice user on a W-CDMA or CDMA-2000 network speaks, her voice is transported over one swath of frequencies while the voice of the person to whom she is listening comes over a different band of frequencies. The uplink and downlink channels are the same size since voice conversations require the same amount of bandwidth in both directions (see Figure 3.5).

Figure 3.5: Symmetric or Asymmetric data on IMT-2000 networks



Source: ITU adapted from: http://www.itu.int/ITU-D/tech/imt-2000/warsaw/pdf/2_1_Menzel.pdf.

These identically-sized uplink and downlink channels, while suited well for voice, neglect Internet usage patterns of mobile Internet users. In the broadband world, ADSL technologies have allowed operators to offer faster download speeds in return for slower upload speeds by repositioning some of the unused, original upload frequencies to the download side. Since mobile networks using FDD have fixed upload and download channel sizes, they may be poorly suited to providing asynchronous Internet connectivity that corresponds to typical Internet usage patterns.

TD-SCDMA

The third IMT-2000 radio interface, TD-SCDMA, addresses inherent problems with data downloads over a mobile network by using Time Division Duplex (TDD) rather than FDD for data. The carrier frequency on a (TDD) system is used for both the uplink and downlink. This is possible by alternating time slots for sending and receiving data and allows an asymmetric transmission flow that is much better suited to delivering typical Internet data.[8] TD-SCDMA is closely related to W-CDMA, differing mainly in the division duplex method. TD-SCDMA networks have not yet appeared but many carriers around the world have expressed keen interest in the technology.

EDGE, IMT-SC

As mentioned earlier, 2.5G services could not provide fast enough speeds to handle dedicated Internet traffic to villages because services such as GPRS offered maximum speeds of up to 171.2 kbit/s by combining up to 8 time slots simultaneously to send packet switched data.[9] However, these theoretical speeds were practically out of reach of individual users on a single cell, making high-speed mobile data over GPRS difficult. Instead, GSM operators are increasingly turning to Enhanced Data rates for GSM/Global Evolution (EDGE) as a way to provide higher-speed mobile data over both high-speed circuit switched data (HSCSD) and GPRS connections. EDGE essentially offers a way to triple the amount of data that can be sent simultaneously. This is done through a modulation scheme that can represent 3 bits at any given time, rather than the one bit building block of digital transmission.[10] EDGE services are beginning to appear in countries around the world as mobile Internet connections, often sold separate from mobile telephone services. They offer individual users between 150-200 kbit/s data transmission, usually for a flat rate.

There are two main ways EGDE networks are being marketed. In many developed ICT economies, EDGE services are sold as mobile Internet connectivity for laptops and PDAs. Instead of subscribing to a mobile phone service, users simply subscribe to wireless connectivity, the same way they may subscribe to Wi-Fi services. In many developing economies, EDGE services may play a larger role in delivering faster data to mobile phones. EDGE cards may also be used in fixed, desktop computers to offer Internet connectivity.

One of the biggest benefits of EDGE is it can be implemented on both TDMA and GSM networks, offering a unified path towards 3G data delivery.

EDGE network rollouts are appearing in economies around the world. Examples include, CTI Movil (Argentina), Claro (Brazil), Telefonica Moviles (Chile and Mexico), and TIM Brazil. In July 2004, there were 28 operators offering commercial EDGE services to customers, 32 operators who are actively deploying EDGE, 33 planned EDGE deployments, 8 operators with EDGE-capable networks, and 7 other operators with EDGE networks reported in the trial phase[11].

Box 3.3: Ghana – On the cutting EDGE in Africa

How a new mobile wireless technology in Ghana will provide mobile Internet connectivity

Ghana’s Scancom is currently preparing to build Africa’s first 3G network based on EDGE technology. The current GSM radio network will be upgraded to support EDGE and allow users fast mobile data. The new network will be available on EDGE enabled phones as well as PC LAN cards for computers. The fast connections should be a boon for Ghanaians looking for mobile data access.

EDGE services such as Scancom’s will most likely be built around densely populated areas or rural areas bordering urban centres. However, if initial trials are successful, services should expand into more rural locations.

Source: http://www.ghanaweb.com/GhanaHomePage/NewsArchive/artikel.php?ID=54599.

3.3 Fixed wireless

IMT-2000 technologies can provide inexpensive, low-speed connectivity to areas unserved by traditional telecommunication infrastructure. They are well suited for an initial connection to a village but do not remain cost effective as the number of users in the village increases beyond a certain threshold. Since IMT-2000 services were initially designed for mobile phone users, the technologies will cover the highly mobile but lower-speed connections while newer fixed wireless technology will fill the niche of high-speed, long distance, but stationary connectivity.

Fixed wireless connections have traditionally been used as backhaul connections between cities by telecommunication providers using microwave technologies. However a new set of fixed wireless standards are emerging that could be used as replacements for wired broadband connections. Some of these new technologies show huge promise for bridging the digital divide by increasing the amount of data that can be sent wirelessly to a city, village, community access centres, or even end users.

Currently, the bandwidth of fixed wireless technologies is determined by the allocation of the radio spectrum, a finite resource. Typically, 1 Hz of spectrum can yield 1-4 bit/s of throughput, depending on various factors (such as modulation technique and environmental conditions). Most fixed wireless systems use a band of frequencies between 900 Mhz to 40 Ghz. The inherent trade-off for fixed wireless systems is distance vs. speed. Higher frequencies carry far more data but cannot travel as far as lower frequencies, which often require line of sight. Higher frequencies also require more complex equipment that can put them out of consideration for small villages under severe financial constraints. Lower frequencies on the other hand, travel further and are cheaper, but cannot transmit large amounts of data.

Fixed wireless systems have been slow to gain ground when compared with traditional, wired high-speed connections. This is due to several factors including the lack of standardized fixed wireless equipment and variations in spectrum allocations among countries. As a result, the most promising technologies of several years ago, LMDS and MMDS, have been relegated to small, highly specialized rollouts. These technologies also never made much impact on bridging the digital divide because the expensive equipment never reached an economically viable level for small Internet shops in developing economies.

However, a new set of technologies is promising to change fixed wireless adoption the same way Wi-Fi has changed localized Internet access. Two promising new standards, IEEE 802.16 and IEEE 802.20 are competing to become the new standard of choice for high-speed wireless connectivity.

IEEE 802.16 (WiMAX)

WiMAX or "Worldwide Interoperability for Microwave Access" may revolutionize the way users in the developing world access the Internet. WiMAX is a new fixed wireless technology that promises to reduce the need for wired long-haul, high-capacity Internet connections. WiMAX is expected to be able to transmit a full 70 Mbit/s over a range of 50 Km. Higher frequencies would require line-of-sight but could transmit the most data. At lower frequencies, the distances could be increased but overall speeds would be reduced.[12]

WiMAX can utilize either a point-to-point or a point-to-multipoint architecture making it an ideal candidate to branch out from the furthest fibre deployment in an economy. The initial version (IEEE 802.16) was developed to meet the requirements for broadband wireless access systems operating between 10 and 66 GHz. A recent amendment (IEEE 802.16a) does the same for systems operating between 2 and 11 GHz.

WiMAX makes use of a new modulation technique called Orthogonal Frequency Division Multiplexing (OFDM) that maximizes the amount of data that can be transmitted at one time. OFDM divides a radio signal into multiple smaller sub-signals that are sent simultaneously at different frequencies to the receiver. Once they arrive, the receiver recompiles the various sub-signals into the original transmission[13].

The WiMAX Forum is hoping to replicate the astounding success of a shorter-range wireless technology, 802.11b or Wi-Fi. In following with the work of the Wi-Fi Alliance, the WiMAX working group includes leading companies in many industries whose clout in their individual markets can help promote a common standard.[14] Second, the WiMAX Forum will also offer a "stamp of approval" that one manufacturer's equipment will interoperate with other certified products, further helping to create a single common standard.

WiMAX was initially destined to be a fixed wireless standard. However, recent developments—including the slow rollout of third-generation mobile data services—have left a strong demand for inexpensive mobile data untapped. As work on the 802.16 standard evolved, the working group introduced the ability of 802.16 to accommodate mobile applications, called 802.16e. Researchers in the Republic of Korea are currently on the cutting edge of developing a practical mobile WiMAX solution based on the evolving IEEE 802.16e standard called WiBro (see Box 3.4).

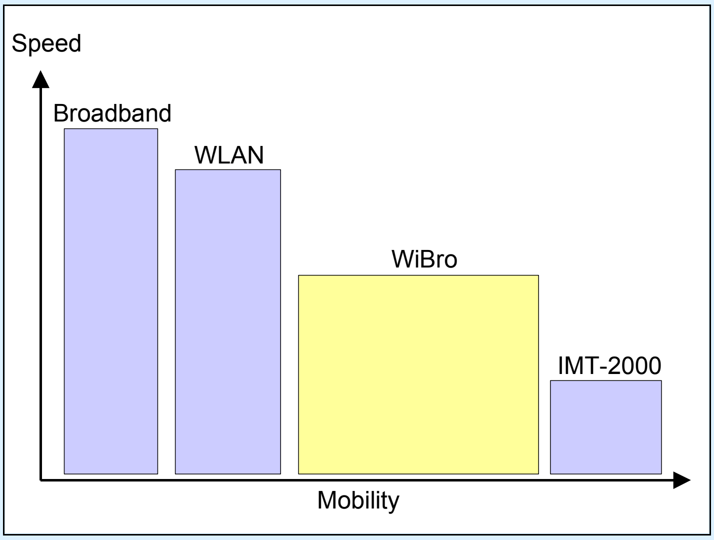
Box 3.4: Korea’s WiMAX vision for WiBro

How Korea’s appetite for mobile Internet applications is fuelling development of a WiMAX based wireless technology

Korea’s policy-makers, broadband providers, and mobile operators have come up with a plan to develop a new data network that is more efficient at offering mobile data than current broadband or mobile networks. This plan is called WiBro for “Wireless broadband” and is based on the evolving IEEE 802.16e standard using the 2.3 GHz frequency band. WiBro is a technology that fits well between WLAN and IMT-2000 in terms of mobility and speed (see below). It would offer a 512 – 1024 kbit/s connection to users for a flat monthly fee. Operators have not said how much they will charge but industry watchers assume the prices will be about USD 15 per month.

All major telecommunication players in Korea have plans for the 2.3 GHz frequency allocation that was finalized in February 2004. KT, for example, has already introduced a “seamless” offering through its Nespot Swing, a bundled package that where users can roam between Wi-Fi hotspots and the CDMA2000 1x EVDO network, when out of Wi-Fi range. Including WiBro coverage is the next practical step for the service.

WiBro has several advantages over WLAN and IMT-2000 for delivering data. While Wi-Fi is limited to a range of roughly 100 meters, WiBro will be accessible in a 1 km radius around a base station with connection speeds of 512 kbit/s guaranteed to moving vehicles at 60 km/h (see Figure 5.3, right). Mobile carriers are especially interested in WiBro because of their significant investment in cell towers throughout the country that can quickly be leveraged to offer WiBro services. This upgrade can be effectuated simply by adding a second set of radios on the towers.



WiBro at a glance	
General	
Frequency:	2.3 GHz
Licenses:	Awarded by ministry
Bandwidth	
Per user:	512 - 1024 kbit/s
Total:	100 MHz
Maximum accessible speed for users:	
Practical:	60 km/hour
Theoretical:	250 km/hour
Pricing estimates	
Flat rate pricing:	15 USD/month, est.

Source: ITU case study: Republic of Korea at: http://www.itu.int/osg/spu/ni/futuremobile/general/casestudies/koreacase-rv4.pdf.

WiMAX is one of the most anticipated technologies for connecting the developing world to fast, efficient broadband connectivity. While marketing hype can sometimes push expectations beyond a point technology can truly deliver, the sheer strength of backing behind a unified WiMAX standard will help keep costs low and increase its penetration. Analysts and equipment manufacturers are expecting the first shipments of WiMAX equipment to arrive in 2005 as outside-premises equipment. Then, in 2006 Intel will introduce WiMAX chips for portable computers[15] (see Box 3.5).

Intel, and other companies have a very positive view of the demand for WiMAX-enabled devices, especially in developing economies. However, for costs of WiMAX equipment to reach a level that that are affordable for small Internet kiosks, there must be broad adoption throughout the developed world in homes and businesses to push down equipment prices. Competition among device manufacturers and economies of scale could make WiMAX adoption in developing areas much more cost effective.

WiMAX rollouts in developing and rural areas will likely make use of longer-distance point-to-point connections standardized as 802.16a. These connections would be ideal for connection a single location in a village or town via a high-speed wireless link back to the nearest fibre point of presence. However, as fibre backbones expand and equipment comes down in price, mobile versions of WiMAX (e.g. 802.16e) could play a key role in bringing fast access to mobile phones over shorter distances.

Box 3.5: Intel's vision for WiMAX deployment

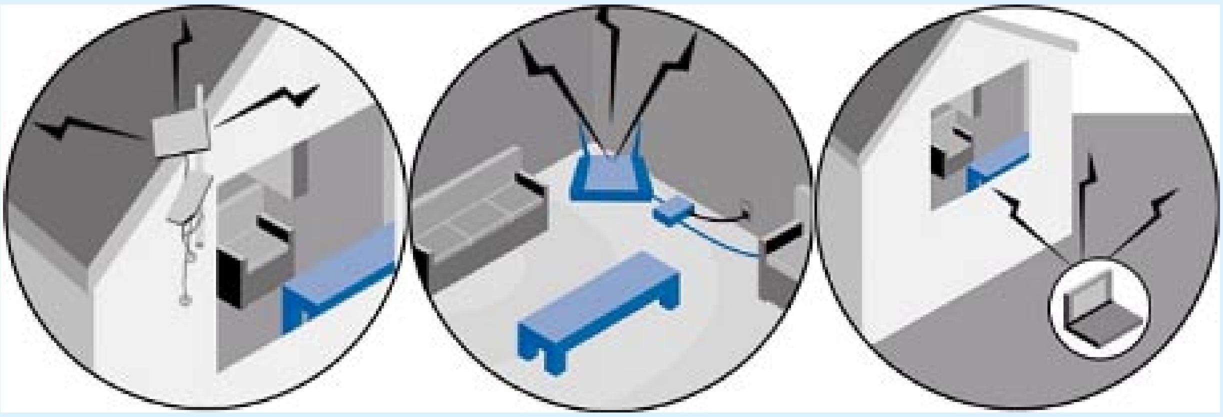
Intel believes connections will start with outdoor setups and quickly move to mobile devices

WiMAX received a big push when Intel, the world's largest chip manufacturer, promised laptops and other mobile devices could contain WiMAX chips in 2006. However, developing economies and rural areas may benefit even earlier from technologies that are scheduled to appear in the first half of 2005.

Intel believes that WiMAX's evolution will start with products such as external receiver/transmitters that could pull a signal into a cybercafé or house within range of a WiMAX base station. Clearly the push in the developed world will be to connect businesses and residences out of reach of traditional fixed-line infrastructure such as DSL or cable.

In the developing world however, equipment produced during the first two stages will most likely target cybercafés/kiosks, schools and community access centres. The final stages of Wi-MAX also show particular promise for developing economies as connectivity extends to mobile phones, which far outnumber fixed lines.

First half (2005)	Second half (2005)	(2006)
Antennas mounted outdoors	Antennas on fixed devices indoors	Antennas built into small devices



Source: *http://www.intel.com/netcomms/technologies/WiMAX/*

IEEE 802.20

WiMAX began as a fixed wireless technology that is currently being adapted to allow for mobile access. However, the "fixed" roots of WiMAX may leave it with legacy elements that inhibit efficient connectivity at high speeds. As a result, a new technical standard, named IEEE 802.20, is evolving that focuses solely on long-range, high-speed mobile connectivity.[16]

The new 802.20 standard is also much more flexible with the amount of spectrum it requires. As a fixed wireless protocol, WiMAX requires large swaths of spectrum, of which most of the optimal bands are already occupied. The 802.20 standard is designed to work in much smaller bands that can be scavenged amidst existing spectrum allocations.

WiMAX already has considerable backing through industry leaders such as INTEL, Fujitsu, Proxim and Seimens. The backers of IEEE 802.20 include Flarion and ArrayComm. Several network operators are running trials of early 802.20-type services (see Box 3.6). However, WiMAX appears to have a much stronger marketing push, and may win out in the long run.

Box 3.6: Early 802.20 trails in the United States

Nextel's FLASH-OFDM technology provides wireless connectivity for a flat rate in Raleigh/Durham, South Carolina, USA.

Nextel communications has built a new network based on networking equipment from Flarion, one of the main proponents the IEEE 802.20 standard. The network is based on proprietary Flash-OFDM technology to deliver data to users. While the IEEE 802.20 standard has yet to be decided, the technology Flarion is using is considered a very likely candidate.

In the test area of Raleigh/Durham, South Carolina, in the US, users can choose between plans ranging in price from USD 34.99 to USD 74.99, depending on speed. At the lower price points, users can download at 700 kbit/s and upload to the network at 200 kbit/s. Users who pay more have access to higher speeds, roughly 1.5 Mbit/s and up to 3 Mbit/s in short bursts. These speeds put Nextel's service in the range of CDMA 2000 1x EV-DO.

The prices for unwired access throughout the city are high, even for many users in developed economies. However, if similar services could be set up to connect Internet kiosks and cybercafes the costs could be borne by a larger number of users.

One of the most interesting aspects of the network is the ability to offer different priority levels to different levels of subscribers. Users paying higher subscription fees will have first packet priority on the network, ensuring a higher quality of service for uses such as video streaming. Other users may prefer lower fees in exchange for a lower priority on the network.

While Nextel's initial trail has now expanded to commercial service, there are still questions about the future of the network. First, the network could be a risk for Nextel since the standards have not be formally adopted. Industry watchers also fear that by choosing a new, unproven standard, Nextel may repeating the same scenario that doomed MMDS and LMDS systems.

Source: http://wifinetnews.com/archives/cat_80220.html and http://www.nextelbroadband.com/about_the_trial.html.

Free space optic (FSO) technologies

Most wireless technologies use radio waves to send and receive data. However, one medium-range, wireless technology makes use of lasers to transmit data. The technology is free space optics (FSO) and is based on the same principle of fibre optics, but without the fibre. A laser forms a connection between two pieces of equipment within direct line-of-sight. Once calibrated, the laser transmits data into the air by switching on and off at very high speeds. The receiving equipment then can decode these flashes of laser light into data.

FSOs can be used effectively to form backbone infrastructure between buildings in the same city. One key benefit is they do not require an allocation of spectrum and can transmit at very high speeds, up to 1 Gbit/s. They can be very cost effective in areas without wired infrastructure (See box 3.7). The niche market for FSOs will likely be developed areas with high infrastructure building costs as FSOs eliminate the need to dig up existing roads to lay infrastructure. The FSO backbone can then be used to pass traffic back and forth between other wireless and wired networks. FSOs are particularly useful in conjunction with wireless networks because they don't cause interference with each other.

While an FSO network is relatively inexpensive and quick to set up, there are drawbacks to the technology that can hinder its performance. For example, atmospheric disturbances can affect transmissions. Humidity and fog disrupt the laser since tiny fragments of water in the air can slow down or momentarily block transmissions. Second, the lasers and reception equipment must be absolutely immobile and calibrated to ensure reception by lens on the other end of the connection. The tall buildings that are best equipped for line-of-sight also have a tendency to sway in the wind and can be problematic for FSO transmissions.

Although FSO transmissions require fixed and calibrated connections to transfer data, they may still be used as backbone infrastructure for the portable Internet. They could be used to backhaul traffic between Wi-Fi hotpots or mobile towers in areas where fixed line infrastructure would be too costly. Another key benefit of FSO technology is it can be taken down when no longer needed (e.g. when fibre lines are available) and reinstalled in another location.

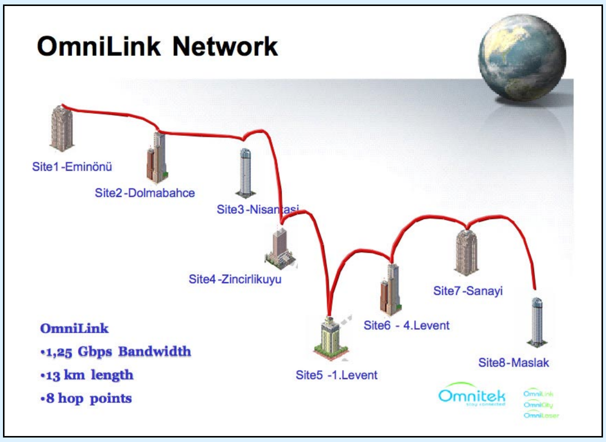
Box 3.7: Lasers passing data in Istanbul

How free space optic technology provides high-speed connectivity in Turkey's largest city.

Businesses in Istanbul are now benefiting from increased competition for connectivity due to a new FSO network in the city. The backbone network connects 8 buildings, each 1.2 – 2.3 kilometres apart, over a 13 kilometre stretch of the Maslak-Eminönü route of the city. Each of the eight "node" buildings then disperses connectivity to other surrounding buildings via optical wireless spurs.

The network was built by Omnitek as a way to offer high-speed connectivity to businesses and residential customers. As a savvy business move, the eight buildings selected for lasers also had the largest potential for good clients, although other buildings in the area can also connect via wireless spurs.

The economics of FSO greatly outweighs that of fiber. "If we were going to do this investment by laying fiber, it would have cost us $7.85 million. What we actually spent on the FSO equipment and installation was more like $1.4 million" explained Murat Akay, deputy general manager of the OmniLink network. Corporate connections from Turkey's existing main provider are often exorbitantly expensive. A July 2004 press release quoted Murat Akay giving costs of the incumbent provider as $220 per month for a 128-kbit/sec connection, $7,000 per month for a 34-Mbit/sec connection, and more than $18,000 per month for a 155-Mbit/sec connection. Omnitek's services cost 40% of Turk Telecom's, expressed Akay—and offered over dedicated lines. Turk Telecom offers only shared lines today, he says.



Source: *http://www.omnitek.com.tr/tr/default.asp*, fSONA at *http://www.fsona.com* and *http://lw.pennnet.com/Articles/Article_Display.cfm?Section=Articles&ARTICLE_ID=208105&VERSION_NUM=1*

HAPS/LAPS

High and low altitude platform stations (HAPS or LAPS) offer the coverage benefits of satellites at costs closer to fixed infrastructure. HAPS and LAPS are balloons or other low and high altitude platform stations that can provide data services over a large area for relatively low cost. Balloon systems are typically tethered via a cable and hover at an altitude of around 3 Km. A fibre optic cable is run alongside the tether cable up to the balloon which then uses radio frequencies to send and receive data traffic from users on the ground. Untethered systems hover at much higher altitudes of 21 km above the ground and rely on radio communication for traffic between users and the HAPS as well as between the HAPS and the ground station's Internet connection.

Several companies are developing different types of HAPS and LAPS technologies in an effort to provide satellite-type coverage at a fraction of the cost. SkyTower has developed a solar-powered, unmanned aircraft that can hover at an altitude of 18 kilometres for 7-14 days and for more than 6 months at lower altitude, covering a range between 50-250 miles on the ground. Another company, Skylinc has a proposal to deploy 18 tethered air balloons across the United Kingdom that will hover 1.5 kilometres in the sky and supply access within an 80 km footprint.

The key market for LAPS and HAPS will likely be rural and developing areas that are underserved by traditional infrastructure. However, they could also play a key role for newer wireless technologies such as WiMAX. Since LAPS and HAPS are simply platforms for delivering a range of wireless connectivity, their radio equipment could make use of the most current technologies to provide fast connectivity within line of sight. Since the line of sight requirement would be met for many applications, the frequencies and corresponding transmission speeds could both be much higher.

Satellite technologies

The longest-range wireless connections are achieved via satellites. Satellite data services cover a vast area of the globe and can provide access in areas where no other services are available. Satellites provide essential connections in remote areas (oceans, mountains) as well as densely populated areas that are not served by other telecommunication providers.

Satellite technologies offer the longest range but are expensive for even small data streams. They can also suffer from latency problems (the delay between a signal being sent and received)[17] that can make time sensitive transmissions, such as voice, difficult.

The high costs and low speeds of satellite technologies have relegated them to truly a last-option broadband technology. In addition, new wireless technologies such as WiMAX could further erode satellite market share for Internet connectivity.

In the past, communication satellites[18] have provided radio, telephone and television links around the world. Communication satellites have traditionally been launched in a geostationary orbit. Like other geostationary satellites, they orbit at a height of 35’650 km and rotate with the Earth, thus appearing stationary. A fleet of three GEOs can provide complete global coverage. However, the height of GEO’s makes broadband access for consumers and mobile devices impractical.

In the past decade, many companies invested heavily in building networks of satellites that orbit much lower in the sky, in better reach of consumers, but in a constantly moving rotation. These low-earth orbit (LEO) satellites orbit between 650 km and 2’575 km above the Earth. Each LEO satellite is only in view for a few minutes, and rotates around the world every few hours. This means multiple LEOs are required to maintain continuous coverage by having at least one satellite in “sight” at all times. LEO constellations have the advantage of shorter transmission delays because they are much closer to the Earth’s surface. However, they also require more complicated handsets and equipment on the ground that is capable of tracking the satellites to maintain a connection.

While satellite technology has been proven, the economics of many satellite systems have not, with some earlier attempts to build extensive LEO satellite networks ending in failure. Examples include narrowband Global Mobile Personal Communications by Satellite (GMPCS) systems, such as Iridium and ICO, as well as satellite broadband start-up Teledesic: Teledesic’s initial plan for 840 LEO satellites was eventually cancelled before a single satellite had been launched.[19]

3.4 WLAN (Wireless Local Area Networks)

Fixed-line broadband connections offer the fastest speeds but are confined to wired connections. However, subset of wireless technologies is expanding the reach of broadband in the 100 metre range, WLANs. By definition, a wireless local area network (WLAN) is defined as a local area network of which at least one segment uses electromagnetic waves to transmit and receive data over short distances. In a typical WLAN configuration, mobile devices tie into a wired, broadband network via an "access point". The radio in the mobile device communicates with another radio in the access point to pass data back and forth. It is worth noting that the phrase “wireless LAN” is somewhat of a misnomer, given that the wireless network typically extends the reach of a “wired” LAN, to which it is connected.

As mentioned earlier, the typical range of a WLAN connection is roughly 100 meters. This means that WLAN implementations typically branch off of a wired Internet connection. Indeed, WLAN technologies have been extremely popular with home users who use them to share one household broadband connection with several computers and devices. WLAN technologies are designed to spread a network connection over a short range but they are increasingly being used as backbone telecommunication infrastructure in developing economies with great success.

The WLAN market is currently dominated by one technological standard, IEEE 802.11b – commonly known as Wi-Fi. although several new variations are gaining popularity quickly.[20] This section will briefly examine Wi-Fi, as well as several other promising WLAN technologies.

802.11b (Wi-Fi)

IEEE 802.11b is the most popular WLAN technology in the world and is the most common choice for public hotspot access. IEEE 802.11b is known by its common name, "Wi-Fi" even though Wi-Fi is a certification trademark for devices that are tested and proven to pass interoperability criteria. Wi-Fi networks are appearing all over the world and show great promise for shorter-range connectivity over wide areas (see Box 3.8)

Box 3.8: Unwiring the all the streets of Philadelphia for USD 10 million

An ambitious plan to connect 1.5 million people in the city via Wi-Fi

The city of Philadelphia, Pennsylvania in the United States is looking into covering its entire 350 square kilometres with Wi-Fi connectivity, reaching all of the city's 1.5 million inhabitants. The network would likely require over a thousand hotspots to be strategically placed throughout the entire city, possibly on lampposts. The total cost of the project has been estimated at USD 10 million with yearly upkeep costing roughly USD 1.5 million.

The network could be a boon for some of the poorer regions of the city that have traditionally been unable to afford the high costs of broadband and Internet connectivity. While the plans have not been finalized, the city is considering making access to the network free, or at least highly subsidized to encourage its use.

While the project is still in its initial phases, it will certainly face some stiff resistance from broadband providers in the area. Philadelphia happens to be the headquarters of Comcast, the largest cable operator in the United States.

Source: http://www.mcall.com/business/local/all-wirelesssep01,0,1606449.story?coll=all-businesslocal-hed

Wi-Fi equipment uses the 2.4 GHz frequency band that is set aside in many countries for unlicensed use. The 2.4 GHz frequency range allows for transmission through objects (e.g. walls, ceilings) while also allowing high data throughput. In direct line-of-sight scenarios, Wi-Fi has a range of 100 meters. However, inside offices and residences, Wi-Fi's range is much lower. Directional antennas and amplifiers can be used to extend the range of 802.11b products provided the total power radiated does not exceed what is allowed by nationally applicable regulations.

802.11b is a half duplex protocol—whereby transmissions can either be sent or received at one give time, but not simultaneously. Interference can also be an issue as the 2.4 GHz range is also used by many cordless phones, microwave ovens and some wireless local loop (WLL) radio systems. Wi-Fi allows for a throughput speed of 11 Mbit/s under optimal conditions. As the amount of interference or distance between radios increases, the maximum connection speeds also decrease.

Table 3.1: Wi-Fi ranges

	Range	
Environment	**Maximum**	**at 11Mbit/s**
Outdoors / open space with standard antenna	225-300 m	45-100 m
Office / light industrial setting	75 - 100 m	30-45 m
Residential setting	40-60 m	20-25 m

Source: The Wi-Fi Alliance at: http://www.weca.net.

While Wi-Fi is surely one of the key technologies of the wireless Internet, the standard has some drawbacks that may hinder faster development of some portable Internet applications. First, Wi-Fi offers no quality-of-service guarantees for users. Essentially, Wi-Fi does not have a way to guarantee that transmissions arrive at a certain time or with a dedicated amount of bandwidth. This causes problems for applications such as voice and video that require dedicated and continuous streams. In times of congestion or interference, gaps can interrupt voice and video communication.

In addition, Wi-Fi is inherently insecure due to a fault in implementation of the RC4 encrpytion scheme. This flawed implementation means that the encryption can be broken in less than a day of heavy traffic using freely available programs on the web such as AirSnort or WEPCrack[21]. The Wi-Fi Alliance is working on a new security protocol that is meant to enhance the security of Wi-Fi. The new technology is called Wi-Fi Protected Access (WPA) and allows for much stronger encryption while "plugging" the hole left by the flawed RC4 implementation[22]. Despite the promise of WPA, researchers have been able to break it quickly if the the network is protected with a passphrase of words found in a dictionary[23]. In the end, WEP and WPA can only be seen as one level of a multilevel security implementation that should also include additional encryption such as Remote Authentication Dial-In User Service (RADIUS) protocol and Point-to-Point Tunneling Protocol (PPTP).

Finally, Wi-Fi radio equipment requires more battery power than many other wireless technologies, including CDMA and W-CDMA. This means that while portable Wi-Fi equipment may offer faster speeds than mobile phones, the amount of time a user can talk on a Wi-Fi enabled phone may be reduced.

802.11g

While Wi-Fi (802.11b) is the most popular and widespread WLAN protocol, a faster variation of the technology is starting to take the place of original Wi-Fi equipment around the world. 802.11g uses the same 2.4 GHz unlicensed band of spectrum as Wi-Fi but incorporates a different modulation technique to send data. 802.11g uses Orthogolnal Frequency Division Multiplexing (OFDM) and allows for much faster transmissions due to more efficient use of the spectrum. 802.11g networks have a maximum speed of 54 Mbit/s in contrast to 11 Mbit/s on traditional Wi-Fi networks. In addition, 802.11g equipment is backwards compatible with Wi-Fi, allowing "g" users to connect to "b" networks. However, 802.11g speeds are only possible if both the access point and the user's PC card use the "g" standard. Otherwise the network runs as fast as its slowest component.

As the price of 802.11g equipment approaches that of 802.11b products there should be a gradual shift from "b" uses to "g" products to take advantage of the increased speeds and better spectral efficiency of the standard

802.11a (Wi-Fi5)

Both 802.11's "b" and "g" variants work in the unlicensed 2.4 GHz band but 802.11a, sometimes referred to as WiFi5, takes advantage of the less-congested 5 GHz range. The "a" variant of the standard is not as common as Wi-Fi but and has been mainly adopted by enterprise for its fast speeds. Both Wi-Fi and Wi-Fi5 share a common heritage but are incompatible with each other. In addition to operation in a different frequency range, the modulation techniques of the two technologies are different. 802.11a makes use of Coded Orthogonal Frequency Division Multiplexing (COFDM), which sends data in parallel streams to increase capacity[24]. This allows for speeds nearly five times as fast as Wi-Fi.

Table 3.2: A vs. B vs. G:

The tradeoffs between different 802.11 technologies

	802.11a	802.11b	802.11g
Number of channels	Superior		
Interference	Superior		
Bandwidth	Superior		Superior
Power consumption		Superior	Superior
Range/penetration		Superior	Superior
Upgrade/compatibility			Superior
Price		Superior	Superior

Source: Adapted from Network World Fusion at: http://www.nwfusion.com/details/466.html.

Currently, 802.11 "b" and "g" products are less expensive and much more prevalent that 802.11a technology, with the majority of hotspots opting for "b" and "g" based networks in the 2.4 GHz range. However, 802.11a may succeed in the end due to the open spectral space it occupies. As the 2.4 GHz range become more crowded, users may gravitate towards "a" equipment to avoid interference. A decision by the ITU World Radio Conference in July 2003 to release additional spectrum for WLAN use in the 5 GHz range may also add to its popularity. Also, the introduction of combination "a", "b", and "g" wireless cards on the market should also help spur demand for "a"-based networks.

Table 3.3: Wireless networking technologies

Name	Speed	Range	Frequency	Notes
802.11b (Wi-Fi)	11 Mbit/s	100 m	2.4 GHz	Most popular and widespread[25]
802.11a	54 Mbit/s	50 m	5 GHz	Newer, faster, higher frequency
802.11g	54 Mbit/s	100 m	2.4 GHz	Fast, backwards compatible with Wi-Fi
802.16 (WiMAX)	70 Mbit/s	50 Km	10-66 GHz	QoS, Very long distance, line of sight req.
802.16a (WiMAX)	70 Mbit/s	50 Km	2-11 GHz	QoS, Very long distance, robust trans.
802.16e (WiMAX)	70 Mbit/s	50 Km	2-11 GHz	Mobile version.
802.20	(NA)	(NA)	(NA)	Mobile to 200 km/h, sm. spectrum bands
RadioLAN	10 Mbit/s	35 m	5.8 GHz	Specializes in wireless bridges
HomeRF	1 Mbit/s	50 m	2.4 GHz	Replaced by HomeRF2
HomeRF2	10 Mbit/s	100 m	2.4 GHz	QoS, better encryption, not widespread
HiperLAN2	54 Mbit/s	150 m	5 GHz	European standard, QoS, for voice/video
HiperMAN	NA	50 Km	2-11 GHz	European, compatible with 802.16a
Bluetooth	1 Mbit/s	10 m	2.4 GHz	Cable replacement technology, good QoS.
Infrared LAN	4 Mbit/s	~20 m	350’000 GHz	Same room only, no negative health effects
ZigBee	250 kbit/s	10-60 m	868, 915 MHz 2.4 GHz	M2M communication. Long battery life

Source: ITU, updated from “Birth of Broadband”, 2003.

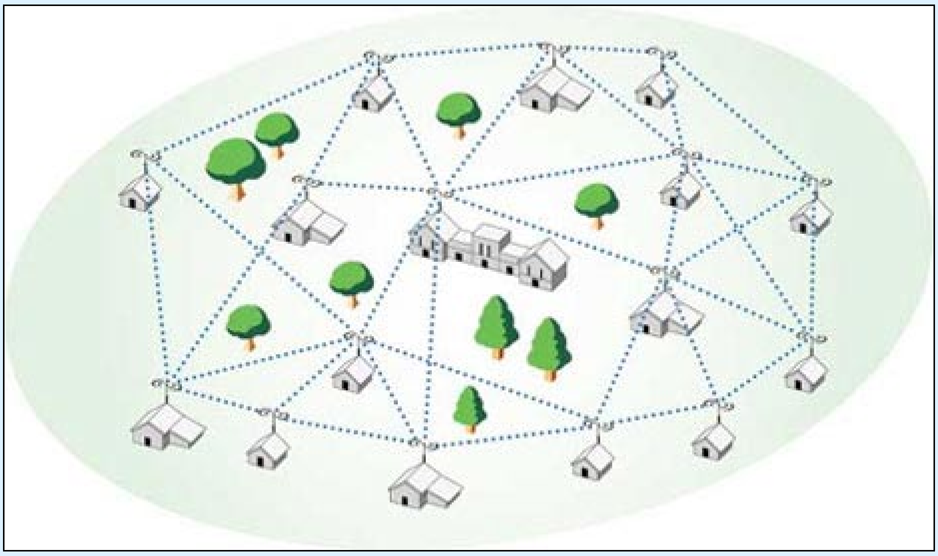
3.4.1 Mesh Networks

So far, this paper has looked at technologies that can branch out from the last wired point of presence (POP) in an area to end users. As engineers improve the ranges of wireless technologies the reach of the network extends further. While this type of “spoke and hub” networking from a POP is common for broadband access, new mesh networks are blurring the line between backbone and end-user connectivity as well as greatly extending the range of telecommunication networks.

In traditional networks, backbone infrastructure reaches out to smaller networks of users, with the end-user premises becoming the final points on the network. However, mesh networking technology changes the network architecture to allow for any device on the network to pass other traffic as if it were part of the backbone, enabling multipoint-to-multipoint networking. Mesh networks rely on each user also becoming a broadcaster in the network. Technically, each subscriber access point is also part of the routing infrastructure – acting as a relay for traffic destined to users further out from the source of the transmission (see figure 3.6). This topology offers incredible benefits for quickly expanding network access. As users are added to the network, the reach (and capacity) of the entire network expands.

Figure 3.6: Mesh networks

Each user on the network can use the broadband connection while forming part of the infrastructure that carries others' traffic.



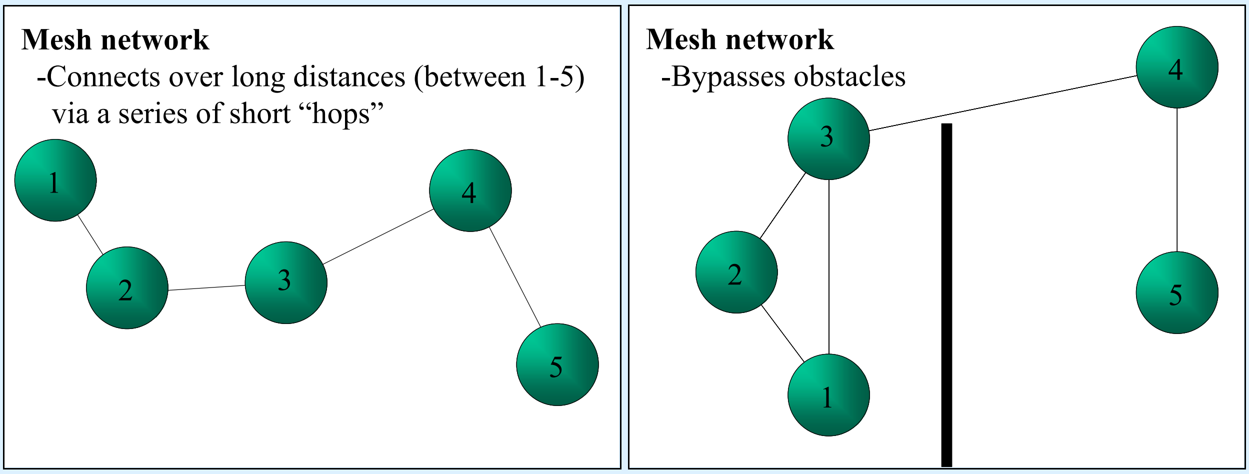
Source: “Wireless Mesh Networks for Residential Broadband”, Dave Beyer, Nokia. http://www.iec.org/events/2002/natlwireless_nov/featured/tf2_beyer.pdf .

One area where mesh networking could make significant inroads is rural access. A mesh network provider based in a metropolitan area could offer services in remote areas by “piggybacking” connectivity over a series of subscribers in the direction of the end user. Data traffic on the outer edge of the network in a remote village would only need a wireless connection strong enough to reach the next, closer subscriber to the metropolitan area. This second subscriber would then pass the traffic to another, closer subscriber and the process would continue until the traffic reached the backbone Internet connection. By using all subscribers as transit points, the mesh network can quickly reach distant areas with relative ease.

A key benefit of mesh networks is they do not require line of sight. Many fixed-wireless systems at high frequencies require line of sight in exchange for faster data transfer rates but mesh networks can work around obstacles by essentially routing to bypass them (see Figure 3.7).

Figure 3.7: Passing traffic in a mesh network

Each device (e.g. cell phone, PDA) in a mesh network can pass along other users' traffic across the network. This significantly extends the reach of the network and increases capacity with each new device.

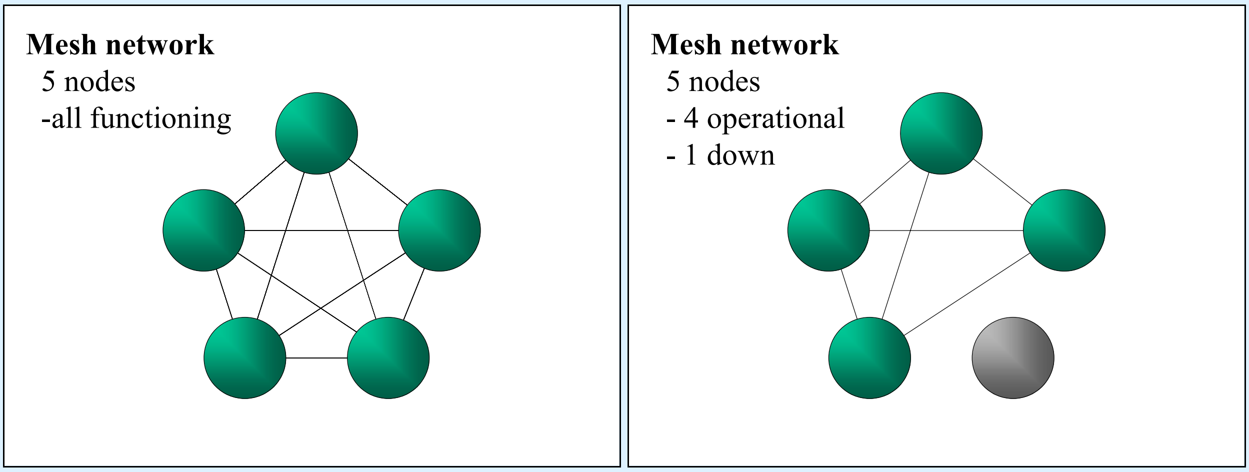


Source: ITU

Another key feature of mesh networks is their resiliency to the failure of a node. Just as the Internet can reroute traffic around problem areas, a mesh network can quickly reconfigure and network around trouble spots. This could be critical for developing areas where electricity power supply is not constant and nodes are commonly down (see Figure 3.8).

Figure 3.8: Mesh networks can re-route past problem nodes

One of the key benefits of mesh networking is its ability to re-route around problem nodes. The left figure shows a fully-functional network where all nodes can pass traffic. The right figure shows how the network can still function when a node fails.



Source: ITU

Box 3.9: Building mesh networks with WLAN

Multiple WLAN technologies can form the backbone and delivery connectivity for new mesh networking technologies.

BelAir Networks has developed a mesh network that makes use of two WLAN technologies to deliver broadband connectivity. The hotpots (shown at the right) are mounted externally and can provide Wi-fi (802.11b) access to computers up to 1 km away. The hotspots are then connected to each other in a mesh using 802.11a for the backbone connectivity. Since the two technologies work in different spectral bands, there is no interference from the backbone network transmissions and connectivity to users.

Currently the hotspot mesh uses 802.11a technology as the backbone transport but future versions will likely use WiMAX for its longer range and higher throughput.

Ottawa, Canada has begun rolling out the mesh network in association with Telecom Ottawa. However, some of the most promising applications of the mesh network should be in developing economies. A developing economy can use a satellite connection for international Internet connectivity. Then the VSAT terminal on the ground can disperse the connection over a mesh network of access points using WLAN technologies.

Source: BelAir Networks
http://www.forbes.com/personaltech/2004/06/14/cx_ah_0614tentech.html

Mesh networks show great promise for connecting rural areas and developing economies with high-speed access but there are also concerns about using mesh networks in certain circumstances. First, since each device (or node) on the network is functioning both to connect an end user as well as pass traffic, most of the devices must stay turned on. Second, battery life will decrease on portable mesh network devices since they are constantly operating to pass other traffic. Finally, some privacy advocates say they fear a system where users are passing large amounts of others' traffic. However, cable modem users and Internet surfers in general face similar risks from via their connections and the risks are minimal.

4 Technology and policy decisions

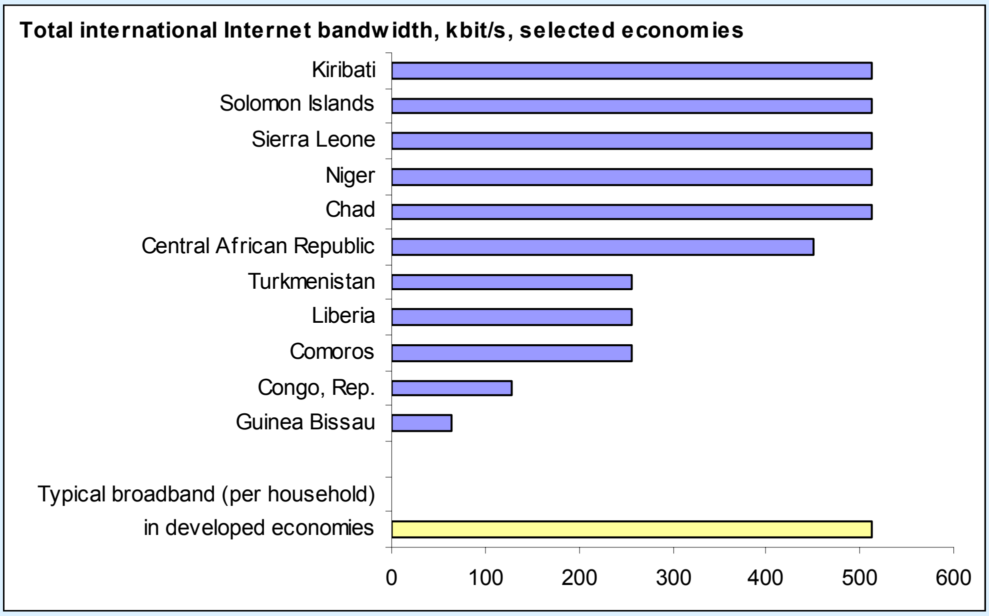
New wireless technologies show incredible promise for developing economies and developing areas. However, decision makers must decide which of these technologies can be successfully included in the current infrastructure, within existing geographical and economic constraints.

International Internet connectivity

The technologies described in Chapter three are simply tools that can be used to extend an Internet connection. Without international Internet connectivity however, even the best emerging technologies will be severely limited at bridging the global digital divide. This is increasingly apparent in developing economies where local content is scarce and web browsing and information gathering must be done via international sites. In fact, in many developing economies, the total international Internet connectivity is similar or less than a lower-speed broadband connection to a single home in developed economies (see Figure 4.1). Some economies have managed to keep the majority of their traffic internal, such as the Republic of Korea where roughly 80 per cent of traffic stays within the country. This has only been possible though because of the vast amount of domestic content in available in *hangul.* For users in many economies, especially those with small populations and minority languages, domestic content provision will be slow to evolve.

Figure 4.1: Our connections to the world

In some countries, the entire international connection to the Internet is slower than a typical, entry-level broadband offering in countries with broadband.



Source: ITU World Telecommunication Indicators Database

Therefore, it is vital that telecommunication firms in developing economies find ways to bring down the costs of international connectivity. In Africa, there are efforts being made to develop national and regional Internet exchanges as a way to cut down on the high costs of having to pass data among African countries via a third region, often in Europe and at high prices.

Costs vs. Bandwidth needs

The costs of Internet connectivity vary greatly around the world and are a function of the level of supply and competition on Internet routes. Providers in developing economies, on a whole, pay more per megabit of bandwidth than developed economies, even when their users have less money to pay for connections. This occurs often because telecommunication firms in underconnected economies must "lock in" to high satellite rates for an extended number of years to have any connectivity at all. Hopefully the new emerging wireless technologies such as WiMAX will increase competition and capacity on many routes and result in cheaper connectivity throughout the developing world.

In any case, policy makers must decide how much bandwidth per user or computer is feasible for the types of connectivity that users are willing to pay for. As both the Indian and Malaysian case studies have shown, innovative providers have been able to offer video e-mail and other multimedia technologies at low bandwidth by decreasing the quality of the picture, etc. Policy and decision makers must thus examine markets to determine how much users can and would be willing to pay for basic types of connectivity and then determine the demand for international bandwidth. If the costs and benefits are in line, the projects should proceed.

Rural vs. urban infrastructure

Rural and urban environments will require different types of technologies. In metropolitan areas with high population densities, the wireless technologies with shorter ranges but higher speeds can be implemented. Examples include Wi-Fi and mobile versions of WiMAX (802.11e). Wi-Fi equipment has fallen drastically in price making it particularly attractive for low power and densely distributed installations.

Entrepreneurs in rural areas will more likely use longer-range fixed-to-fixed connections such as WiMAX (802.16a). Theoretically, a long-range WiMAX connection could be used to connect a cyberkiosk in a rural area with high-speed connectivity for a low price. Other fixed wireless options such as FSO’s do exist but the installation costs are too high for connecting small, lower revenue cybercafe’s. Instead, FSO technologies are better suited to form medium-distance backbone connections that aggregate the connectivity of a larger city, for example, to pass on to a distant fibre optic drop point.

Operators in rural areas should also strongly consider mesh networking technologies because of their ability to quickly extend the network at low cost. Mesh networks could be ideal for smaller cybercafes and kiosks scattered throughout a larger area. While connecting each point directly via a wired connection would not be cost effective, a mesh network could quickly and easily use all nodes to pass information to and from each other. The current drawbacks for mesh networks in rural areas is their price. They are likely still out of range of developing economies but as prices fall, could soon become cost effective for the developing world.

Mobile phones as a digital bridge

One recent success in tackling a divide between developing and developed economies has been the astounding rise of mobile penetration rates throughout the developing world, particularly in Africa and other areas with very little fixed-line infrastructure. Mobile phones have been successful for a variety of reasons, including low infrastructure costs and pre-paid calling plans. This has helped users throughout the developing world gain access to ICTs that were previously out of their reach.

While the growth in penetration rates worldwide have been astounding, many are now asking if mobile phones might be the key to bridging the digital divide in large areas of the world where infrastructure, PCs and computer skills may be in short supply. Currently the correlation between broadband penetration and the number of mainlines per 100 inhabitants is high at 0.60, leaving many developing economies with few choices for a wired Internet experience. However, throughout the developing world, the number of mobile phone subscribers far outpaces the number of fixed lines, often by factors of 15 (see Box 4.1).

Box 4.1: The correlation of fixed lines and broadband

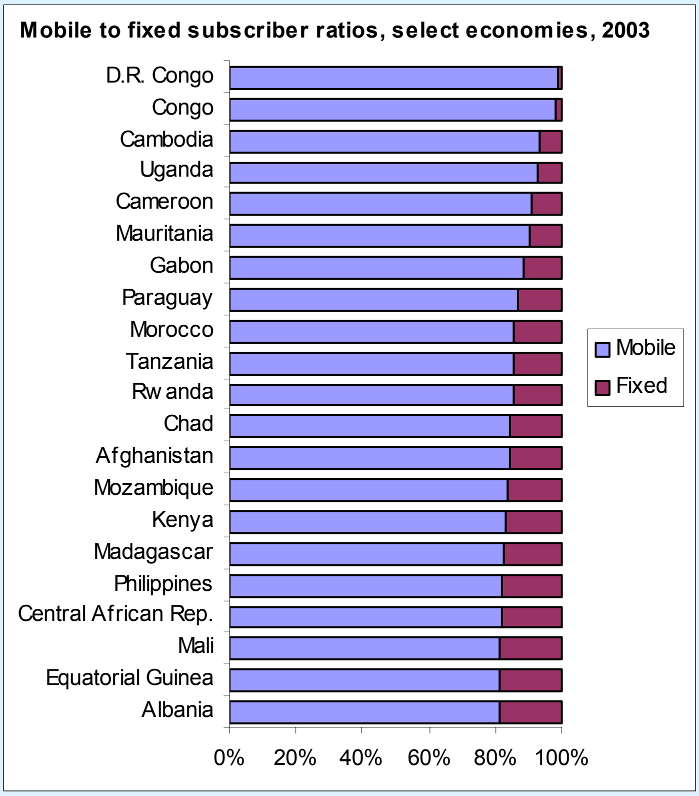
Wireless broadband technologies will be a vital element of the future information society of developing economies.

In 2003, the correlation between fixed-line telephones and broadband penetration was 0.60. This poses problems for telecommunication users in developing economies who want access to broadband but whose economy doesn't have substantial fixed-line infrastructure. For many users, the best alternative to PC Internet access over a fixed line connection may be a mobile phone.

Since mobile phones already account for the vast majority of telephone lines in many economies, the mobile phone would be an excellent candidate for delivering Internet connectivity to the widest range of users as possible (see figure at right).

Many mobile phone operators are beginning to include new, larger screens in their mobile phones that would be able to display more Internet text.

In addition, new technologies offering fast, broadband-type access to mobile devices are on the verge of becoming a reality.



Source: ITU World Telecommunication Indicators Database

Therefore, advancements that can bring Internet usability to mobile devices should be a boon to Internet connectivity throughout much of the world. What remains to be seen is how mobile devices will need to adjust to offer experiences similar to those available to web surfers on a PC. While the experience will definitely be different, the key information available to mobile and wired broadband subscribers could be quite similar.

Policy makers face many difficult questions with regard to implementing new wireless technologies in their economies. Price remains a key, unknown variable that will largely determine whether these technologies will help increase connectivity or remain tools only for users in wealthy nations. However, as Wi-Fi has shown, there is demand for low-cost, high-speed wireless connectivity and markets have responded with healthy competition and lower prices for consumers. Hopefully this can be repeated.

5 Technology as a digital bridge (experiences)

One of the best ways to understand how to build better digital bridges is to examine specific examples of ICT initiatives around the world that are having an impact. This section will look at a range of initiatives and projects around the world that use clever approaches to extend the reach of ICTs.

5.1 Stanford Initiative for Voice over Email

The Digital Visions initiative is a prime example of how Information and Communication Technologies (ICTs) can be used to help bring a sense of self-actualization and connectivity to developing countries[26]. Digital Visions, sponsored by the Reuters CSLI Digital Visions Fellowship at Stanford University in California, USA is embarking on a humanitarian project aimed at bringing local content/software ICTs to the under priviledged. The main overarching goal of the Digital Visions initiative is two fold. The mission is both to increase the number of ordinary people that can use a public Internet centre for the same investment and to surmount obstacles of illiteracy, minority languages and/or computer illiteracy, which are currently serious hampers in the path of realizing the goal of digital inclusion for everyone. The initiative is in collaboration with Philips Research UK, which operates under Philips Global Brand Management.

Digital Visions has established an inexpensive, simple-to-use voice-email device, akin to a combination of an MP3 player with a digital dictaphone. The handset is cheap, hand held and is based on store-and-forward technology. This device enables a blind individual in a rural region for instance, to be able to have his or her email read out aloud to him/her via the email-to-voice end user terminal previously mentioned. The voice-email device enables contact in the following manner: first, someone desiring to check his personal email could do so by browsing icons on the voice-email device looking for emails in various folders or from various senders. Then, he could use the voice-email device to listen to the emails he desires to hear. To reply, the individual would choose his reply recipients by icon or by voice dialling of email IDs. Once the reply recipients are identified, the person can easily dictate an email response which is then reviewed and encoded using Voice codec technology (similar to VoIP, MP3). All of the above can be done at the individuals' own convenience offline. The person would then dock and synch files as well as recharge the batteries of the email-to-voice device at the closest telecentre without queues.

Security to each individual account is maintained at the various telecentres by a tag registration and voice authentication system, both of which are triggered when a new individual logs on.

The current focus of Digital Visions is on the urban slums of Brazil, and representatives from Digital Visions have traveled to Brazil in an initial effort to spread word of the initiative and gain local support. Slight changes to the concept to suit people using their own languages in isolated rural areas or urban poverty such as in India and Thailand, also hold potential.

Digital Visions also has exciting plans for the future applications of this email to voice handset. It is thought that this handset may also be very helpful in the future as regards webcasts or voice bulletin boards of specialist regional content (such as education, health, trade, agriculture). The device could also act as a small device display for emailed pictures as well as for musical entertainment. Lastly, it is thought the device could also act as a medium to capture and spread digital radio broadcasts.

Initiatives such as these that both extend telecentre reach into the households of the underprivileged and also cater to society's most vulnerable (such as the blind, the illiterate, speakers of a minority language and those unfamiliar with computers) act as models for future projects which can use already existing technology to act as a 'bridge' across the digital divide. One of the major future initiatives of Digital Visions is to get a variety of regional services established in developing countries that would follow the model outlined above. This makes an effective and bold statement towards using technology as a tool to reduce today's ever-widening digital divide.

5.2 Wi-Fi bus in rural India

In the Dadobalapur district of Karnataka in India, a quiet wireless revolution is unfolding. In the not-so-distant past, tele-service applications could only be accessed from a taluka (an administrative and geographical block providing tele-services such as e-mail and Internet access), involving a round trip of up to 100 km. Now, residents can save time and money by accessing the services offered by the taluka from their village computer.

Stemming from the need to create an online database of land records, the project was set up by the Karnataka Government in collaboration with the US-based technology consulting company, First Mile Solutions. The project involves a bus equipped with a computer and Wi-Fi, which drives around stopping in different communities to transfer data from and to the community's local computer.

The project uses Wi-Fi equipment and runs at 2.4 Ghz, with a DakNet Mobile Access Point that is mounted on and powered by a vehicle. In a normal day's work, the DakNet-enabled vehicle drives past a village kiosk where it receives and delivers land record queries and responses. This information is synchronised with a central database on a daily basis. Data is transferred through the access point, which automatically and wirelessly picks up and drops off data from each kiosk on the network. The transportation of data can occur up to a radius of 1.25 km of the kiosk and after the bus arrives. This type of store-and-forward connectivity is particularly appropriate for email and for electronic transmittal of remittances.

The Karnataka undertaking is a further example of how Wi-Fi technologies can actually deliver connectivity to underserved populations at a fraction of the cost of alternative wired or wireless technologies[27].

5.3 India’s Wi-Fi lake

With the recent de-licensing of radio spectrum for spread-spectrum packet-based communications in India, wideband connectivity has been extended—using Wi-Fi technology—to reach sparsely populated communities, through a partnership between the Department of Tourism and private companies.

Local boats, called shikaras, are that are used to travel on the five kilometre-wide lake, and are connected to stationary houseboats on the lake. Houseboats on the lake and the shikaras have provided housing for tourists and residents for centuries. These houseboats are have been equipped to provide the lake’s Wi-Fi network connectivity since 2003. The backend connectivity is provided via two domestic ISPs who provide a connection speed of 2 Mbps.

The Dal Lake Wi-Fi project was envisioned by Dax Networks and was implemented in partnership with the Indian Department of Tourism, the state of Jammu and Kashmir (J&K) and an ISP, Ipeaks. A similar Wi-Fi marine service was also set up off the shore of Lake Michigan in the United States in 2004, covering over 32 km.

Now that the project has been successfully implemented, Dax has plans to duplicate the model at other lakes in India—Nainital, Hussain Sagar, Kodaikanal and Kumarakom. During the pre-launch of the project, a representative of Dax Networks stated that this Wi-Fi lake is “not just a bold statement, but also a move that can have cascading effects in the state (of J&K) and a positive rub-off on the overall image of the country”. This “positive rub-off ” will be no doubt aided by the fact that the endeavour was not as expensive as one would think with the entire operation costing Dax approximately USD $21, 276.

The project was not without challenges, however. Obstacles had to be overcome to obtain approval from the J&K government, the Tourism Department and local ISPs. Difficulties were also faced in finding the necessary manpower, resources and even electricity. But it is now operational.

Figure 5.1: Sunset over India’s Wi-Fi lake

A shikara against the sunset on Dal Lake.

Source: IndiaMART.com

6 Conclusion

The digital divide is, and will continue to be a daunting problem for the world for the foreseeable future. However, there is still reason to hope that the situation can, and will improve as technology advances, policy develops and incomes rise. The rapid pace of change in the telecommunication sector can bring with it a sense of despair in economies where technologies are slow to arrive and difficult to implement. However, this rapid change may also hold the key to unlocking a truly global and inclusive information society.

Developed economies, where much of the telecommunications research and development takes place, will benefit from the new mobility offered by the portable Internet and new wireless devices. These advances, however, are not solely for developed economies. In fact, it is the developing world that stands to gain the most from adapting and implementing new wireless technologies as a substitute for traditional infrastructure.

As this paper has shown, developing economies can take many lessons from the experiences seen in promoting broadband and mobile connectivity in richer countries. Government promotion of fibre-optic backbone infrastructure has been very successful at enabling the broadband expansion in several economies.

Investing in fibre backbones may seem like a costly and risky venture, especially in economies where a host of other needs are at least as pressing. However, while the projects may take some time to yield their fruits, they can also enable a vast range of services previously out of reach of many citizens in developing economies.

Once fibre lines, or other suitable connectivity is established internationally, the furthest reaches of the wired network can be extended using new and evolving wireless technologies to reach deep into rural areas that have historically been underserved. Long-range wireless technologies such as WiMAX can extend a connection over great distances to villages from the end of the wired network. Then shorter-range technologies such as Wi-Fi and IMT-2000 can further extend the network from the newly connected village.

Policy makers throughout the world are faced with the harsh reality of economic scarcity; there is simply a limited amount of resources that must be allocated in an economy. However, bridging the digital divide may not need to be an "either/or" proposition. Rather than choosing between telecommunication investment and health care, targeted telecommunication investment could build infrastructure that could help reduce medical costs and make care more efficient. Similar arguments can be made for education. Connecting schools with fast Internet connections gives students much better access to educational materials and can make their school time more productive.

The emerging technologies discussed in this paper are exciting and may offer the developing world a chance to leapfrog ahead in connectivity. Many of the technologies are not yet mature enough for widespread use but policy makers should follow their progress and carefully watch selected rollouts throughout the world. Korean WiBro is one such technology that, if successful in Korea, could pave the way for mobile cell towers throughout the world to be retrofitted with high-speed portable and mobile connectivity. This could be a fantastic boon for nations around the world, especially those where mobile penetration is much higher than traditional fixed lines.

Wireless technologies may indeed offer the best path for finally bridging the digital divide and creating an equitable and efficient information society for all.

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[1] See the World Summit on the Information Society (WSIS) website at: http://www.itu.int/wsis.

[2] The Task Force Report on Rural Connection Mission 2007: Every Village a Knowledge Centre by Professor Ashok Jhunhjunwala, May 2004.

[3] See the Indian case study at: http://www.itu.int/digitalbridges/docs/casestudies/India.pdf.

[4] See "Reykjavik leads the way on fiber to the curb" at: http://www.nwfusion.com/research/2004/0607iceland.html

[5] See the Indian case study online at: http://www.itu.int/digitalbridges/docs/casestudies/India.pdf.

[6] See http://searchmobilecomputing.techtarget.com/sDefinition/0,,sid40_gci505610,00.html for a brief explanation of W-CDMA.

[7] See Nokia's article "High Speed Downlink Packet Access (HSDPA) for WCDMA" at: http://www.nokia.com/nokia/0,,53713,00.html for more information.

[8] See the TDD definition at: http://www.mpirical.com/companion/Multi_Tech/FDDDuplex.htm

[9] See GSM World at: http://www.gsmworld.com/technology/gprs/intro.shtml#1 for detailed information on GPRS.

[10] See http://www.mpirical.com/companion/GSM/EDGEEvolution.htm for a brief explanation.

[11] See http://www.yenra.com/edge-3g/ for more information on EDGE rollouts.

[12] See the WiMAX Forum at: http://WiMAXforum.org/tech/tech.asp.

[13] See Webopedia's definition at: http://wi-fiplanet.webopedia.com/TERM/o/OFDM.html.

[14] The WiMAX forum has detailed information on 802.16 at: http://WiMAXforum.org/tech/tech.asp.

[15] See "Intel: WiMAX in notebooks by 2006" at: http://www.theregister.co.uk/2004/07/02/intel_WiMAX/

[16] More information on the 802.16 and 802.20 comparisons is available at: http://www.wirelessweek.com/article/CA403412?text=gohring&stt=001.

[17] For more information, see Intelsat's presentation at the ITU Promoting Broadband workshop at: http://www.itu.int/osg/spu/ni/promotebroadband/presentations/14-fischer.pdf.

[18] For a short introduction to satellite communications see: http://www.infoplease.com/ce6/sci/A0813065.html.

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[20] See the official Wi-Fi site at: http://www.weca.net/OpenSection/index.asp.

[21] See http://www.airscanner.com/pubs/wep.pdf for more of the weaknesses with WEP.

[22] See: http://www.wi-fiplanet.com/tutorials/article.php/2148721 for more information about the benefits of WPA implementation.

[23] See "WPA's Little Secret" at: http://wifinetnews.com/archives/002453.html.

[24] For more information on 802.11a's modulation technique see: http://www.nwfusion.com/details/465.html.

[25] 802.11b arrived before 802.11a but the letters refer to the order in which the different standards were proposed.

[26] More information on the initiative is available at: http://www.stanford.edu/~prankin/eng/index.html**.**

[27] See: http://infotech.indiatimes.com/articleshow/266500.cms for more information.