The Economic Advantage of Wireless Infrastructure for Development

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Foreword

This paper explores wireless Internet infrastructure and associated costs in health, education, government, and commercial applications. It analyzes the cost-effectiveness of wireless provision of access and services in underserved (especially rural) areas, examining applications around the world. Current private sector activity in Latin America and the Caribbean is presented along with government and international development organizations' efforts to promote wireless technologies in development projects. Attention is given to the policy barriers preventing the private sector from developing these technologies in the context of underserved markets, the role of government in providing universal service, and issues of spectrum allocation. Finally, recommendations are proposed for the IDB's future involvement in the area of wireless applications for development and wireless technology policy.

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Introduction

The World Summit on the Information Society (WSIS) asserted the importance of the use of information and communication technologies (ICTs) for the achievement of the Millennium Development Goals (MDGs).[1] Wireless Internet technologies deserve particular attention not only because of their importance to the development process, but also because of its ability to reduce the costs of providing ICT access and ICT-enabled services to underserved areas.

Access in underserved areas presumes the existence of backbone infrastructure connecting to the Internet (traditionally made of fiber optics or copper) as well as a means of distributing this uplink connection to underserved areas. Some analysts maintain that backbone networks and distribution services are the largest single cost item in the provision of access. The two most relevant wireless Internet standards for low-cost access provision are Wi-Fi and WiMax. Wi-Fi has commonly been used as a distribution service providing a "cloud" of connectivity in "hotspots" and has become increasing popular in the last few years in urban centers around the world. WiMax technology is based on an emerging international standard that will revolutionize the provision of Internet services, serving either as a low-cost alternative to copper and fiber optics for backbone infrastructure in rural areas or as a distribution service capable of serving a large area.[2] For remote areas with no proximate infrastructure, VSAT satellites promise the ability to connect communities to national networks and government services.

The cost of providing access to voice and data networks using wireless technologies, even in rural areas, approaches US$300 per subscriber, compared to US$1,000 for fiber optic or copper networks in urban areas. In addition, wireless technology does not imply significant sacrifices in quality or throughput. Furthermore, while copper or fiber optics usually cost between US$20,000 and US$40,000 per kilometer of connectivity, hundreds of kilometers of wireless connectivity can be provided for US$50,000 (Best, 2003). This cost advantage (which is widening with increasing global use of wireless technologies and resulting economies of scale) can be used to connect rural areas in a cost-effective and even self-sustainable fashion.

Given its unprecedented cost advantages, wireless technologies promise more than a cost-effective way of providing access to underserved populations. For governments, wireless technologies offer a way to deliver valuable services (such as health and education), as well as government services, to citizens living in remote areas.[3] In some cases, rural populations can pay for the capital costs of any necessary equipment as well as the recurring costs of Internet connection. For example, poor rural residents of Tamil Nadu, India, have funded telecenters for as little as US$3 in revenue per day by using a wireless technology similar to WiMax called corDECT. An analysis of Latin America and the Caribbean shows that the same could be accomplished in the region for approximately US$3 to US$14, covering between 100 and 500 households (for a more detailed analysis, please refer to the third section). Recurring monthly costs for wireless Internet connectivity for education purposes in Sucre, Colombia, amount to US$5 per student per year. The latent demand for communication services from poor rural populations could bring financing and sustainability even without government aid.

There have been successful applications of wireless technologies throughout the Latin American and Caribbean region and around the world. For example, in the Dominican Republic wireless

[1] A declaration was issued during the first phase of meetings, which were held in Geneva, Switzerland on December 10 to 12, 2003).

[2] WiMax technology has a range of over 30 miles and a radius of up to 7 miles.

[3] Including such remote areas as the Andes or the Amazon. See case study on the Amazon Association Project in the fourth section and the efforts of the EION Wireless in the Andean countries in the fifth section.

coupled with voice-over-IP (VoIP, a standard which allows voice messages to be sent over the Internet instead of using dedicated phone lines), lowered the cost of calls to Santo Domingo by 40 percent. An Internet connection in remote areas of the Amazon brought expert health care and e-government services, and even commerce, to Caboclo indians. In Uganda, wireless devices helped perform epidemiological surveys, facilitated the delivery of medicines to rural villages, and kept doctors informed about new treatments for endemic diseases. Finally, in Madhya Pradesh, India, residents were willing to pay significant fees to make use of an Internet-based system to communicate with the government. For governments, wireless Internet technologies are a cost-effective social development tool, and also have the potential to spur economic growth. Evidence indicates that if governments create a supportive policy environment, the private sector will make investments in underserved areas.

In sum, experience around the world shows the existence of hidden demand and supply pressures in rural and underserved markets. In Chile, the private sector is willing to invest in rural connectivity even in the absence of subsidies because of the cost advantages of wireless technology. Experience in Mexico shows that, in addition to the latent demand for wireless technology, there is also a willingness to supply these markets. Small wireless Internet service providers (WISPs) in Mexico are planning to cover more than 70 percent of the nation's population, competing or cooperating with the large telecommunications operator, Telmex. Although in the past large telecom operators were not interested in serving nonurban areas, they are now re-examining their assumptions that service to rural markets involves high costs and low demand. Dynamic factors such as pressure from small competitors is forcing the large operators to compete in rural areas. In spite of what some characterize as a "somewhat stringent" regulatory environment in Mexico, competition is increasing and small players are indeed entering the market (Wireless Internet Institute, 2003a).

Given the increasing viability of providing services to rural and underserved markets, it behooves governments to enact policies that ensure competition. The history of close, if not direct, relationships between telecom incumbents and the government has created significant barriers to free competition and market entry. Small WISPs depend, to some degree, on these incumbents for an "uplink" connection to fiber or copper infrastructures, which are owned by incumbent telecoms. The WISPs and other distributors face numerous problems, such as refusal or delay of uplink interconnection and predatory pricing, sometimes in full view of the regulator. Regulatory bodies must be fully independent from incumbent telecoms and enforce a common set of rules in order to encourage competition whenever possible. In addition, the most valuable service that WISPs or community Internet "telecenters" can offer is voice-over-IP, especially in underdeveloped rural markets. According to Best (2003), eight times as many rural consumers are necessary to sustain a telecenter that does not offer voice-over-IP compared to voice-enabled telecenters. However, the lower cost and competition from voice-over-IP technology generally leads to significant resistance from landed telecoms. Thus, governments have an important role to play in balancing the interests of incumbent telecoms with those of small WISPs and socioeconomic development.

When the private sector does not consider a particular area viable for infrastructure investment, governments can intervene to help provide that infrastructure. These interventions, which were historically used to bring phone services to underserved areas, are called universal service regimes and have taken the form of either subsidies or servicing obligations. In the past, given the factors affecting the cost of copper and fiber technologies, telecom incumbents have been fairly uninterested even in subsidized development. However, with wireless technologies, there is increasing interest in serving underserved markets. Successful universal service proposals should therefore incorporate elements of the private sector development model discussed above to address the needs of underserved populations. A successful proposal for a universal service regime might thus involve low entry barriers, including license exemptions or tax breaks, permission to offer valuable services like voice-over-IP, and promotion of small business models through either low interest loans or fair inter-connection rules.

Another important responsibility that governments have in relation to wireless technologies is regulating the radio spectrum. Broadcast radio developed in many countries with strict standards regarding power and bandwidth, but wireless Internet technologies, which also use the radio spectrum, have developed in the United States and Europe in the unlicensed 2 GHz and 5 GHz bands. Although over 130 countries signed a preliminary international agreement at the World Radiocommunication Conference in July 2003, its implementation has been slow.

Aligning the wireless Internet spectrum in these bands, whether licensed or not, will allow Latin American and Caribbean countries to take advantage of existing economies of scale for wireless devices. Although some experts argue against it, licensing is to be expected; it is also likely to be relatively cheap and scaleable.[4] A clear and consistent regional strategy on spectrum management will facilitate private sector investment, since investments in a particular technology could then be leveraged throughout the region.

The Inter-American Development Bank has the opportunity to take a leadership role in shaping the potential of wireless technologies in Latin America and the Caribbean. One overarching goal, of course, is that the Bank should not in any way replace or hinder the significant efforts of the private sector. However, given its unique position as advisor to both the public and private sectors, the Bank can stimulate discussions to promote wireless policies that foster competition and advance development objectives. The Bank could also advice on whether the development of wireless technology should be led by the private sector (with commercial ends) or by the public sector (with development objectives).

As a donor and project financier, the Bank has the opportunity to demonstrate the significant cost savings from using wireless technologies for access and service provision by undertaking pilot projects in the region. Using wireless infrastructure to connect telecenters in underserved areas could provide data on sustainability and also provide valuable input for establishing best practices. The IDB can promote cost-effective development in the entire region by becoming a vehicle to share best practices.

Lastly, because a regional policy consensus is essential for taking advantage of existing economies of scale and attracting foreign and regional investment, the IDB could undertake a comprehensive analysis of spectrum policy in the region in order to promote a regional policy consensus. Such a consensus could generate a wave of economic development in underserved areas and support a burgeoning private sector.

For the reasons discussed above, the Bank has the opportunity to utilize wireless technologies to achieve its objectives of sustainable economic growth, poverty reduction, and socioeconomic equity throughout Latin America and the Caribbean.

This paper explores the opportunities created by wireless technologies for access and service provision, especially in underserved areas. In order to provide a basic technological framework for the discussion, the second section presents a brief primer on wireless technologies and how they relate to other applications, such as voice-over-IP (VoIP). These technologies will be discussed in the third to sixth sections, where cost-efficiency, applicability and policy implications are analyzed.

The third to sixth sections present the bulk of the research on wireless applications for development. The third section, which deals with the cost advantage of wireless applications, provides an economic framework for evaluating wireless technologies for connectivity, by using the model of SARI in India, and an estimate of the cost for providing services, such as education, by examining the example of Red Sucre in Colombia. The fourth section explores compelling examples of wireless technology applications in Latin America and the Caribbean, and other countries. The fifth section highlights private and public sectors activities in the region in terms of business models and policy design. The sixth section discusses policy implications. The last section proposes a set of actions for future IDB involvement in wireless technology.

[4] This observation is based on an interview with Edward Malloy, USAID, cited in the fourth section.

Background Information on Wireless Technology

Although fixed copper lines used to be the standard in communications infrastructure, Paul Gelsinger, Intel's CTO, admonishes that developing nations should "say no to copper" and instead "deploy wireless aggressively" in creating broadband infrastructure (*Computer Weekly*, June 27, 2003). Precisely why wireless technologies should be used instead of prevailing technologies requires a deeper understanding of what the various technologies are and how they are related to economic development. For the purposes of this paper, we will refer to "wireless technologies," "wireless Internet technologies" and "wireless" fairly interchangeably. "Wireless applications" refers to the services that depend on wireless Internet infrastructure.

WIRELESS INTERNET TECHNOLOGIES

Wi-Fi and WiMax

The wireless Internet IEEE 802.xx standards are named after the governing body (the Institute of Electrical and Electronic Engineers, IEEE) and the set of protocols for wireless device communication, which are all classified under 802.xx. The most important standards for business and economic development are the 802.11 standard, otherwise known as "Wi-Fi" (i.e., wireless fidelity) and the emerging 802.16 standard known as "WiMax" (fixed wireless standard).[5] The primary difference between the two is that Wi-Fi has been commonly used to connect devices in a relatively small area (less than 300 feet) whereas WiMax is envisioned for distances between 1 and 30 miles or more. All the 802.xx standards use a "packet-based" approach to communications, breaking up messages into small chunks that do not require a dedicated line. As a result, in many cases, they are able to survive temporary service disconnections. Mobile phone technologies like CDMA and 3G, however, require a more dedicated circuit-switching methodology, akin to the dedicated physical connection required for wire-based phone calls.

Connection to Backhaul Infrastructure

WiFi or WiMax devices do not assure an Internet connection. In order to have a connection to the broader world and the Internet, one of the devices in the wireless network, called an "access point," must be connected to a "backbone" or "backhaul" communications infrastructure. In most countries, this is a wired structure (such as copper and fiber-optic cable) that is usually handled by a major telecommunications company licensed by the government. The telecom company, in turn, gains access to the Internet through a semi-exclusive license to a fiber optic cable, often from only one of a few port cities, that connects physically to other countries and the broader Internet. WiMax's large physical range offers the possibility of connecting communities that were previously too far from established backhaul infrastructure. Alternatively, in those areas where connection to wired infrastructure is not economically practical, such as in remote rural areas, satellites (VSATs) can be used as an "uplink" to the Internet instead of connecting via the wired backbone.

Frequency Spectrum and Bandwidth

Radio standards have allowed radio stations to broadcast with little interference at a particular frequency, range, and bandwidth. For example, in the United States, the FM standard is allocated within a frequency range of 88.1 MHz to 108.1 MHz, with a station getting just under 1/100 of this bandwidth (200 KHz). Therefore, up to 100 different stations can broadcast in the FM band in the same area without interference.

Each wireless standard, like a radio standard, employs a particular band of the frequency spectrum, allowing only a given number of channels for data exchange. The wider a given spectrum band or the more efficient the protocol to transmit over a given band, the higher the capacity for data transmission or simultaneous usage.

[5] WiMax allows for long-range wireless communication at 70Mbit/s over 50 kilometers. It can be used as a backbone Internet connection to rural areas.

Wi-Fi – 802.11 Standards

The Wi-Fi standards (which are contained within IEEE 802.11) have generally been used for "hotspots" for Internet connectivity in companies or cyber-cafes or "hotzones" in larger geographic areas. There are three prime sub-standards 802.11a, 802.11b, and 802.11g. The first two use the 2.4-2.4835 GHz frequency spectrum and the last uses the 5.725-5.85 GHz band. Because the latter frequency spectrum is wider and the protocol is written for more efficient data exchange, it can support 12 channels, whereas the former can only support three (Benson and Gold, 2002). In the United States and many other countries these frequencies have been reserved for unlicensed use. The throughput, or primary measure of data transfer speed, is up to 54 Mbps (Megabits-per-second) for 802.11a and 802.11g, and only up to 11 Mbps for 802.11b.

WiMax – 802.16 Standards

WiMax standards (which are contained within IEEE 802.16) increase the range of wireless communication to between 1 and 30 miles, depending on the desired use and the particular standard. Their sub-standards are 802.16d, and 802.16e, and all have different intended uses. Specifically intended for "last-mile" competition against broadband services like DSL (digital subscriber line), 802.16d devices primarily operate in the 5.8 GHz range and can reach data rates of up to 70 Mbps at up to 30 miles (although there is a trade-off between distance and throughput, since both can be affected by uneven topography or bad weather). It should also be noted that with wireless signal repeaters, the signal can be extended beyond 30 miles at a loss of latency and response time in doing so. The 802.16e operates in similar bands, with a channel size of only 10 MHz compared to 20 MHz, giving it roughly half the maximum throughput at 35 Mbps and half the typical range, but gaining the ability to better handle mobile users.

Point-to-Point (P2P) vs. Point-to-Multipoint (P2MP)

Wi-Fi and WiMax offer two methods for delivery: point-to-point and point-to-multipoint. Point-to-point connectivity generally solves the problem of connecting an access point to its fixed-line backbone uplink, but can be used repeatedly to extend the reach of an uplink to a remote area. The typical maximum distance of one multipoint connection is roughly 6 miles for Wi-Fi and 30 miles for WiMax. By contrast, Point-to-multipoint connections are generally used to provide a "cloud" of connectivity that can be utilized by multiple devices simultaneously, from laptops to personal display assistants (PDAs). Wi-Fi provides this cloud at ranges of up to 300 feet from the access point, and WiMax at ranges of up to seven miles. These distances can be limited by local topography, weather conditions and obstructions. Obviously, wireless networks operate well when the communicating devices enjoy a direct line of sight, although new IEEE standards are being created to deal with non-line-of-sight (nLOS) situations as well, albeit sacrificing some range or throughput.

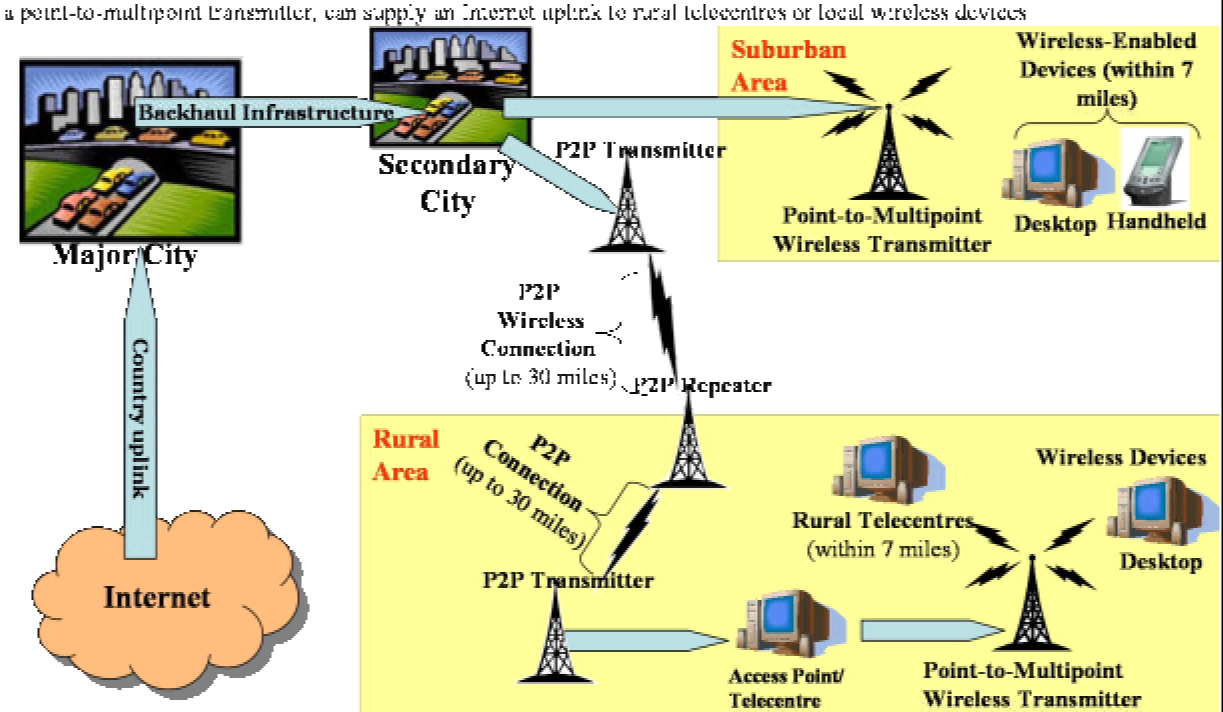
Fixed vs. Mobile Wireless – 802.20 and 3G

Generally, the 802.11 and 802.16 standards imply fixed networks where users are not moving very fast or frequently. However, there are two caveats. First, the 802.16e standard trades off some bandwidth for mobility, since it is designed for user movement at speeds of up to 40 miles per hour. Secondly, the 802.20 standard is designed for high-speed mobile users in particular, allowing travel at higher speeds. The 802.20 standard demonstrates the popular belief (confirmed by microchip manufacturer Intel in a 2004 white paper entitled "Broadband Wireless: The New Era in Communications") that so-called "fixed wireless" standards are converging with mobile wireless standards such as those used by cell phones (3G and CDMA). In fact, according to Sam Churchill ("IEEE Scores 802.16d" posted June 25, 2004 on dailywireless.org), the 802.20 standard could create competition for 3G's upcoming successor, 4G.

From the mobile wireless side, it must be noted that standards such as 3G supplanted their predecessors, in part, by offering the ability to transfer data at higher throughputs. This has major implications for broadband. Indeed, the Intel white paper envisions a technological future with a "best-connected goal, where broadband technologies such as 3G, UWB, Wi-Fi, and WiMax

Box 1 – Sample Access Model for Suburban and Rural Areas

This stylized example shows that where backhaul infrastructure (copper and fiber optic cable) is available and already serving cities, Internet access can readily be provided to suburban areas simply by using a point-to-multipoint wireless transmitter to broadcast wireless signals to suburban areas as far as 7 miles, using the emerging Wi-Max (802.16) standard. The same Internet uplink can be ferried by a point-to-point (P2P) transmitter to a rural area up to 30 miles away. Using a P2P repeater, this same signal can reach even further, perhaps a multiple of 3-4 times as far, sacrificing response time with each repeat. Once received in the rural area, the Internet uplink can provide a local access point with connectivity, and using a point-to-multipoint transmitter, can supply an Internet uplink to rural telecentres or local wireless devices.



will work synergistically to deliver secure data with anytime, anywhere connectivity."

Very Small Aperture Terminals (VSATs)

VSATs use a small earth-bound satellite dish to achieve an uplink to the Internet. This uplink connection can be shared via multiple access points using wireless dissemination. The monthly recurring cost of an uplink Internet connection through a VSAT can be very high (up to US$2,500 per month). As a result, Internet connections must either be subsidized or shared across many users to be sustainable. Using a VSAT uplink implies a self-contained architecture, in the sense that the system does not require any other resources except perhaps electricity.

RELATED APPLICATIONS

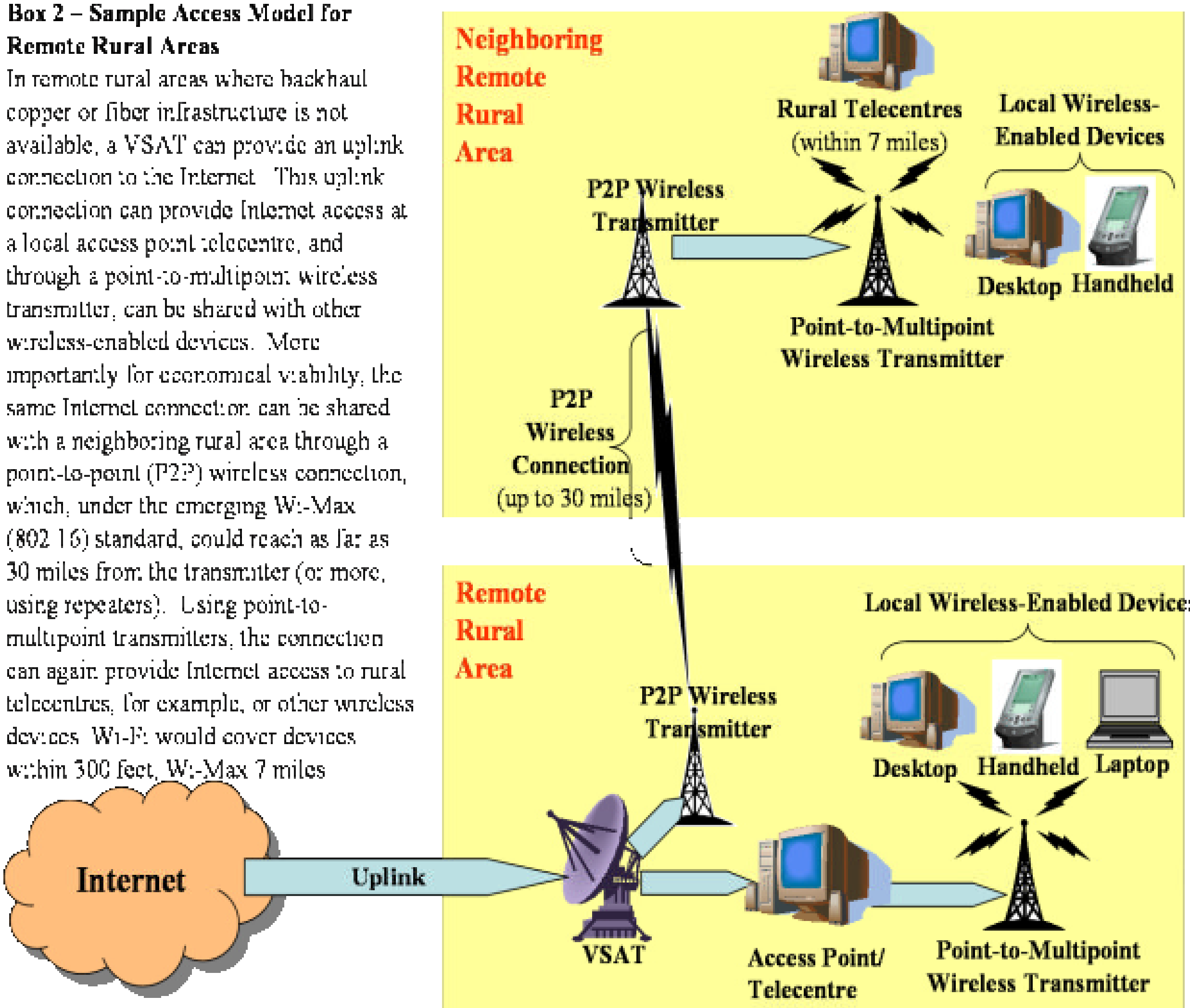
Voice-over-IP (VoIP)

VoIP will allow segmentation of voice messages into a series of IP-based packets that can travel over the Internet and be reassembled for seamless voice conversation.[6] Having enabled cost-effective voice communication, wireless networks will extend an IP-based network to unconnected communities, threatening telecom's potential markets. As is the case of mobile

[6] IP denotes "Internet Protocol" or one of the foundational protocols of the Internet. IP-based packets are usually fragments of messages, individually addressed to the receiver, which may arrive at the receiver via many different paths from the sender. With increasing throughput, especially in broadband, these packets can arrive more accurately at the intended receiver, implying increased quality-of-service (QoS) and eventually sustainable voice and video connections.

Box 2 – Sample Access Model for Remote Rural Areas

In remote rural areas where backhaul copper or fiber infrastructure is not available, a VSAT can provide an uplink connection to the Internet. This uplink connection can provide Internet access at a local access point telecentre, and through a point-to-multipoint wireless transmitter, can be shared with other wireless-enabled devices. More importantly for economical viability, the same Internet connection can be shared with a neighboring rural area through a point-to-point (P2P) wireless connection, which, under the emerging Wi-Max (802.16) standard, could reach as far as 30 miles from the transmitter (or more, using repeaters). Using point-to-multipoint transmitters, the connection can again provide Internet access to rural telecentres, for example, or other wireless devices. Wi-Fi would cover devices within 300 feet, Wi-Max 7 miles



phones, VoIP will provide the ability for real-time voice conversations. The potential for VoIP to obtain a sustainable source of funding is much higher than for many other applications, especially in rural areas where the use of other services may initially be constrained by residents' lack of awareness of their existence.

Mesh Networks

A frontier technology within the wireless realm, mesh networks will enable all wireless devices in a wireless network including computers, handhelds, etc.) to receive information and also to pass it along, somewhat intelligently, to other devices within reach. According to an article by Xeni Jardin in *Wired Magazine* ("Beyond Wi-Fi," dated October 10, 2002, accessed August 13, 2004 from www.wired.com), rather than requiring a central hub/access point for point-to-multipoint access, mesh networks provide the ability to construct ad-hoc networks that "mesh" together, providing more connectivity and flexibility, and less infrastructure than even under the minimal WiMax model. Because the distance between each transmitting and receiving device is generally much less than in the connectivity cloud of Wi-Fi or WiMax, devices in a mesh network can use lower power and, thus, have less chance of interference, much the same as two persons whispering at a party have less of a chance of interfering with other conversations.

Telecenters

Also called community access points, telecenters are often located in small buildings in underserved areas. They offer various services including, but not limited to, e-mail, videoconferencing, faxing, printing, voice connections, and wireless networks. The sustainability of these telecenters, which often have relatively low capital costs but high recurring costs, depends on finding the right mix of services for which the local population is willing to pay. Wireless technologies offer the promise of lowering capital and recurring costs, and VoIP takes advantage of those technologies to deliver cost-effective services that could help make telecenters self-sustainable.[7] The IDB is preparing a manual for telecenters for rural development that will outline a methodology for telecenter sustainability. The Bank is also planning to undertake a number of pilot projects in Costa Rica, Nicaragua, and Colombia based on this methodology.[8]

corDECT

corDECT, a software/hardware platform for wireless Internet service in rural areas, was developed at the Indian Institute of Technology in Madras and engineered specifically for cost-effective universal access, but providing a lower bandwidth (1.1 Mbps) than Wi-Fi or WiMax.[9] Although corDECT equipment was developed before the WiMax standard, it is still providing remarkable results in the evaluation of cost-effective and sustainable rural Internet access service.

[7] See section on India's SARI Telecenters and how VoIP services impact sustainability.

[8] Seventeen pilot projects are planned in Costa Rica, Nicaragua, and Colombia. In addition, Honduras, Panama and Brazil may also host pilot projects, bringing the total to 30 or 40. The methodology will be evaluated after six months of implementation.

[9] Information from the report *corDECT – Wireless Local Loop* by the iComm Access Division, http://www.icommtele.com/cordect.htm. Quoted throughput of 1152Kbps was converted to equivalent 1.125Mbps.

Canopy

A Motorola software/hardware platform, Canopy supports point-to-multipoint wireless connections for a radius of up to 15 miles, or point-to-point wireless connections of up to 80 miles. Canopy is deployed in over 75 countries around the world.[10] Also marketed before the WiMax standard was in use, the Canopy platform demonstrates the cost-effectiveness of wireless technologies.

IMPLEMENTATION ISSUES

A number of factors may influence the deployment of wireless solutions in underserved areas and lead to trade-offs between costs and performance. For example, voice-over-IP does not tolerate latency (delay) greater than 150 milliseconds, which is affected by the sequential use of VSATs and multiple terrestrial repeaters. However, connections at the low end of broadband with little latency may work well for voice-over-IP applications. While many development applications do not require a broadband connection, others, such as imagery for medical or veterinary remote services or e-learning applications, are likely to require it.

It is therefore important to assess the mix of potential applications in a given area before opting for a local wireless communications infrastructure. Additional concerns particular to implementation include possible radio interference from other devices and the need to secure radio broadcast transmissions. The four key issues: latency, jitter, radio interference, security, and interoperability are discussed below.

Latency is the amount of delay, measured in milliseconds, that affects a data transmission. Often measured through a "ping" command from a user's PC, latency is not related to speed but most often to the configuration of the backhaul infrastructure used. Even at light speed, signals to a geostationary satellite 23,000 miles above the earth's surface experience delays: it takes two 46,000 mile roundtrips (or 92,000 miles) to connect a user and a server. When coupled with repeaters or other "hops" on ground, each taking

[10] Information taken from Motorola's website, at http://motorola.canopywireless.com.

additional milliseconds, latency can limit the use of voice-over-IP.

Jitter is defined as the irregular intervals between receiving successive IP-based packets of information, which distort voice quality in VoIP-based conversations.

Since the regulation of radio bands is uneven and in some cases unpredictable, one concern for deployment is *radio interference* caused by other wireless devices. If other devices (including radios, microwave ovens, etc.) are broadcasting over the same spectrum, the performance of wireless Internet transmissions will be lowered. Policymakers must address this issue by licensing particular bands for particular equipment, or allowing license-free bands in the 2.4 and 5.7 GHz bands (as in the United States and Europe). In any case, implementation requires careful attention to any local devices operating in the same band.

Given the nature of radio waves, anyone could potentially listen in with a wireless receiver and decipher private information not intended for their use. Wireless Internet technologies therefore present the potential for identity theft and cyber-crime. *Security* issues have traditionally involved the Wired Equivalent Privacy (WEP), which uses a secret 40-bit or 128-bit key to encrypt user information before broadcast. The intended receiver, presumably the only one with knowledge of the key, would be able to unencrypt the information and view the contents of the transmission. An eavesdropper would not be able to read the contents of the transmission unless he also knew the key. WEP is not foolproof, however. According to an article by Eric Griffith in *Wi-Fi Planet* ("802.11i Security Specification Finalized," June 25, 2004, accessed October 15, 2004 from www.wi-fiplanet.com) a much less vulnerable security standard was implemented in the 802.11i Wi-Fi standard in June 2004 and devices of this type have already appeared in the market.

Evolving Standards and Compatibility

In the context of the evolving standards for wireless devices, great care needs to be taken in ensuring the compatibility of transmitters, receivers, and other devices in the network. Often, new standards supersede old ones and new devices are not compatible with older ones. As an example, although the new 802.11i standard offers a dramatically better security solution for wireless networks, nearly all transmitters and access points are currently unable to implement it, requiring the purchase of new devices. As with most technology, there is also a cost trade-off: as a rule, the older the standard, the cheaper the technology that implements it. When designing and implementing policy, it is necessary to be informed on current limits, and future potential and costs of wireless technologies.

CHEAPER CONNECTIVITY

Providing access to voice and data networks using wireless technologies, even in rural areas, approaches US$300 per subscriber, compared to US$1,000 for optical fiber or copper networks in urban areas, without significant trade-offs in quality and throughput. Furthermore, while the cost of copper or fiber optics is between US$20,000 and US$40,000 per kilometer of connectivity, hundreds of kilometers of wireless connectivity can be provided for US$50,000 (Best, 2003). This cost advantage, which will keep growing as wireless technologies are more commonly used around the world, can be used to connect rural areas in a cost-effective and even self-sustainable fashion.

Self-sustainable Connectivity

Telecommunications companies have historically been subsidized or given temporary monopolies over a user base in order to allow them to recoup the high fixed costs involved in providing communications infrastructure. Given this situation, it has rarely been suggested that telecommunications infrastructure could pay for itself, let alone in a rural area with a per capita income of approximately US$1. However, according to Neto, Best and Gillett (2004), "even low-income countries have exhibited firm demand and willingness to pay for basic communications services." Moreover, a 1 percent increase in per capita income is associated with a 1.4 percent increase in communications-related expenditures (Pentland, Fletcher and Hasson, 2004).

An example of a wireless platform is corDECT, a communications solution based on wireless technology developed in India before the Wi-Max standard was in effect. The corDECT standard optimizes for rural applicability but provides less throughput (maximum throughput is in the order of 1.1Mbps) than its Wi-Fi or Wi-Max cousins. Using the corDECT platform, the Sustainable Access in Rural India (SARI) pilot project has shown that rural communities can finance and sustain their own telecommunications infrastructure and telecenters. Following Michael Best's economic analysis of the SARI project, it can be shown that these telecenters can be sustainable with a daily revenue of only US$3, which is feasible when infrastructure serves as few as 100 low-income rural households (Best, 2003).

Economic Model for Wireless Connectivity in Rural India (SARI Project)[11]

Michael Best's economic evaluation of wireless Internet service demonstrates that this technology is highly cost effective. Best begins by estimating the potential revenue stream per rural household, and balances it against the initial capital cost, amortized over a loan period, and recurring monthly costs of having a rural access point in the state of Tamil Nadu, India. He then estimates the minimum number of households that would be able to sustain such a project. From the results obtained for the SARI project in India, and adjusting for disparities in population densities and connectivity in the countries of Latin America and the Caribbean, we can estimate the number of households necessary to support a local access point in a rural area. The assumptions, results and extrapolation of Best's model to Latin America are summarized in Table 1 and discussed below.

Assumptions:

- *Revenue*: Citing an ITU estimate, Best's first assumption is that "rural and poor communities might be willing to spend at least 1.5 percent of their incomes on information and communication needs." This is a conservative assumption, given that in Melur, which is covered by the SARI project, average expenditures on ICTs (information and communication technologies such as post, telephone, cable, news) are 3 percent of income, and reach up to 16 percent for those reporting positive monthly expenditures (Blatt-

[11] This section draws on Michael Best's 2003 analysis in section 7.4 of Chapter 7 of "Wireless Revolution and Universal Access."

Table 1. Estimations for Latin America and the Caribbean
Extrapolation of Results from the SARI Project

	Rural India	Caribbean	Central America	South America
Population Density (persons/km^2)	297	250	50	20
Assumptions				
Capital Cost (US$)	1,300	1,300	1,300	1,300
Recurring Cost (US$)	320	320	320	320
Income Used for ICTs** (%)	1.50	1.50	1.50	1.50
Marginal Network cost per subscriber per month	0	0	90	248
Using Existing Backhaul Uplink				
Sustainable Daily Revenue (US$)	3.00	3.00	6.27	12.52
Number of Households	100	100	200	420
Number of Households Necessary for Sustainability Without VoIP***	800			
Observed Sustainability Multiple of Having VoIP	8x			
Using VSAT Uplink (if necessary)				
Sustainable Daily Revenue (US$)	3.00	3.00	7.95	14.25
Number of Households	100	200	250	475

Notes:
(*) Figures for Rural India from Best, 2003. Figures for Latin America and the Caribbean are estimated in the Appendix.
(**) From the International Telecommunications Union (ITU), as quoted in the second section.
(***) Observed empirically in rural India, referenced in Best (2003).

man, Jensen and Roman, 2002). Other figures indicate that up to 5-6 percent of per capita GDP is spent on ICTs (Jhunjhunwala, 2001).

- *Costs*: Capital costs for SARI access points average US$1,300 for a computer, network equipment and battery backup, and US$300 for other equipment such as a fan and furniture. Assuming that these costs are financed over a period of five years at a 10.5 percent annual interest rate, this yields a monthly debt service payment of US$28. Recurring monthly costs were estimated at US$320 in 2003, but were expected to decline to US$200, as estimated by the Indian Institute of Technology, Madras, whose corDECT technology was employed in the project. Additional monthly costs include US$25 for rent and electricity and US$15 for unlimited uplink access.

- *Other local assumptions*:

  – Most of rural Tamil Nadu is within 30 miles of a fiber optic backbone.
  – The physical terrain of the Madurai district, where the project was based, is fairly flat and not very limited by geographical obstructions.
  – The population density in rural Tamil Nadu is 297 people/km^2, higher than in many parts of the world. Applicability to Latin America and the Caribbean is discussed below.

Results:

- *Breakeven revenue analysis*: Given total monthly costs of less than US$70 (US$28 for debt service, US$25 for rent and electricity, and US$15 for Internet access) and six-day workweeks, the daily revenue necessary to break even would be US$2.70. Any revenue over US$2.70 per day would, therefore, be considered profits.

- *Breakeven household analysis*: Given two adult incomes per household and a daily income of US$1 per worker, household income per day would be US$2, of which 1.5 percent, or US$.03, could be used for ICTs, according to the ITU. Therefore, 100 households in a given area would generate US$3, or more than enough to sustain the local telecenter, although some time for local awareness and adoption of ICTs should be factored in.

- *Breakeven without VoIP*: Because SARI telecenters have been unable to provide voice services, such as voice-over-IP, due to government regulation, Best has observed a breakeven point at a higher rate of 800 households per telecenter. Underscoring the importance of voice services in sustainability, Best's observation implies, more generally, that eight times as many households are necessary for sustainability without voice services.

Extrapolating the Model to Latin America and the Caribbean:

- *Adjusting for population density*: For simplicity, Latin American and Caribbean countries can be grouped into three categories according to their population density (see the Appendix). The model can be adjusted accordingly for each group:

  - Primarily Caribbean countries: since the population density of countries in this group is similar to that of India, i.e. a median of 245 persons/km^2, the findings for India hold.
  - Primarily Central American countries: this group has a population density of approximately 50 persons/ km^2. Although this lower density does not affect capital costs, it increases network cost per subscriber by US$90 per month, implying a breakeven daily revenue of US$6.27.
  - Primarily in South American countries: the population density of countries in this group is approximately 20 persons/km^2, implying a breakeven point of about US$12.52 per day.

- *Adjusting for less connectivity*: If the rural areas in question are not close to a fiber or copper backhaul infrastructure, the only option for uplink Internet connectivity may be a VSAT. In this case, each group would have a daily breakeven revenue of: US$3.00 for the Caribbean countries (unchanged due to small territory and the resulting proximity to urban fiber or copper connection points); US$7.95 for the Central American countries; and US$14.25 for the South American countries.[12]

- *Breakeven number of households*: Based on Best's income-expenditure model, the number of households necessary near a given access point offering voice-over-IP services to allow it to break even would be: 100 for the Caribbean countries; 200 to 250 for the Central American countries; and 420 to 475 for the South American countries.

Summary

SARI has produced surprising results. According to Best (2003), "In the 2,000 km^2 of the service area, 23 percent of the population of some 32,000 have used the Internet, compared with an Indian average of 1.5 percent (the worldwide average is 9 percent)."

The cost of providing wireless access for Latin America and the Caribbean can be estimated from Best's model. The Caribbean region follows nearly exactly India's pattern of population density and proximity to fiber connectivity, meaning that wireless access points could be provided in a sustainable manner with less than US$3 in daily revenue. Lower population density in Central America produces a breakeven revenue of US$6 to US$8 depending on proximity to backbone infrastructure, which is still fairly reasonable. Because of a much lower population density in South America, the break-

[12] Groups two and three were extrapolated based on Best's model, assuming an additional US$500 in capital costs and US$30 recurring monthly costs for VSAT connection.

even revenue is US$12 to US$14 depending on proximity to backbone infrastructure, which might indicate an opportunity to use more appropriate technologies (such as Canopy or future WiMax technologies) for providing access in areas with low population density. In any case, the cost of these devices will decrease significantly as economies of scale increase around the world.

Another notable finding from this model is that self-sustainability requires approximately eight times the number of households without voice-over-IP services as it does with it. Indeed, especially among lower-income citizens in rural India, telephone expenses represent almost all their ICT expenditures (Blattman, Jensen and Roman, 2002). It may even be argued that voice-over-IP is a necessary service for self-sustainable rural telecenters. This finding has important policy implications, since many telecommunications companies are reluctant to accept voice-over-IP and its presumed threat to their dominant position in rural markets.

It should be noted that corDECT technology is only one of many wireless applications that has been used for wireless connectivity and that it has its own limitations, namely throughput. However, the cost factors observed above are reasonably representative of rural wireless access costs.

SERVICES AT A LOWER COST

Ultimately, if governments are to invest in wireless technologies, they must provide more than access. They must also ensure that wireless technologies provide a cost-effective solution for providing basic services such as education and health care. If this is the case, then government budgets that are already allocated to these sectors, can be diverted to finance wireless technological solutions instead of more traditional ones. Often, as is the case with telecenters, large up-front investment costs are not the barrier, but, instead, high recurrent costs prevent sustainability years after development authorities stop paying attention. In Colombia's relatively poor state of Sucre, the Red Sucre Project provided Internet-powered education for a relatively low recurring cost. Preliminary project results, presented below, provide an example of the cost of wireless applications in Latin America and the Caribbean.

Providing Education in Sucre, Colombia

The state of Sucre is marked by high poverty and illiteracy rates and, until some years ago, uncontrolled violence. After security was re-established, population increased by 30 percent without a commensurate increase in the state budget. The Corporación Politécnica Nacional de Colombia, a partnership between the government and the private sector, was created in an attempt to control high school dropout rates and improve the cost-effectiveness of education.[13]

Through a grant (that is considered a social investment) from the Ministry of Education for approximately US$220,000, the Politécnica connected 11 schools across the state using wireless technologies, provided new computers, and trained local staff at each school in hardware and LAN maintenance. Recurring costs of the Internet connection, software upgrades, ISP uplink costs, and network infrastructure amount to US$5 per student per year, which, so far, has been funded by the state government.

The initial response was not as good as expected. The availability of Internet did not by itself promote its use, and neither did the services offered when the project was launched. However, after adding customized services, including course management software as well as human and capital resources, software usage increased. Students and professors have reacted very positively to the Internet connection and the software, and they now routinely create websites and participate in classes via videoconferences from state universities. This experience shows that simply providing Internet connections is not enough to promote its usage or address development problems. In addition to providing connectivity, investments should be made to develop customized services.

[13] Sixty-three percent of eligible students enrolled in primary school and only 8 percent did so in secondary school. Approximately 1 percent of students finished secondary school and went on to post-secondary education.

Examples of Successful Applications

An important question is what basic services can be provided in a cost-effective manner using wireless applications. Some of these services, as we will see, can be delivered to people who do not know how to use a computer. Successful applications of wireless technology have been reported, especially in e-health, e-education, e-government, and e-commerce. Although the following applications could equally run on wired or wireless infrastructure, many have used wireless technologies for deployment at unprecedented prices and speed in areas with no existing infrastructure. The following examples from Latin America and the Caribbean as well as other countries provide a broad picture of possible applications.

VOICE AND SERVICES IN THE DOMINICAN REPUBLIC[14]

A village-area network (VAN) was installed in Bohechio, Dominican Republic, in March 2001 as part of the LINCOS project headed by the Costa Rican Foundation for Sustainable Development. The rural community of Bohechio, one of the least developed communities in the country, is situated in a mountain range and has a population of approximately 7,000 people.

The VAN covers an area of approximately one square kilometer and took three days to install. The cost was less than US$20,000 (prices fell significantly in recent years) for six computers, two telephones, a multifunction fax/scanner/ printer, a cash machine, an environmental testing lab, FM radio station broadcasting ability, a big-screen TV, and a telemedicine unit. A VSAT provides uplink connectivity via satellite link and, using a 802.11b network, gives access to wireless devices, including PDAs and voice-over-IP telephones at a radius of up to 1 kilometer and at speeds of up to 11 Mbit/second.

Applications currently provide assistance to schools, a medical clinic and farmers. The VoIP solution and associated IP-based telephones installed around the town compete with the telecom provider, offering rates of US$0.18 per minute on calls to the city, compared to US$0.30 on fixed lines. INDOTEL, the national telecommunications regulatory authority, has relaxed its regulations so that spectrum used in the project is valid and has offered significant support and partnership.

E-COMMERCE IN ECUADOR

The "world's first Wi-Fi linked e-payments network" was created in the Mall of San Marino in Guayaquil, Ecuador, through a partnership between the US e-payments equipment and services provider, Verifone, and the wireless equipment provider MediaNet, a subsidiary of D-Link. The wireless network eliminated multiple dial-up phone lines and Internet access points, using instead a central uplink and IP-based Wi-Fi to connect Verifone's "multimodal network access point-of-sale terminals" in the stores. This resulted in lower charges for long-distance calls for merchants and 24-hour/7-day availability. The speed at which payments were processed and data transferred improved by 350 percent, with an average of four seconds per transaction. Verifone's marketing director for Latin America and the Caribbean stated that the company expects "wireless-enabled POS terminals to become more mainstream over the next several years, particularly when the solution is delivered with the right partners" (Burger, 2004).

COMMUNICATION, MEDICAL AND OTHER SERVICES IN THE AMAZON

The Amazon Association, a Brazilian NGO, and the Solar Electric Light Fund, a nonprofit organization based in Washington, D.C., teamed up to provide basic services and economic opportunities to the Caboclo indians by means of broadband wireless Internet. According to the Wireless Internet Institute (*Rainforest IP*, November 2003) many members of this indigenous community lack basic health care, education, and economic opportunities. In the absence of

[14] From Best (2003), Box 7.2.

phones, electricity, or an Internet infrastructure, solar panels are being used to power a permanent satellite uplink to a local telecenter. The telecenter was built in four days and is expected to be self-sustainable in four years. In addition, it is expected to extend connectivity to other communities along the Jauaperí river in a cost effective manner by using Wi-Fi technologies and sharing costs. The project has applied for a spectrum license from Anatel, the Brazilian national telecom.

The Wireless Internet Institute, in the article mentioned above, quotes an official of the Solar Electric Light Fund, who noted that merely "communicat[ing] on a regular basis with the outside world has provided a tremendous psychological lift to the community." The Amazon Association has been able to stay in permanent contact with community members who have learned to use e-mail, and can report on problems at the reserve, participate in decision-making, and request supplies and medicines. This example shows that wireless technologies are means for establishing outreach, empowering a community and promoting civic involvement. The project has become a source of income for local craftswomen, who can now sell their wares through the Amazon Association.

Health services are also provided through the joint efforts of the East Carolina University Telemedicine Center and the University of South Alabama. Using a vital signs monitor with connection to the telecenter, doctors in the United States are able to check blood pressure and perform EKGs, as well as measure pulse, oxygen levels, and body temperature. Through videoconferencing facilities the doctor can then communicate with a nurse over the Internet to provide a diagnosis and instructions on treatment. This is an excellent example of how telecenters can be used to provide basic medical care in remote and isolated areas.

PDAs AND E-HEALTH IN UGANDA

Malaria, tuberculosis and AIDS have ravaged many African countries and been largely responsible for the current health crisis in the continent. SATELLIFE, a Boston nonprofit organization, has been using WideRay servers, rugged plastic boxes equipped with a GSM cell phone and StrongARM processor in an effort to help ameliorate the critical situation.

Equipped with wireless-capable PDAs in rural areas in Uganda, health workers, many of whom had never used a computer before, are able to relay information to the Ugandan Ministry of Health on drugs needed by the population and local epidemics. The International Development Research Centre (2003) notes that, prior to this innovation, reports were hand written and requests for medicines took months to reach those able to fulfill them. The introduction of the PDAs has significantly reduced the time lag to receive needed medicines in rural areas, and has also made it possible to relay information back to healthcare workers in the field regarding the most cost-effective approaches or latest treatments for endemic diseases. In addition, reporting errors have been drastically reduced, improving the quality of the information available to policymakers. As a result of improved information on the health status and burden of disease of the population, important improvements can be expected in the management of national health budgets.

The application of these new low-cost technologies in Africa shows the type of improvements in social wellbeing that can be brought about by the use of wireless technologies. Like the example from the project in the Dominican Republic, this project demonstrates the success of using simpler technologies (i.e., PDAs with wireless) in cases where those involved may not know how to use computers.

EDUCATION IN CHILE[15]

The Red Universitaria Nacional (REUNA) project in Chile uses point-to-point and point-to-multi-point wireless services to provide network access to 25 suburban and rural colleges from two urban universities. The system took advantage of existing fiber and cable backhaul infrastructure available in Valparaíso and Temuco, providing access to neighboring colleges using wireless technologies. Because distances between points varied, the network "topology" presented different features. In Temuco, universities were close enough to one of two urban

[15] From Jaque (2003).

universities to be covered in a point-to-multipoint cloud of connectivity. However, some colleges in Valparaíso were not close enough to use point-to-multipoint, so the wireless signal had to be channeled into a point-to-point connection, in some cases with repeaters, in order to reach more distant colleges. Once the signal reached the college, a local cloud of connectivity was provided using Wi-Fi technologies.

Through a community choice system, where students decide the order and content of class "programming," students at the receiving colleges used videoconferencing to customize their curriculums, choosing from among a large selection of classes. Additionally, project participants point to the spontaneous creation of self-managing communities and research networks as a result of the project.

As a result of greater economies of scale and declines in the price of wireless components, equipment costs for access (the transmitting university) and remote (the receiving college) points fell to US1,054 and US$394 respectively, which represents a cost reduction of 40 percent.

Although, in theory, Chilean law allows for wireless communication without a license, in practice, SubTel (*Subsecretaría de Telecomunicaciones*) authorized the project to operate at power levels that would limit the signal to the inside of a building. The government reserved the 2 GHz and 5 GHz bands for wireless use, but prohibits unlicensed distribution of signals past a building's walls. Therefore, REUNA sought temporary authorization for open-air broadcasting. In many cases, governments in the region have been willing to relax existing licensing regulations for development projects.

E-GOVERNMENT IN INDIA[16]

Through e-government services a government can stay connected to remote populations and, with fee-based servicing, can ensure a steady stream of revenue so that local communities are able to run self-sustainable access points.

The Gyandoot project in the Dhar district of Madhya Pradesh established a set of telekiosks (small, self-service telecenters) that bring e-government services to the local population. The government has promised a one-week response time on local grievances for a fee of approximately US$0.20. This has become the third most popular service, behind market prices and job availability (Best and Maclay, 2002). Additional services provided include assistance in obtaining legal certificates for land deeds, e-mail, village auctions, on-line matrimonial listings, and educational guides. Although most of the current network is based on wired infrastructure, wireless technology is being used to reach isolated and remote areas.

[16] Based on information from the article "Gyandoot : A Community-Owned, Self-Sustainable and Low-Cost Rural Intranet Project" at http://gyandoot.nic.in/gyandoot/intranet.html

The Potential for Wireless Technologies in Latin America and the Caribbean

There is significant interest and activity in the field of wireless technologies in the private and public sectors in Latin America and the Caribbean. In many countries, the private sector is now using wireless technologies to provide access to different services. Profitable business models are being developed for urban and suburban areas, as well as for underserved areas and rural communities that never had access before. In some cases, big telecommunications companies are partnering with small equipment and services firms to provide access to underserved areas. In addition, public-private partnerships, sometimes spurred by international development institutions, are providing more support for the use of wireless technologies and helping to create sustainable business models for wireless access provision. Governments in the region are increasingly implementing wireless-based development projects or promoting competition through liberalized spectrum policy.

OUTLOOK FOR THE PRIVATE SECTOR

According to a Business News America report, Latin American telecommunications companies were expected to spend over US$3 billion to expand broadband services in 2004. A closer look at some recent investments reveals a burgeoning realization of the importance of wireless Internet technologies by the private and public sectors. Industry experts contend that fixed wireless technologies could play a major role in the establishment of broadband in Latin America and the Caribbean because of the lack of adequate fixed-line capacity in the region. As discussed in the third section, fixed wireless technologies offer a much cheaper alternative for connecting suburban and rural areas. Although the large telecoms have played a major role in the adoption of wireless technologies in the region, they are not standing in the way of smaller operators, and often see the provision of rural services as an alternate revenue stream rather than a competitive threat. As a result, smaller operators are sprouting up throughout the region. The Mexican market provides an example of the interest in wireless technologies from big and small private sector operators.

Wireless Competition in Mexico

Although Mexico's telecom regulations can be characterized as stringent, and the country has one of the least competitive broadband markets, several companies have emerged to provide fixed-wireless networks. For example, Ultravision has established a WiMax network that covers the city of Puebla, and Baja Wireless has created a 7,500-acre hot zone of wireless connectivity in a rural area 65 miles south of San Diego. Both companies have plans to expand, and Baja Wireless has contracted with Telmex for future projects using wireless local loop technology, especially in underserved rural areas. MVS Comunicaciones is in the process of completing high-speed network coverage of Mexico's three largest cities and has plans to expand its customer base to include 70 percent of the population. The Mexico City network uses non-line-of-sight (nLOS) networks, and has provided continuous service to vehicles moving up to 100 kilometers per hour. In addition, this network can use a single tower to provide service to indoor receivers in an area up to 16 kilometers away (OECD, 2004).

As is often the case, the actions of these small operators are prompting telecom incumbents to change. In May 2003, Telmex responded by ordering that wireless systems operate in the 3.5GHz band to extend basic coverage to rural and suburban areas. It also launched "Prodigy Movil," an 802.11b free service for existing DSL customers at only US$19 per month for stand-alone service. The prices are "some of the least expensive in the OECD for metered access, suggesting that Telmex believes it will be subject to considerable competition in this market segment" (OECD, 2004). Likewise, despite the presence of big telecom competitors undoubtedly possessing economies of scale, Embratel is launching a similar local fixed wireless network in Brazil, and CTR is rolling out fixed wireless in seven Chilean cities (World Markets Research Centre, 2004c).

Broad-based Movement

These advancements are not limited to the large economies of the region. The Bolivian operator Cotas, for example, signed a US$7 million deal with the Israeli equipment provider Alvarion for deployment of a 3.8GHz eMGW broadband wireless access solution (World Markets Research Centre, 2004b). Also, Orbitel, an existing long-distance and ISP company from Colombia, plans to create Internet access networks in five cities using wireless local loop equipment (Business News Americas, 2004c).

The Future of WiMax

According to the World Markets Research Centre (2004d), "WiMax could be attractive as it will in theory be able to provide last-mile access where there is no digital subscriber line (DSL) or cable broadband coverage, and be used to deliver wireless connectivity for mobile devices. Wireless technologies are likely to play a greater role in large emerging markets such as Brazil, China, and India, where there is insufficient landline infrastructure." Millicom Argentina,[17] a wireless broadband operator, announced the construction of several pilot WiMax networks across Argentina in the fall of 2004 in partnership with INTEL (Business News Americas, 2004d).[18] Because of the newness of the WiMax standard, and the fact that few devices are yet certified as WiMax compliant, the partners selected a pre-WiMax platform to deliver broadband connectivity. The initiative is gradually gaining momentum. Wireless technologies, and especially WiMax, will make infrastructure an increasingly economical investment.

OUTLOOK FOR THE PUBLIC SECTOR

International Development Organizations

Given increasing cost advantages and fanfare surrounding wireless technologies, Latin American and Caribbean governments are explicitly supporting these technologies in their development agenda, and multilateral development banks are supporting them in their efforts. For example, USAID has earmarked US$10 million for the Last Mile Initiative, which provides ICTs to the rural poor in developing countries (including Latin America and the Caribbean). Of particular interest to USAID are wireless metropolitan area networking (Wi-Man) technologies, which provide point-to-multipoint high bandwidth links at reasonable prices. In addition, the agency is interested in fostering regulatory changes to ensure the success of initiatives based on innovative technologies in the countries that receive its aid and, in some cases, has been granted exemptions in order to implement wireless access projects in rural communities. World Bank interest in promoting wireless technologies is evident in the fact that the organization hosted a seminar on the topic in 2004 (Wireless for Development: New Connectivity Solutions for Digital Inclusion).

Public-private Business Models

As the previous examples show, many governments are relying on wireless technology to deliver education, health, communications and other social services in remote areas. The aim is that these services will become self-sustaining in five to ten years with the advent of e-commerce. The governments of Argentina, Colombia, Ecuador and Peru have partnered with a Canadian wireless company (EION Inc.) to carry out these activities. The company sells wireless equipment, services, and technical assistance for pilot projects implemented by the governments. Although the business model is not appropriate for all environments, it has proved successful in areas that lack wired infrastructure such as the Andes or other areas where topography presents connectivity problems. As part of the solution, EION often proposes a self-contained model with a VSAT connection that provides an uninterrupted uplink, which can be leveraged through wireless technologies to connect several neighboring communities. The availability of relatively inexpensive WiMax devices in the market, and their successful application in the Andean countries, shows that this business model could be applied more widely. EION has not yet had significant problems with spectrum policy or licensing regulations.

[17] http://www.millic.com.ar/htmls/nota_26072004. htm
http://www.millic.com.ar/htmls/nota_15092004_02.htm

Government Leadership

Some Caribbean countries have taken yet more aggressive steps. The Government of Trinidad and Tobago is including wireless technologies as a cost-effective means for providing access in its "fast-forward" development program, whose aim is to transform the country into a knowledge-based society by 2008, and provide universal access at the lowest cost. The Government of St. Maarten has formed a partnership with WaveRider Communications to make wireless Internet broadband accessible throughout the entire island. Because the island is heavily forested, the government-owned telephone company was unable to provide island-wide services until the advent of non-line-of-sight (nLOS) technologies. To get connected, subscribers will simply need an indoor antenna, WaveRider modem, and their personal computer or other wireless device. The system will rely on one or two transmitters to deliver up to 2 Mbps throughput at a range of 2 miles for indoor antennas and 5 miles for outdoor antennas.

Latest Policy Developments

Several governments are in the process of liberalizing spectrum policy. In 2004, the government of Trinidad and Tobago requested comments on changing regulations so that no license is necessary to make use of the 2.4GHz and 5GHz spectrums. If this happens, the spectrum allocation will be similar to that of the United States and Europe, and Trinidadian consumers will be able to take advantage of the ever-increasing economies of scale for wireless devices. The economic advantages of unlicensed spectrum are further discussed in the next section.

In June 2004, Anatel, the Brazilian telecom regulator, released consultation papers on allocation of additional wireless spectrum, Wi-Fi regulation, and local loop unbundling. Conscious that current mobile spectrum licensing hinders competition and the adoption of new technology, the regulator is proposing limiting big telecoms to the small frequency spectrum. Following complaints of radio interference, the regulator is proposing to limit the power of unlicensed devices in the Wi-Fi 2.4 GHz band. Lastly, by "unbundling local loop" or forcing telecom incumbents to open up their networks at a reasonable price, Anatel is considering changing interconnection costs and fixed and mobile tariffs. Such changes are both laudable and emblematic of how aware the countries of the region are of the potential of the private sector for developing wireless Internet technologies in a favorable policy environment. Although local loop unbundling will be controversial, it is likely to promote investment.

Policy Issues

Wireless technologies clearly represent a great opportunity for economic development and delivery of services in developing nations. As expressed by the Secretary General of the United Nations in the Conference on "Wireless Internet Opportunity for Developing Countries," held in New York in June 2003:

> "*Wireless technologies have a key role to play everywhere, but especially in developing countries and countries with economies in transition. With considerable speed and without enormous investments, Wi-Fi can facilitate access to knowledge and information, for example by making use of unlicensed radio spectrum to deliver cheap and fast Internet access. Indeed, it is precisely in places where no infrastructure exists that Wi-Fi can be particularly effective, helping countries to leapfrog generations of telecommunications technology and infrastructure and empower their people.*"

This section discusses policy issues in Latin America and the Caribbean, drawing on the examples presented previously, when applicable, and presenting dissenting viewpoints to balance the discussion when possible. Each country in the region is in a different stage of telecom liberalization and wireless policy development and, for that reason, a comparative analysis between countries is necessary. Nevertheless, it is useful to present a general discussion of common issues if wireless technologies are to be used for development.

MARKET-BASED DEVELOPMENT

Rural Broadband Markets Are Promising

The OECD (2004) points to an emerging policy change resulting from the shifting view of rural markets. It has been assumed that rural areas do not attract new entrants, have insufficient demand, require high prices, have lower quality of service, or will need to be subsidized. These assumptions are flawed because they do not take into account new ways of providing services, including wireless technologies. The use of wireless technologies in rural areas might lead to increased growth across the ICT sector. The OECD points to higher take-up rates for broadband access services in rural areas as one example of latent rural demand. The actions of Baja Wireless, Ultravision, MVS Communications, and Telmex in Mexico show that there is sustained and increasing interest from the private sector to serve rural areas. In addition, wireless technologies promise to quickly and broadly expand access to rural populations in both directions. As wireless networks expand in scale and scope, the rural markets themselves will become more valuable, and the private sector will become more interested in it.

Ensuring Competition

If rural wireless and broadband markets are indeed commercially viable, then the main goal for governments should be facilitating market entrance and competition for rural consumers rather than providing subsidies. This potential competition therefore has a significant bearing on policy actions, if competition is stronger, less subsidies for infrastructure will be needed. In fact, if such competition exists, why should the government promote wireless technologies at all? The answer lies in the observation that wireless technologies are still new to the marketplace and that market imperfections are preventing the private sector from taking advantage of them. The major source of imperfections comes from the fact that telecommunications has historically been a heavily regulated industry and, in some countries, has been either a long-term private monopoly (10 or more years) or a simple public monopoly. Entrepreneurial wireless providers in underserved areas are inevitably dependent on these large incumbent telecoms for services such as uplink connections to the Internet. In this environment, entrepreneurs cannot innovate if the government does not remove existing obstacles. Furthermore, although telecom providers often claim that they are competing on a national scale with many other providers, state or local monopolies or duopolies often maintain prices higher than would otherwise be the case.

Barriers to Competition in Rural Markets: The Role of Government

According to Theodore Schell (2003), government policy is most important in reducing barriers to competition and ensuring fairness. Even with support and encouragement from the regulator and the government, significant obstacles remain. Anti-competitive behavior from incumbent telecoms, often with the full knowledge of regulators, includes predatory pricing, uplink interconnection at extremely high rates, provisioning orders that are routinely ignored, and inadequate billing support. Competitive barriers can take a long time to overcome. Policymakers, therefore, can help not only by establishing appropriate legislation, but also by enforcing rules of competition and fairness in order to ensure a level playing field for all entrepreneurs. The cost of providing local connection to the backbone, often called "interconnect fee," comprises the largest line-item of connectivity fees in developing countries, exceeding sometimes technology for infrastructure.

According to USAID the key element of the policymaking process is a regulator who is completely independent from the telecom especially in countries where the telecom was once owned by the national government.

Proponents of the market-based solution often agree that entrepreneurs are more than willing to bring wireless-based services to rural areas if given assurance of a level playing field. However, forcing incumbent telecoms to provide these services could lead to a suboptimal solution. As Best (2003) explain, encouraging fair partnerships between small businesses and major telecom operators could be "good for all parties... since major operators are not, in general, making money in these markets, it may be to their advantage to enjoy enhanced revenues." Finally, some advise that governments who still own telecom operators should "stop treating their telecom monopolies like cash cows… [instead, they should] invest in areas like R&D on wireless Internet telephony and voice-over-IP, so that the technology is seen as a market opportunity on a global scale and not a threat on a local scale" (Rao, 2004).

Sustainability of Rural Telecenters and VoIP

Realizing that shared access is the key to "economic self-sustainability of the Internet in rural areas" (Best and Maclay, 2002), telecenters, where users share one or many computers and Internet connection, have been created throughout Latin America and the Caribbean. Many were brought together by Somos@Telecentros,[19] a network of telecenters throughout the region. However, because telecenters were previously considered a public good, the monthly recurring costs of telephone, Internet access, software, personnel and power were often ignored until too late. These recurrent costs, and therefore the telecenter sustainability itself, are "primarily related to issues of government policy and competitive environments" (Best and Maclay, 2002). The IDB has formulated a methodology for telecenter sustainability in rural areas based on a solid business model, local leaders, and strategic alliances that will directly address this problem.[20] Presently, most telecenter projects are trying to achieve sustainability by offering a set of fee-based services that are of interest and use to local populations. This can include business services such as fax or e-mail, health care, as in the case of the Amazon Association's activities in Brazil, or government interactions as in the Gyandoot project in India.

The last policy issue surrounding free and open competition actually bears directly on the sustainability of telecenters: the provision of voice services using voice-over-IP (VoIP). Internet connections through phone lines have greatly held back sustainability, often doubling the cost of Internet access (Best and Maclay, 2002). Wireless provision of connectivity will greatly reduce the cost of connecting these telecenters to the Internet, but even so, they will have to be paid for.

[19] http://www.tele-centros.org/english/new/index.html

[20] Guillermo Castillo, Metodología ACTTA: una herramienta para la creación de telecentros autosostenibles para el desarrollo comunitario, Sustainable Development Department, Information Technology for Development Division (SDS/ICT).

As observed in the case of SARI in India, voice services offer a cost-effective way to make these telecenters self-sustainable and possibly even able to be financed through its own revenues. According to the SARI model, the difference between offering, or not, voice-over-IP services was an eightfold difference in the number of households needed to make a particular telecenter sustainable. In addition to driving down communication costs, VoIP can generate substantial revenues from international call termination fees while also providing much needed revenue and foot traffic for telecenters. According to Best and Maclay (2002), "Core communication services remain the most critical application for most rural ICT facilities, meaning that basic voice services, voicemail, e-mail, video chat, and so forth are central gateway applications. The full range of services should be allowed… including telephony (through VoIP service and public payphone services.)."

Obviously, there will be significant resistance to liberalizing voice services from the telecommunications incumbents in any given country. However, the VoIP is central to the package of services offered to rural areas to support sustainability[21] and therefore there is a real need to balance the entrenched pecuniary interests of the private sector and needs of rural communities. If allowing for VoIP, governments will need to modernize licensing regimes in a staged and cautious manner, perhaps limiting initial grants of VoIP licenses at first solely to underserved areas or bundling in attractive VoIP licenses with universal service obligations (discussed below). Hence, there is a significant role for government policymakers to liberalize markets, opening up voice and other services to free market competition and, in the process, providing the means for rural telecenter sustainability.

GOVERNMENT INTERVENTION

Universal Service Regimes

In the absence of perfect competition or a viable market for wireless and broadband services, governments must take an active role in bringing connectivity and services to all underserved areas, often called "universal service." Some governments have taken a variety of approaches toward providing universal service, among them:

- Grouping rural service requirements with lucrative urban area licenses;
- Providing universal service access provider (UAP) licenses for rural areas, according to government policies; and
- Subsidizing rural access programs through universal service funds (USF).

The first measure, grouping rural and urban areas together, was seen as necessary in the past given the incredibly high costs of bringing infrastructure such as copper, fiber, electricity, and telephone service to rural areas, but may not be necessary given the cost advantage of wireless service provision. Forcing telecoms to cover unprofitable areas, when entrepreneurs are perfectly willing to do so, could also cause the economically inefficient solution mentioned above.

Universal Service Proposal

According to Best (2003), existing spectrum allocation licenses often discriminate against rural operators, since they pay the same amounts for their licenses as their urban counterparts, but serve less dense and profitable areas. Instead, barrier-free entrance of small entrepreneurs must be encouraged to enable success, perhaps by dismantling large up-front license fees for rural areas. The critical elements of the "basket of public policies" that make up a UAP license are therefore:

- Low entry barriers (e.g., license exemptions or tax breaks);
- Permission to offer value-added services with few regulatory restrictions (e.g., permission for VoIP and other packet-switched services); and
- Encouraging micro- and small business models (e.g., USF subsidies, fair interconnection rules, and zero-interest loans).

[21] Interview with Edward Malloy, Telecommunications and Information Policy Adviser, EGAT/EIT, USAID, on Wednesday, August 18, 2004.

As stated by Neto, Best and Gillett (2004), these measures usually have limited success because they are often targeted at incumbent or large operators who are not interested in these approaches. Any subsidies for universal service, therefore, should be applicable to new market entrants and alternative technologies and should be "targeted, flexible, and accessible."

Against Universal Service Mandates

As a counterpoint to universal service measures, wireless services providers have even more incentive than their wire line counterparts to connect more users to the network, given that the marginal cost to service each additional user is much less than in the case of fiber or cable (Best and Maclay, 2002). Given this natural incentive for universal service, the OECD (2004) cautions against market-distorting subsidies: "Broadband is, in fact, rolling out apace and has one of the fastest take-up rates for all new communication services… If rural broadband is not developing apace, in a particular country, this could signal the need for a review of the competitiveness of market settings before considering the need for subsidies that are likely to further distort competitive outcomes." Country governments are experimenting with new regulatory approaches, offering, for example, no-fee licenses in Bolivia in exchange for commitments to rural service and education. Although Chile created a fund to spur rural service provision, a reverse auction determined that in many cases no subsidy was necessary (Best and Maclay, 2002).[22]

Backhaul Infrastructure

In the past, "last-mile" service delivery represented the majority of all infrastructure costs (Best and Maclay, 2002). With increasing knowledge of the cost-effective last-mile connectivity solution provided by wireless solutions, "it is increasingly apparent that the major barrier to rural broadband may not be the 'last mile' but backhaul required to service that local access network (i.e., the so-called middle mile)" (OECD, 2004). Given that wireless signals can only travel 50 km, and only a few times more with repeaters and latency limitations, governments have a continuous policy role to play in this respect. They will need to determine how to cost-effectively provide physical infrastructure or other technologies to cover the "middle-mile" if they intend to efficiently provide services to their citizens. Governments, large users of Internet connectivity themselves, can play an important role in generating economies of scale and aggregating demand that can then be parceled out through wireless, cable, or fiber infrastructure eventually to rural areas in a cost-effective manner.

How to Prioritize: Private or Public First?

A natural question to ask is in what order wireless objectives should be pursued. Considering the business model that EION Wireless uses with Andean governments, governments will sponsor wireless telecenters in rural areas initially with a concrete social objective in mind, putting off telecenter sustainability, but providing infrastructure for private business. Alternatively, wireless technologies could be pursued through a small business private sector-led connection of rural areas, followed by government provision of services through these existing connections. The last option is obviously cheaper, since infrastructure is funded by the private sector. In either case, compelling user content, like local commerce and services, will have to be created at the outset, for development objectives in the former case, and for private services in the latter case. In both cases, government policy will need to evolve to take advantage of the technology, in the first case to explicitly undertake development objectives in its mandate, and in the second, to liberalize the market. Although there is no universal answer, it is certainly possible to begin both private-sector and public-sector led strategies at once, emphasizing public sector initiatives when the market is immature, and have both strategies meet in the middle.

[22] According to an interview with Edward Malloy (USAID), in this reverse auction, private sector bidders bid for rural projects and were ranked by decreasing amount of requested subsidy. In many of these auctions, the private sector bid "0" or no subsidy.

SPECTRUM ISSUES

Spectrum Harmonization and Universal License Exception

Wireless technologies generally operate in the 2.4GHz and 5GHz spectrums which are unlicensed in the United States and much of Europe (Neto, Best and Gillett, 2004) and 96 percent of all developed nations, but only in 41 percent of all developing nations (Leblois, 2003). While they were primarily unlicensed for consumer electronics like microwave ovens, they have proved infinitely more useful for providing a predictable spectrum over which wireless devices can communicate. According to Neto, Best and Gillett (2004), a "natural conclusion, then, is that unlicensed spectrum and the low-cost wireless technologies that operate on these bands could be of particular value to the low-income countries with poor telecommunications and Internet infrastructures. Moreover, license-exempt regulations should provide a friendly environment for entrepreneurship, reducing barriers to entry and the risk of regulatory failure." However, as a counterpoint, licenses do grant entrepreneurs a sense of legitimacy and credibility. From this standpoint, licensing regimes could encourage entrepreneurship if they take a flexible stance towards technologies and most importantly remain "foreseeable, cheap, and extendible."[23]

Economic Advantages to Harmonized Spectrum

Simple license-free regimes that are common across Latin America and the Caribbean could provide two significant economic advantages as well. First of all, the countries of the region have the opportunity to take advantage of existing wireless device economies of scale in the United States and Europe if they reserve the same spectrum (2.4GHz and 5GHz) for wireless. Secondly, as Neto, Best and Gillett (2004) argue about Africa, "significant heterogeneity in regulation of 2.4 GHz and 5.7 GHz bands across the continent of Africa inhibits growth of telecommunications and the Internet by diminishing potential economies of scale. It also promotes confusion, uncertainty, and lack of enforcement capacity, which can harm, in particular, new entrants and small players." Significant heterogeneity of policy in Latin America will likewise curb investment and inhibit economies of scale. In terms of wireless applications for development in particular, it must be noted that the projects in the Dominican Republic and Chile previously discussed had to seek special legislation or injunction to service their rural populations with wireless technologies.

Government Allocation of Spectrum

In their defense, licensing regulations serve a complex democratic purpose, existing primarily to "strike a balance around a number of issues, namely: increased access, the rights and privileges of incumbents and existing providers, quality of service guarantees and consumer protections, management of interference between multiple uncoordinated transmitters, rent-seeking activities, and perhaps issues of national security" (Neto, Best and Gillett, 2004). Policymakers must therefore be conversant in a wide variety of issues related to the new technology. The management of interference, one particularly problematic issue, requires an "appropriate balance between lowering barriers to entry and ensuring the well functioning of radio transmission on these bands" (Neto, Best and Gillett, 2004). Enforcing an "orderly use of spectrum" may "require setting up unbiased oversight bodies with legal authority and a clear charter to promote the broadest access possible to users at the lowest possible cost" (Leblois, 2003).

TECHNICAL ISSUES

Privacy and Security

Given that wireless technologies imply communications and commerce in open air, anyone with a receiver could, in theory, listen in on these conversations. To solve this problem, encryption technologies have been built into the Wi-Fi standard and are actively being included in the emerging WiMax standards. Nonetheless, technical issues of this nature mandate that government officials understand the technologies involved and implications of radio spectrum communication. For example, government poli-

[23] Based on an interview with Edward Malloy, USAID.

cies should be cognizant of new possibilities such as identity theft and cyber-crime.

SUMMARY

There is an enormous opportunity for wireless technologies to provide access and services to remote populations. There are many policy considerations to take into account, most of which need to work together to free up the private sector and encourage universal service while balancing the interests of many parties. As Leblois (2003) summarizes, policy should ensure, "A competitive regulatory environment, free access to spectrum within guidelines, alliance between private sector and government bodies, and between incumbent telecom providers and newcomers, and an international agreement on the basic framework available to wireless Internet systems can nurture the development of the networks and further bridge the digital divide."

Recommendations

The Inter-American Development Bank has the opportunity to take a leadership role in shaping the enormous potential of wireless technologies in the region. One overarching principle is that the Bank should not in any way replace or hinder the significant efforts of the private sector. There are, therefore, four primary initiatives related to wireless technologies that the Bank can lead: convening policy discussions across sectors, streamlining existing country operations through pilot projects, generating and sharing best practices, and fostering a regional policy consensus. The Bank has the opportunity to utilize wireless technologies to achieve its objectives of sustainable economic growth, poverty reduction, and socioeconomic equity throughout.

COUNTRY POLICY DISCUSSIONS

Taking advantage of its advisory capacity to governments and the private sector, the Bank can support discussion to promote wireless policies that will enable the private sector to provide access in underserved areas and the government to achieve its development objectives. Given its technical expertise, multi-country operations, and existing advisory role, the Bank is uniquely qualified to convene and lead these technical discussions, advising, for example, on the problem of whether wireless-related development should be led by the private or public sector in the context of a particular country. Also serving as an impartial arbiter, the Bank can promote liberalization and modernization of the State alongside effective development practices. This is especially urgent in view that, in many countries, the private sector is willing to invest if given a supportive policy and regulatory environment.

STREAMLINE COUNTRY OPERATIONS THROUGH PILOT PROJECTS

Given the cost-effectiveness of wireless technologies as a mechanism to provide connectivity and basic services to underserved areas, the Bank should naturally be interested in using the technology to implement development projects in a more cost-effective manner. Pilot projects will demonstrate to the Bank staff and to other development agencies the feasibility of using wireless technologies in providing connectivity and services in a variety of environments. A prime opportunity could be the inclusion of wireless technologies in the telecenter pilot projects that will result from the SDS/ICT ACTTA Methodology. Significant opportunities also exist for involving the private sector in the development process, a modality in which the Bank is already a leader. New financial instruments will require new forms of partnerships, and the experience will enrich the Bank's existing knowledge and capabilities as they relate to development partnerships.

GENERATE AND SHARE BEST PRACTICES

Having observed the development impact and pitfalls of wireless applications for development as an observer and as an actor in its own pilot projects, the Bank is in an ideal position to generate and share best practices related to wireless applications for development. Greater dissemination of these best practices will not only avoid common pitfalls for using wireless technology, but create a greater awareness of the possibilities of using the technology in development initiatives. The IDB can also lead in the proposal and discussion of financial instruments for development and their timely use. Public-private partnerships, which will play a key role in the development of wireless services, can be compared and contrasted in different countries and best practices for financing will also emerge.

ENCOURAGE REGIONAL POLICY CONSENSUS

A regional policy consensus on wireless technology policy is essential to spur the private sector innovation, attract foreign investment, and take advantage of the existing economies of scale of wireless devices. The Bank has already engaged stakeholders in a series of conferences on global municipal government and wireless technologies in Brazil and Mexico in partnership with the UN ICT Task Force, UNITAR, and the Wireless Internet Institute (W2i). In support of a regional policy consensus, the Bank could arrange for a comprehensive analysis of spectrum policy in the various countries of the region. Armed with this information, the Bank could pull together key decision makers from all countries in the region to promote a regional consensus, which could generate a wave of economic development in underserved areas and support a burgeoning private sector.

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Appendix

Population Density in Latin America and the Caribbean

Country	**Persons per km^2**
Barbados	602.77
El Salvador	281.81
Haiti	249.79
Jamaica	244.92
Trinidad and Tobago	214.83
Dominican Republic	168.04
Guatemala	113.77
Costa Rica	72.53
Honduras	53.60
Mexico	52.15
Ecuador	45.38
Nicaragua	39.23
Colombia	37.84
Panama	36.56
Bahamas	28.17
Venezuela	26.31
Peru	20.80
Brazil	20.32
Chile	20.00
Uruguay	19.06
Paraguay	13.68
Argentina	13.42
Belize	10.34
Bolivia	7.36
Guyana	3.58
Suriname	2.67

Source: CIA World Facts (1999).

Note: In this table, Latin America and Caribbean countries are separated into three major groups according to their population density: the first with average population density at 250 persons per square kilometer, the second with average population density closer to 50, and the last with density of 20. The first group roughly represents the island nations of the Caribbean, the second mostly Central American countries, and the last group is primarily South American countries. Population density is a valuable statistic because wireless fixed costs can be shared by a larger population. Thus, greater population density implies greater economies of scale.