CHAPTER 7: The Wireless Revolution and Universal Access

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We need to think of ways to bring Wireless Fidelity (Wi-Fi) applications to the developing world, so as to make use of unlicensed radio spectrum to deliver cheap and fast Internet access -- United Nations Secretary General Kofi Annan[1]

7.1 **Introduction**

Kofi Annan recently added his voice to a growing community of technologists, public policy officials and telecommunications practitioners who foresee a revolution in rural universal access. This revolution will be founded on a new suite of wireless technologies, matched by supportive public policies and business approaches, that can provide Internet access and voice service cheaply to rural and under-served communities.

One basic approach looks something like this: small entrepreneurs provide Internet and voice services within their own communities by purchasing inexpensive basic radio equipment and transmitting on unlicensed frequencies. Collections of these local operators, collaborating (and interconnecting) with larger Internet and basic service operators, begin to weave together a patchwork of universal access where little or no telecommunications services existed before. This access patchwork would be cheap, robust, and extremely responsive to innovation. While more has to be done to prove this model will be sustainable, recent experiments in India and elsewhere have been demonstrating that the basic approach is sound.

New and creative enterprises can make rural and poor markets profitable, affordable, sustainable and served in ways that meet national and local development objectives. But this requires innovation, advanced technology and creative business and public policies. In order to make universal access profitable--and in order for this wireless revolution to truly take off for these communities--several critical innovations are necessary, including the following:

- **New and low-cost technologies, especially terrestrial wireless infrastructure --** Per-line costs, and prices for subscriber premises equipment, can and should be brought down, by an order of magnitude, from thousands to hundreds of dollars.

- **Micro and small enterprises that provide locally tailored value-added services --** A broad basket of value-added services flowing from community-based ICT facilities can ensure revenue flows and create value to the community.

- **Supportive public policy --** Policy-makers must view rural and universal access as drivers of development and not sources of government revenue. In particular, spectrum licence exemptions can allow for low entry barriers for small entrepreneurs.

This chapter will review some state-of-the-art technology, business and public policy initiatives that are making universal access sustainable, profitable and empowering. The chapter concludes with a very simple economic model that summarizes and underlines how sensitive profitability is to conditions in the technological, business and policy environment. In the end, the argument is that universal access can pay for itself.

7.2 Wireless Network Technologies

7.2.1 The Network Standards

A central requirement for profitability in the context of universal access is that capital costs for network construction and user equipment be low. The good news is that new technologies--especially in the terrestrial wireless domain--are dramatically driving down these costs.

Box 7.1 How to Speak Wi-Fi: A WLAN Glossary

802.11 – A family of wireless technical specifications for broadband access developed by working groups of the Institute of Electrical and Electronics Engineers (IEEE).

802.11a – A specific wireless technical specification for use in the 5 GHz bands, termed the Unlicensed National Information Infrastructure (U-NII) bands in the United States.

802.11b – A specific wireless technical specification for use in the 2.4 GHz Industrial, Scientific and Medical (ISM) bands. 802.11b is currently the most popular specification and is popularly known as Wi-Fi.

802.16 – An emerging set of standards for fixed wireless broadband access.

Access Point – A WLAN transmitter/receiver that generally acts as a bridge between a wireless network and a wireline network. It can also, however, act as a wireless bridge between multiple wireless networks.

Hotspot – A WLAN available to the public in a location, such as an airport, coffee shop or neighbourhood.

Point-to-point -- A point-to-point radio has two highly directional antennas on either end of the radio link. It provides a symmetric connection between the two antennas.

Point-to-multipoint -- A point-to-multipoint radio has a broad coverage antenna at the hub side of the link and a highly directional antenna at the subscriber side of the link. Multiple subscribers can make use of the same hub.

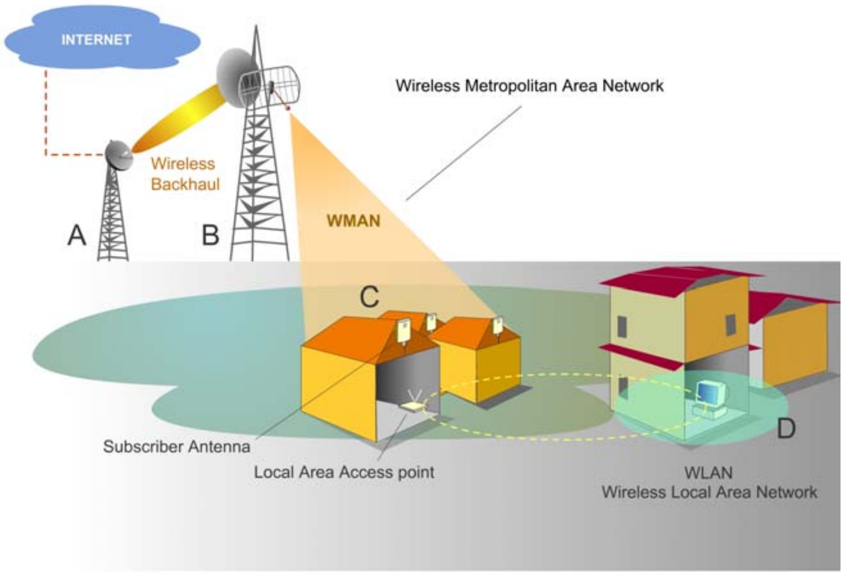
Wi-Fi -- Short for Wireless Fidelity, a radio networking technology generally used to connect PCs (or other appliances) to a local network and often using the IEEE 802.11b protocols. Also referred to (with some variance) as a WLAN.

WLAN - Wireless Local Area Network, a radio networking technology used generally to connect PCs (or other appliances) to a local network. Also referred to (with some variance) as Wi-Fi.

WMAN - For Wireless Metropolitan Area Network, a radio network that is larger than a WLAN, either in terms of geographic coverage or subscriber capacity; WMAN access might be offered across a community or city.

In order to understand current wireless technologies it is necessary to first appreciate some of the basic concepts. Consider a hypothetical wireless network installation, as depicted in Figure 7.1. This schematic drawing shows two radio towers (A and B), houses and other buildings (C), and a personal computer inside a building (D). Radio tower A is connected through a wireline link to an Internet point of presence owned by an Internet service provider. So the PC shown at point D ultimately is connected to the Internet by several wireless links.

Figure 7.1: Connectivity in Wireless Networks
This illustration shows a collection of radios and antennas illustrating wireless backhaul, WMAN, and WLAN deployments.



Each of these wireless links illustrates important differences in the way radio technologies can be deployed. The link from radio tower A to tower B is a point-to-point connection, because it supports just a single radio and antenna on either side of the link. A point-to-point radio connection is a bit like a spotlight; it is a highly focused beam of radiation.

On radio tower B, below the point-to-point connection to tower A, is a set of radios and antennas that establish a point-to-multipoint connection. Tower B serves as a single point on a link, but it emits a broad sweep of radiation that covers an entire area around it, including all of the buildings marked C. A point-to-multipoint connection will use one or more broad coverage antennas at the hub side (at tower B) and very focused antennas at the multiple subscriber points (buildings marked C). A point-to-multipoint connection, then, is a bit like a theatrical light with a broad beam emitting from the hub.

Finally, the picture envisions a radio connection between the subscriber equipment mounted on the side of the building (point C) and the individual personal computer inside the building (point D). Here, an access point emits radiation throughout the interiors of the building, allowing all personal computers outfitted with a simple wireless network interface card to connect to the access point--and ultimately, back up the chain to the Internet. Continuing the lighting-fixture metaphor, an access point is a bit like a standard incandescent light bulb, but without any sort of lampshade or focus. It lights up the entire room but cannot travel the distances of a spotlight or theatrical light.

With this simple illustration in mind, it is possible to apply some of today's common wireless terms.[2] The access point inside the building is providing what is called a Wireless Local Area Network (WLAN) connection. The point-to-multipoint connection from tower B to the buildings marked C is often referred to as a Wireless Metropolitan Area Network (WMAN) connection, which necessarily covers more area than a WLAN. And the point-to-point connection from towers B to A can be called a wireless backhaul. As one moves from WLANs to WMANs and then to backhaul systems, the use of more intensely focused microwave radiation allows transmission over greater distances. It can also diminish the chances of interference and reduce the necessary power emitted. Further down the network, toward the less-focused end, WLANs and point-to-multipoint WMAN deployments allow multiple subscribers to share the same hub. They also support greater flexibility and mobility and can be easier to install.

Figure 7.2. Picturing WLAN Connectivity

An access point provides WLAN connectivity to a laptop. The access point is connected directly to a wireline network. The picture shows various types of access points.

Source: ITU.

One technology that is capturing the attention of industry and consumers is called "Wireless Fidelity" or "Wi-Fi." Wi-Fi describes a constellation of wireless technologies that comply with technical standards defined by the Institute of Electrical and Electronics Engineers (IEEE)[3] under the nomenclature of 802.11b.[4] Note that sometimes the term "Wi-Fi" also is used to refer to other technologies employing different but related standards, such as 802.11a.[5] Wi-Fi technologies are particularly well suited to providing WLAN connectivity that enables broadband Internet access like that illustrated between points C and D in Figure 7.1. Recent attention has particularly focused on the deployment of Wi-Fi "hotspots" in places like airports, fast food restaurants, and coffee shops. A hotspot is like any other private WLAN deployment, technically, but it is made available to the public—often with a fee for use.

While the concept of a wireless hotspot inside a fast food restaurant is unlikely to conjure images of enhanced universal access, Wi-Fi and related terrestrial wireless technologies have actually been used to build network "infrastructure," such as the point-to-point and point-to-multipoint links discussed above. While 802.11b, in particular, was engineered specifically for use in a WLAN context, it has provided WMAN and backhaul service in some deployments.

There are three important elements of new terrestrial radio equipment that are central to its role in providing profitable universal access: (1) the decreasing cost, (2) the increasing capability of the technology and (3) the utilization of licence-exempt radio bands. Coverage distances continue to increase and prices continue to drop with Wi-Fi and related radio technologies. WLAN indoor access points can currently provide blanket coverage over a 100-meter radius for less than USD 75.[6] Newer access points provide coverage over 300 meters.[7] The wireless network interface cards that connect to a subscriber's personal computer can now be purchased for less than USD 50.

Outdoor routers employing 802.11b, which today still cost more than USD 1000, can provide point-to-multipoint or point-to-point coverage up to 20 kilometers, although generally at reduced data rates. Through a technique known as "multi-hopping," in which multiple repeater radios are strung together, transmission networks of up to 100 km have been achieved.[8] Outdoor 802.11b routers, providing hotspot coverage, have been demonstrated with up to a 1-km radius using high-power radios.[9] And one Wi-Fi equipment maker has claimed the world record of a 310-km, point-to-point link using 802.11b.[10] This result, however, came from a stand-alone demonstration environment, with high-power radios and high-gain antennas. It seems unlikely that high data rates at these distances can be realized in the field, given standard maximum power regulations and the realities of potential interference.

Figure 7.3: How They Stack Up

This chart provides a comparison of the relevant features of selected wireless network standards and vendor equipment that can be used for universal access development. Note that these figures offer only rough estimates, because field performance often varies from test or lab performance. Furthermore, improvements are rapidly being made to these technologies.

	IEEE Standards		Vendor equipment			
	802.11b	802.16	Canopy	corDECT	CFO-SS*	Root Inc. Wireless router **
Pt-to-pt max distance	20 Km	50 Km	55 Km	-	20 Km	16km
Pt-to-multipoint max distance	1 Km	13 Km	15 Km	25 Km	10 Km	5km
Bandwidth	11 Mbps, shared, large overhead	70 Mbps, shared, large overhead	10 Mbps, shared, large overhead	70 Kbps, dedicated	10 or 18 Mbps, shared	11Mbps
Uses unlicensed spectrum in many countries	Yes	Yes	Yes	No	Yes	Yes
Advantages	Popular, inexpensive	Good range, good speed	Good range	Inexpensive, proven in rural settings	Good range, high throughput, without reducing data rates;	Multi point to Multi point. IP routing.

Disadvantages	Reduced data rates at long range, inefficient spectrum use	Still emerging	Proprietary system, relatively expensive	Requires license	Proprietary system, relatively expensive	Insufficient spectrum use

Note: *CFO-SS (Carrier Frequency Offset-Spread Spectrum) was developed by KDDI R&D Laboratories. ** For more information about the Root Wireless router, please refer to http://www.root-hq.com.

Other technologies are also emerging that increase the capability and lower the price of wireless networks. The 802.16 standard—also a protocol being defined by the IEEE—attempts to deliver higher bandwidth and relatively long range for point-to-point and point-to-multipoint backbone networks.[11] Unlike 802.11b, this is not a standard for WLANs. But it can provide high bandwidth for backbone networks, with bandwidth of up to 70 megabits per second (mbps) compared to 11 mbps for 802.11b.[12] And transmissions can currently cover up to 50 kilometers in a single hop. Meanwhile, a proprietary system, called the Canopy[13] system, has been developed for point-to-point and point-to-multipoint networks. With a Canopy installation, access points can reach fixed wireless subscribers at distances of up to 15 kilometers, and the backhaul equipment can transmit over distances of up to 55 kilometers. Signaling rates are 10 mbps, which in a point-to-multipoint system would be shared by all subscribers.

Finally, attention is focusing—particularly within the developing world—on the corDECT system invented at the Indian Institute of Technology, Madras.[14] The corDECT system is engineered specifically for cost-effective universal access. The distance possible between a subscriber unit and a point-to-multipoint base station (similar to an access point) is rated at 10 kilometers. Relay base stations can be used to extend this distance a further 10 kilometers. These distances may be conservative, because with favorable line-of-site and terrain factors, 40 kilometers has been achieved in the field. Transmission rates are currently 35-70 kilobits per second, with dedicated capacity fully delivered for each subscriber. The system can support simultaneous data and voice transmission.

Here is the punch line: initial trials have demonstrated that networks for voice and high-bandwidth data can be deployed over hundreds of kilometers, at costs currently under USD 50,000. Put another way, at per-subscriber costs approaching USD 300[15] (and continuing to drop), communities in relatively rural and dispersed areas can receive voice and data connectivity. Compare this to standard fiber and copper technologies deployed in many urban areas. There, network backbone costs can range from USD 20,000 to USD 40,000 per kilometer and, as a rule-of-thumb, per-subscriber costs hover at about USD 1000.

7.2.2 Low-Cost Subscriber Equipment

Increasingly, policy experts agree that the concept of universal access should not end with basic voice services, but must also embrace value-added services, including the Internet. This is not simply because of the social and economic value of the Internet--although that would be reason enough—it is because the Internet is critical to the financial sustainability of rural access. The economies of scope, the ability to support highly-localized applications and the local content capable of being provided through full Internet access are vital for achieving community self-sustainability. (See, e.g., Chapter 6)

In order to support full Internet access, subscriber premises equipment must, to one degree or another, include a personal computer. Developments in low-cost wireless network technologies are heartening, but the affordability of state-of-art or appropriate Internet appliances (both the hardware and the software) remains woefully inadequate. Today's PCs, by and large, remain expensive (about USD 1000 for a system that can adequately manage the full range of multi-media applications). They also consume considerable electric power (a desktop PC can draw more than 200 Watts under full operation). Furthermore, they are difficult to use and maintain (especially given current operating systems, which are not suitable in the context of universal access), quickly obsolete, English language-centric and environmentally insensitive.

All that said, there are a few recent examples of new Internet appliances that may alleviate some or all of these concerns. This includes experiments with "thin clients"--stripped-down PCs that often do not include a hard drive but rely instead on a network for storage. And there are also hand-held appliances. One such hand-held system, designed specifically with universal access in mind, is the Simputer.[16] This system was designed by faculty members of the Indian Institute of Science in Bangalore and engineers from Encore Software. Current versions of the system include a color screen, enhanced power management, a LINUX based operating system with a purpose-built user interface, text-to-speech capabilities in English and major Indian languages, integrated speakers and a microphone.[17] Systems can currently be purchased for under USD 300. One catch, however, is that the system does not currently directly support WLAN connectivity. Another example is Thailand's Sinsamut ICT computer, designed to bring 1 million PCs to Thai families.[18]

Box 7.2 The Village Area Network

A "village area network" (VAN) provides mobile and fixed ICT services to an entire rural community via a pervasive network. The goal of a VAN is to provide services and capabilities that enhance the economic development of rural communities, raising living, medical and educational standards. An early VAN was implemented in the rural community of Bohechio, Dominican Republic, in March 2001. Located 220 kilometers northwest of the capital, Santo Domingo, Bohechio is situated within a mountain range in the province of San Juan. There is little or no industrial growth in the region. The primary economic activity in the region is agriculture, with the main crops consisting of beans, rice, coffee and tomatoes. The village of Bohechio itself is home to approximately 7000 people and is one of the least-developed communities in the country.[19]

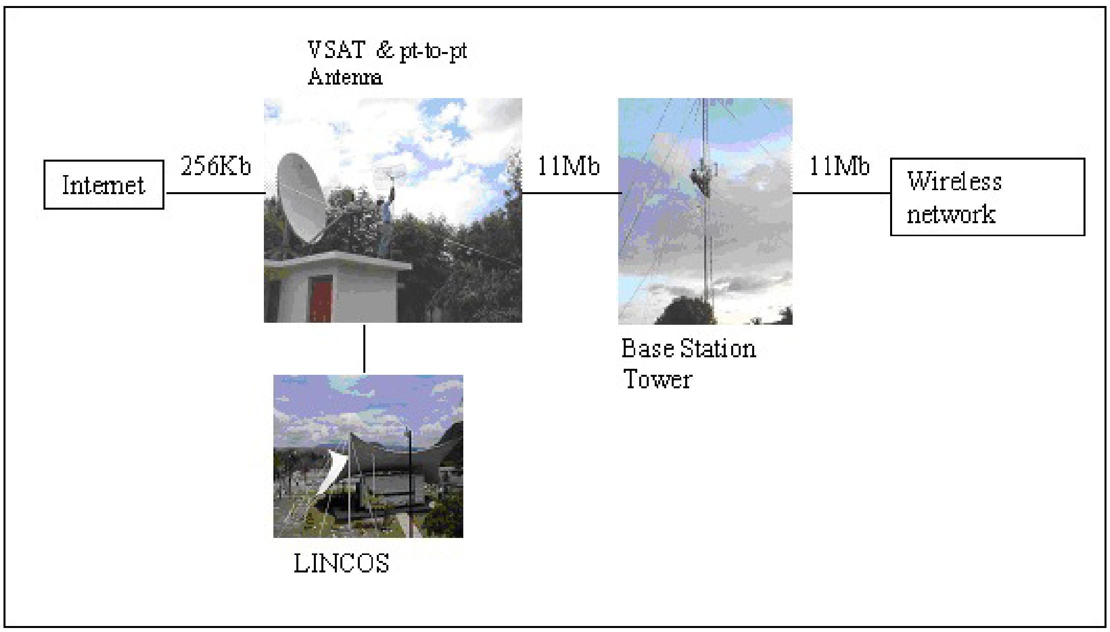
The VAN network, covering about one square kilometer, took three days to install, at a cost of less than USD 20,000 (and these prices have fallen considerably in the last two years). It employs a set of outdoor radio antennas and routers operating under the IEEE 802.11b standard at 11 mbps.[20] The VAN extends the facilities of a multipurpose community telecentre (MCT) throughout the village, via mobile and fixed wireless devices and services.

The telecentre is part of a project dubbed LINCOS--an effort of the Costa Rican Foundation for Sustainable Development.[21] The LINCOS unit in Bohechio consists of a recycled steel shipping container, protected by a large tent and containing six computers, two telephones, a fax/scanner/printer/copy machine, a cash machine, a soil and environmental testing lab, broadcast equipment for an FM radio station, a big screen TV and a telemedicine unit. The telecentre uses a

VSAT (very-small aperture terminal) satellite link and a fixed-wireless telephone connection. Residents have used LINCOS to form agricultural cooperatives, launch e-commerce initiatives, create their own radio station and access online education and employment information.

The overall VAN architecture (see Figure 7.4) consists of external radios and antennas, mounted on a mast tower, with radio links providing a connection to the LINCOS telecentre unit, then from there to the VSAT and ultimately the Internet. The link to the VSAT is made through a point-to-point antenna (depicted below), which communicates with a similar antenna installed on a radio mast tower on top of the Bohechio municipal building. This is then connected, through a cable, to an outdoor router located on the top floor of the building. The router then connects via cable, amplifier and splitter to four 90-degree, point-to-multipoint antennas. From this tower-mounted configuration, the four 90-degree antennas create a wireless VAN throughout the entire village. Users can access the network within a radius of roughly 1 km, at speeds of 11 mbps, shared.

Figure 7.4. The Village Area Network Topology

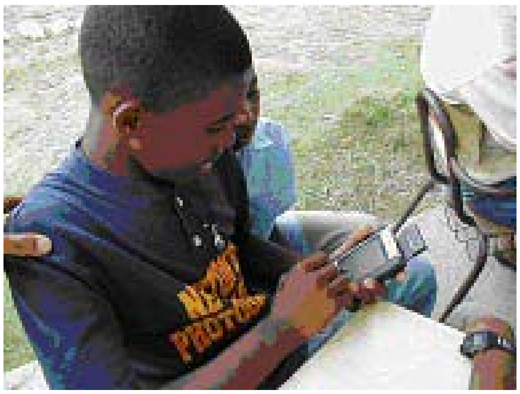


The LINCOS telecentre (bottom image) is connected to the Internet via a VSAT (dish in upper left image) and to the mast tower via a radio and hyperbolic antenna (held by technician in upper left image). The mast tower (upper right image) hosts an array of Wi-Fi radios and point-to-multipoint antenna that provide wireless coverage thought the village. (Photos by Michael L. Best)

The VAN provides network access to the community's school and medical clinic. Furthermore, it has become an excellent platform to increase telephone service penetration rapidly in the town. A voice-over-IP (Internet protocol) call-processing unit and IP telephones have been deployed throughout the village. Moreover, VoIP services, along with experimental applications, have been deployed using hand-held appliances. A commercial hand-held appliance,[22] running Windows CE, has been deployed with a Wi-Fi network card, which interfaces with the handheld's PC card slot (see Figure 7.5). The hand-held has an integrated full-duplex sound card with speaker and microphone, making it very suitable for VoIP communications experiments.

The VAN has had a number of impacts on the community. Before the project, there was only a single provider of phone and cable television service in Bohechio. The LINCOS and VAN intervention has introduced price competition for outgoing calls. At the last time of evaluation, calls to the capital city were made for 18 cents a minute, compared to 30 cents per minute in the past, through the traditional single provider. Furthermore, applications to assist the schools, a medical clinic and agriculture have all been deployed.

Figure 7.5. A Hand-held Appliance within the Village Area Network



A hand-held appliance was Internet enabled and deployed within the Village Area Network. A Wi-FI card was inserted into the hand-held's PC card slot. The wireless card's "pigtail" antenna is visible protruding from the very top of the hand-held. (Photo by Michael L. Best)

Moreover, the project has had significant support from the national policy-maker and regulator. The telecommunications regulatory authority of the Dominican Republic, INDOTEL, was a partner in developing the VAN experiment and took an active role in studying the policy implications and issues raised by the project. INDOTEL participated in site surveys and relaxed its spectrum regulations, allowing the project to use higher-powered radios than would be allowed in metropolitan areas.

7.3 Spectrum Management for Wireless Technologies

The sense of excitement and potential now surrounding wireless LANs and their kin is by no means confined to the technologies themselves. Rather, the technologies are empowering--and being empowered by--new techniques and paradigms for spectrum management itself. This section explores how these new wireless technologies often go hand-in-hand with the most current policies on opening up markets to rapid technological deployment.

7.3.1 Unlicensed Uses of WLANs

While low costs and long distances are core strengths of these new technologies, another critical element (perhaps *the* critical element) is that most of them work in radio spectrum bands that are licence-exempt throughout much of the world. In those licence-exempt jurisdictions, entrepreneurial operators can deploy and operate 802.11b, 802.16 or proprietary systems such as Canopy without time-consuming and expensive licence application proceedings.

The 802.11b standard operates in the 2.4 gigahertz microwave spectrum. In the United States, the Federal Communications Commission (FCC) has set aside the 2.4–2.4835 GHz band for Industrial, Scientific and Medical (ISM) uses.[23] While equipment emitting at these frequencies must have FCC certification, users of the radios require no licences. Certification is particularly focused on ensuring that the transmitted power of the radios is less than a certain allowed ceiling. For 2.4 GHz operations the maximum is set at 1 watt. The Canopy technology also operates in radio frequencies that are licence-exempt in the United States. These radios transmit at 5.2 GHz and 5.7 GHz, which are within bands known in the United States as the Unlicensed National Information Infrastructure (U-NII) bands.

A majority of European Union countries also currently allow licence-exempt use of the 2.4 GHz band and (to a lesser degree) the 5 GHz bands. However, the exact policies vary from country to country. The European Commission has recently developed a recommendation calling for the free use of these bands and the harmonization of policies across member countries.[24] In the United States, the FCC already has allocated 300 MHz of unlicensed spectrum for WLANS in the 5 GHz band, in addition to spectrum at 2.4 GHz. Two-thirds of that spectrum is in the 5.2 GHz band and a third is in the 5.7 GHz band. Industry forecasts, however, have predicted that growth in the demand for wireless LAN devices will require at least an additional 240 MHz of spectrum by 2010. So in a rulemaking notice released June 4, 2003, the FCC proposed to allocate additional spectrum in the 5470-5725 MHz spectrum band to unlicensed wireless devises in an effort to increase wireless broadband access and investment.

Moreover, at the 2003 World Radiocommunication Conference—held June 9-July 4, 2003--the member countries of the ITU agreed on a global allocation of 455 MHz for WLANs, or "radio local area networks" (RLANs). The allocations are in the 5150-5250 MHz band, the 5250-5350 MHz band and the 5470-5725 MHz band.

The regulatory policies applied to the 2.4 GHz and 5 GHz bands vary considerably, however, across the rest of the globe. For instance, in Ghana licences are required for the use of all spectrum, including 2.4 GHz and 5GHz. In India, the 2.4 GHz band has been de-licensed for use by wireless LAN technologies, but only if they are contained within a single building or used only by a single organization (See Box 7.3). [25]

Box 7.3 CorDECT: A Home-Grown Technology Solution from India

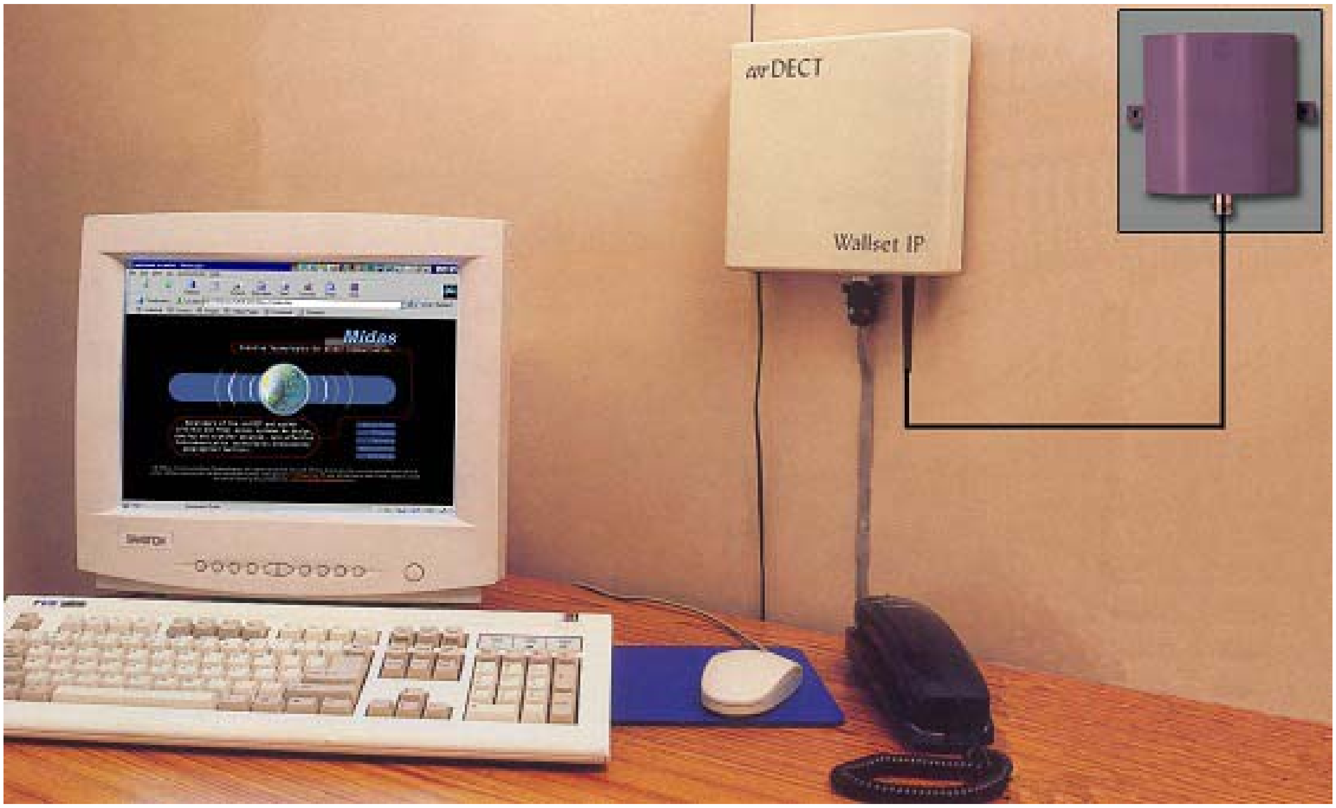
The corDECT system was developed by the TeNeT group at IIT, Madras.[26] It is a wireless access system that provides simultaneous, toll-quality circuit-switched voice service, along with packet-switched data transmission at 35-70 kilobits per second.[27] The corDECT system was specifically engineered to serve rural and developing areas. The design philosophy focused on a number of critical concepts:

- Internet provision--at rates that can handle applications such as video chat--is fundamental;
- Toll-quality voice services will remain a core application, and simple connectivity to the public switched telephone network (PSTN) is critical; and
- Affordability and robust performance is more important than unnecessary new features.

Indeed, keeping both capital and recurring costs low has been a key driver of the system design. For example, operational costs are reduced by de-multiplexing the voice and data at the system's interface unit. In this way, data can be routed directly to an Internet service provider without having to be subject to phone charges while being routed over the PSTN.

The corDECT system is based on the Digital Enhanced Cordless Telecommunications (DECT) standard of the European Telecommunication Standards Institute (ETSI). DECT has become a common technology, especially in consumer products such as cordless telephones. This has helped to harmonize equipment manufacturing, reducing prices and enhancing reliability.

The basic corDECT network topology is designed around a central base station (called a compact base station), which connects to a DECT interface unit on one side (the "hub" side). The DECT interface unit provides ongoing connection to the PSTN and the Internet. The base station also consists of a set of point-to-multipoint antennas that provide wireless connectivity to multiple subscribers. The subscriber equipment, meanwhile, consists of inexpensive wall sets that provide both telephone and Internet connections. There also are simple point-to-point antennas. Relay base stations can be supported, allowing the network to be extended farther from the interface unit.



The corDECT wall set with PC and telephone connections and cabled to external antenna. (Source: Midas Communication Technologies Pvt. Ltd.)

It is worth noting that India's recognition of its low Internet and telephone penetration has been part of the inspiration for this Indian-developed solution. The research, design and manufacturing of the system was done primarily in India. Nevertheless, the system has prompted global interest, and there are now deployments in Africa and Latin America.

7.3.2 The Potential Impact of WLANs

The proliferation of unlicensed wireless network technologies may be nothing less than revolutionary. What certainly *is* groundbreaking is the novel paradigm that WLANs represent. Multiple unlicensed users can operate overlapping (even competing) wireless networks, all transmitting within the same frequency bands. Indeed, this small-scale, entrepreneurial approach may become a central element in bridging the digital divide and making universal access pay for itself. Imagine a telecommunications network--built from the bottom up, in a sense--by a large number of small and local entrepreneurs. Each mini-telecommunications operator could provide services within its local community just by purchasing the basic radio equipment and transmitting on these unlicensed frequencies. The model is inexpensive, responsive to local needs and realities, can grow organically and is fully scalable. In addition, most of these technologies enable broadband access. As the number of local providers increases, so does the overall capacity of the network. Each new operator increases the number of pathways between any two points.

Nicholas Negroponte of the Massachusetts Institute of Technology calls this the "lily pad and the frog" effect.[28] Each local entrepreneur builds a lily pad of wireless network connectivity. Other entrepreneurs in surrounding communities are doing the same thing. Eventually, the "lily pads" of network connectivity grow closer and closer, and some even overlap. Sooner or later, the "pond" is going to be completely covered by connectivity. Telecommunications users--the frogs--will then jump from network to network. This "lily pad" model is made increasingly possible by ongoing research into mesh networks, in which equipment may be simultaneously an end-user terminal and a router for data traveling to other subscribers, creating a fluid, decentralized and constantly evolving network.[29]

To be sure, there are some downsides to operating within licence-exempt frequencies. But the inability to collect fees or rents from operators or users should not be viewed as one of them. If universal access is to be achieved, network deployment must be seen as a tool for development, not as a source of government revenues.

Rather, the chief downside of unlicensed use is that a proliferation of radios operating on the same frequencies may cause interference among competing networks. Under the U.S. regulatory regime, radios transmitting in ISM bands must employ spread-spectrum technology, which helps reduce interference.[30] In U-NII spectrum bands, however, spread-spectrum operation is not required, and other techniques are employed to reduce interference. Meanwhile, cutting-edge research is exploring ways to dramatically reduce or eliminate the effects of interference.[31]

Interference concerns, while real, are often much less of an issue in rural areas, where spectrum usage in *any* band may be quite low. The amount of deployed radio equipment is usually minimal, compared to the level deployed in urban areas. Moreover, wireless networks can operate over limited ranges and at relatively low power levels. Therefore, the connectivity to be gained, quickly, through unlicensed deployment of wireless networks may far outweigh any concerns about interference, which may be more relevant in metropolitan areas.

Security is another concern often raised with wireless networks. While security is an ever-present issue for all networks (wired and wireless alike) it is a particular concern for wireless networks. Emitted radiation is likely to travel beyond those areas physically controlled by the network owners and, similarly, the network's radios are potentially easy to reach by rogue transmitters. These two problems are solved for wireless networks through encryption, to remove the threat of eavesdropping, and access control to protect against theft of service or other misdeeds from rogue transmitters.

Unhappily, the initial security standards for 802.1lb have been shown to be inadequate.[32] Worse still, many wireless routers for 802.11b do not have the computing power to adequately provide what security is currently supported under 802.11b. Indeed, most commercial routers are shipped with security capabilities turned off. Nevertheless, extremely robust security protocols for wireless networks, including 802.11, have been proposed and, in many cases, already implemented. These include the 802.11i strong encryption standard and the 802.11x authentication standard. So, while early-generation systems have had some security flaws, wireless networks generally can support a level of security comparable to that of wired networks.

Figure 7.6 Global Wi-Fi Policies

In the 2003 ITU World Telecommunication Regulatory survey, governments were asked if they had put in place any particular policies for wireless LANs (including Wi-Fi networks). Fifty-eight percent of the countries professed to have some policy in place. The chart below indicates selected national policies on WLANs.

Country	Position
Bahrain	No licence required for Wi-Fi.
El Salvador	Free use as long as systems are within power and coverage limitations.
Ghana	All users of public frequencies are required to seek authorizations that are covered by fees.
India	De-licensed use of 2.4GHz for "indoor" use.
Ireland	Licence-exempt unless the operator intends to provide public telecommunications services, in which case they must apply for a general or basic telecommunications licence.
Japan	Providers of Wireless LAN services in 2.4 GHz and 5 MHz bands shall obtain permission from the sector Minister for Type 1 telecommunication business (facilities-based carriers) and submit the document to the sector Minister in case of Type 2 telecommunication business (service providers).
Korea (Rep)	A policy is in place but has yet to be implemented.
Lithuania	No authorization is required for WLANs used in certain frequency bands and under usage conditions specified in the secondary legislation.
Malta	A licence is required for fixed-wireless services.
Mauritius	Transmissions within a radius of 500 meters are licence-exempt.
Togo	Approved for use by ISPs.
United States	ISM and U-NII bands are licence-exempt.

7.3.3 The Universal Access Provider Licence

Section 7.3.1 reviewed spectrum management policies allowing for licence-exempt bands. That is one approach regulators can take to help ensure that universal access is profitable. If policy-makers do not opt for this approach, however, they can still implement steps to spur universal access at the entrepreneurial level by lowering barriers to entry, deregulating diverse and innovative value-added services and licensing small and micro operators.

Some countries--for example, South Africa--have begun to organize this collection of supportive policies under a single special licence, which can be called a "universal access provider" (UAP) licence. This authorization can be offered to a micro or small enterprise to establish basic and value-added services in particular geographic markets. A market can be judged appropriate for UAP licensing if it meets the following criteria:

- It is overwhelmingly rural and does not contain metropolitan areas or large cities;
- Its population is predominantly characterized by low per-capita income; or
- It is not served (or is under-served) by telecommunications, including basic voice service.

One key to a successful UAP licence is to allow barrier-free entry for small entrepreneurs. Many countries require large up-front licence fees and performance guarantees as part of basic service licences. Such fees should be waived or significantly reduced for UAP licensees. Performance guarantees, designed to spur a high quality-of-service (QoS) level, may be relaxed, if necessary. In fact, QoS delivered by UAP licensees may well be high without monetary guarantee requirements, because competition and responsiveness to local demand may require it.

Standard basic service licences often require that certain network build-out levels be met. For instance, they might require operation across an entire province or state and be accompanied by certain service coverage thresholds for rural areas. Since UAP licences are designed to apply solely in under-served areas (many of which are rural), and to support micro- and small-enterprises as operators, such service-area requirements (obligations) would not make sense for UAP licences.

Similarly, basic service providers are often required to contribute to a universal service fund. Since UAP licensees would provide service solely within areas to be served by a USF, they should be exempted from making such contributions. In fact, universal service funds could be made available to UAP operators--for instance, in the form of zero-interest, small-business loans.

Box 7.4 Rural Voice Service in Bhutan

Bhutan Telecom, using resources provided by the ITU, has been experimenting with the use of 802.11b technologies to provide rural voice services. Bhutan is a small, land-locked country in the heart of the Himalayan mountain range. Bordered by Tibet and India, it has one of the world's smallest and least-developed economies and a teledensity of only 3.4 phones per 100 inhabitants.[33]

As the sole provider of voice and Internet services, Bhutan Telecom offers domestic and international telephony, Internet, fax and pay phone services, as well as leased lines and radio communications, in rural areas. It is a public, state-owned corporation with 600 employees. Currently, Bhutan Telecom is operating a totally digital network, with satellite earth stations for international calls and a 34 mbps digital microwave backbone.[34]

Bhutan Telecom has deployed a trial wireless IP voice system in two remote rural areas: Gelephu in the South (eight villages) and Limukha in the West (six villages). In deploying the networks, authorities considered a variety of wireless technologies but ultimately chose 802.11b. Wi-Fi can support broadband data as well as voice. It is cheap (and prices continue to fall). It can be easily and rapidly installed. Moreover, it is scalable, and it uses relatively little power. There were, however, some concerns with 802.11b. First, it was not fully proven for outdoor, rural use. Second, it can cause quality-of-service problems, including degraded voice quality. Finally, it was unclear how the rigorous natural environment--and in particular the monsoon rains--would effect performance.


A customer premises antenna and call-processing unit. (Source: Bhutan Telecom)

Initial results of this trial project, however, suggest that 802.11b and related technologies can be effective in providing rural universal access. The network at Limukah was commissioned in June 2002, with the first services billed beginning in July of that year. Aside from occasional complaints, the project seems to be successful so far. The network at Gelephu, however, faced many initial problems caused by excessive rain and lightning storms. This resulted in considerable service disruption at first. But reports from mid 2003 indicate that the system was performing well, even during heavy monsoon rains.

An outdoor repeater site in Bhutan. (Source Bhutan Telecom)

In addition, basic service licensees are often subject to strict terms or regulations on their rate-setting practices. This may prevent price gouging, serve to average price levels among high- and low-cost areas or meet other social goals. A UAP licence should include terms for basic service tariffs that are in line with prices found in high-income and urban areas. However, where possible, tariffs should be cost-based and market determined, particularly for value-added services.

Fair and transparent network interconnection that encourages innovation, competition, and new entrants is the basis for strong telecommunications regulations. For small rural providers to be viable, terms for sharing or leasing facilities from major operators must be fair and cost-based. In fact, equitable revenue-sharing terms between the existing basic service operators and UAP licence-holders may 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 that are fairly shared with UAP operators. Any revenues they derive from new users to the national network are monies they would otherwise never receive at all. In other words, while an incumbent's overall, national market share may decline slightly as a result of market entry by UAP licensees, revenues will increase through interconnection and increased calling to and from new users in UAP-served areas.

In some cases, as with the universal access provider licence proposed in South Africa, arguments have been made for asymmetrical termination charges between the major operators and the small universal-service operator.[35] In essence, the UAP licensees would have the right to command larger termination charges than they would pay to the major operators (see Chapter 3 for a more detailed explanation of asymmetric interconnection).

UAP licensing does not have to involve a mandated technology such as Wi-Fi. Where possible, licences should be technology-neutral, allowing the choice of a wide range of terrestrial wireless networks. Some technologies currently operate within licence frameworks, including corDECT. In these cases, however, UAPs should be exempt from paying spectrum licence fees for operating in rural areas. It is worth noting that in many countries, spectrum allocation policy actually discriminates *against* rural operators. This is because carriers usually receive spectrum licences covering a prescribed geographic area. A licence for an urban area will naturally cover vastly higher population numbers (known as "pops") than rural licences, giving urban licensees a large advantage in terms of potential subscribers with which to defray network costs. As an example, the annual spectrum licence cost, per mobile phone subscriber, in rural India is 20 times higher than the average cost per subscriber in New Delhi.

Economies of scope are crucial for sustainable universal access. Core communication services remain the most critical application for most rural ICT facilities, meaning that basic voice services, voice mail, email, video chat, and so forth are central gateway applications. The full range of services should be allowed under a UAP licence, including telephony (through VoIP services and public pay phone offerings).

Finally, taxes and duties on ICT goods should be rationalized and reduced for UAP licensees. In many countries, excise taxes, sales taxes and customs and import duties can double the cost of technologies. UAPs should receive relief from these tax payments. Furthermore, in this era of convergence, the taxation framework should be technologically neutral. Standard circuit-switched telephone operations and Internet technologies should all be taxed at identical and predictable rates, where they are taxed at all.

While the social benefits of universal access are often discussed, UAP licences may also bring sustainable economic growth. As explored in Chapters 5 and 6, micro-level and small entrepreneurs--people who have historically been excluded from the ICT sector and the economy as a whole--can profit from and enhance communication services within their own communities. In other words, universal access can not only broaden the range of people *using* the services, it can also enrich the range of people *providing* the services.

Box 7.5: The SARI Project for Sustainable Rural Access

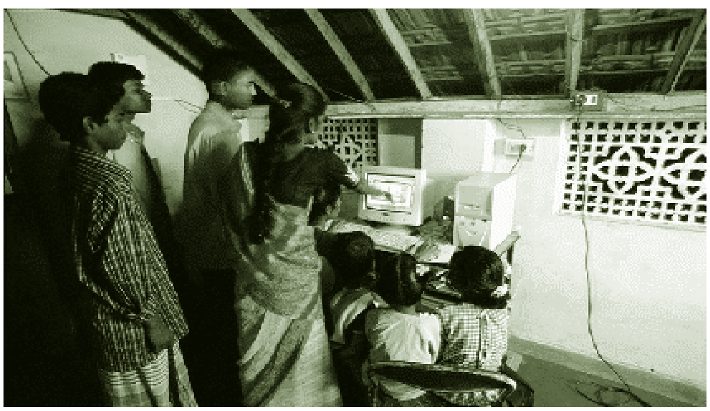
The Sustainable Access in Rural India (SARI) project aims to establish the economic self-sustainability of rural communications and, ultimately, to demonstrate how networks affect social and economic development. A close analysis of the economics of this rural Internet program can help ground any understanding of the business case for sustainable universal access.

India has the second-highest population in the world, but only 40 million (or just 4 percent) of all Indians have a fixed-line telephone. Moreover, while nearly 70 percent of Indians live in rural areas, telecom operators have focused predominantly on large urban centers.[36] To date, neither the private sector nor the Indian government has been successful in providing full connectivity to rural India, particularly at rates that would be affordable by the majority of the populace or at a quality that could sustain sufficient Internet data rates. The result is a vast untapped Internet and telephone service market in rural India.

Under the SARI project's pilot phase, Internet access, applications and content are being provided at more than 80 sites in 50 villages in the Madurai District of the southeastern state of Tamil Nadu.[37] Initial *tele-kiosks* were installed in late 2001, and early applications include communications, education and training, tele-agriculture, tele-medicine, entertainment and e-government. While discussions continue with national telecommunications authorities and private operators, there are currently no circuit-switched voice services. However, the technology and facilities deployed fully supports toll-quality voice services and the project will begin providing circuit-switched voice as soon as the appropriate sanctions are cleared.

In the 2000 square kilometers 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 average size of a village with a tele-kiosk is 1000 households, while the smallest villages have fewer than 300 households. The average per capita income is less than USD 1 per day. To date, more than a quarter of the village tele-kiosk facilities are breaking even or profitable.

SARI has utilized the corDECT wireless local loop system developed at the Indian Institute of Technology-Madras (IIT, Madras).[38] This system supports simultaneous voice and data with transmission rates of 35-70 kilobits per second, and it can effectively cover rural areas. Currently, corDECT's per-line costs are approximately USD 320, but they ultimately should decline to USD 200 according to figures from IIT, Madras. Multimedia PCs, with battery back-ups, are provided for each tele-kiosk facility. The entire initial capital costs are averaging USD 1600 per subscriber facility. This includes USD 1,300, on average, for the PC, corDECT network equipment and a battery backup, as well as USD 300 or so for additional facilities such as a fan and furniture.



A village community tele-kiosk in Padinetakudi village. The kiosk operator, a young entrepreneur in the village, points at the computer screen. (Photo: David de Souza)

Operating costs have averaged USD 25 per month for rent, electricity, and general upkeep. The Internet access costs have been fixed at USD 15 per month for unlimited usage. Connectivity is provided through a leased fiber line, the cost of which is shared among all subscribers. The fiber link connects to the nearest metropolitan area network, and then to a commercial ISP that provides ongoing connectivity.

SARI is a project of the Indian Institute of Technology-Madras, Harvard's Berkman Center for the Internet and Society, MIT's Program on Internet and Telecommunications Convergence, and the I-Gyan Foundation. N-logue Communications Pvt. Ltd. is the private sector implementing partner.

7.4 An Economic Model for Wireless Universal Access

As Box 7.5 illustrates, it is possible for small, entrepreneurial rural service providers to employ low-cost wireless connectivity to achieve financially sustainable operations. In fact, sustainability could be achieved at revenues of as little as USD 3 per day (and this figure may even be declining). Based on assumptions concerning the amount of expendable income available for ICT services in rural areas, this means that entrepreneurs could be able to sustain services in villages of roughly only 100 households, with a per capita income of just USD 1 per day.

It is useful to attempt to extend and generalize this business "model" to other areas of the world. First, however, it is important to take note of how the Madurai area of Tamil Nadu, where the SARI Project is unfolding, may be similar or dissimilar to typical rural areas:

- Tamil Nadu's rural population density is 297 people per square kilometer. This is certainly higher than most parts of the world.[39]

- Most of rural Tamil Nadu is within 50 kilometers of a fiber backbone network. This is a favorable condition not present in much of the developing world.

- The quality of grid electricity in the Madurai district is fair. Outages average a few hours a day and can be accommodated reasonably well with inexpensive, battery-powered back-up technologies.

- The physical terrain of the Madurai district is fairly favorable for terrestrial wireless systems requiring line-of-site transmissions. Much of it is flat, with only moderate foliage. But there are some mountainous areas that do produce radio "shadows."

- Although the SARI communities are poor, and economic activity is largely agricultural, there are high levels of awareness and sensitivity to the value of ICTs, which help to drive interest in Internet services.

Box 7.6: Running the Numbers: The SARI Project

The ongoing SARI project is yielding basic financial numbers that provide an opportunity to model business sustainability for rural, value-added services in poor communities.

Capital expenditures for computer equipment have run about USD 1300**.** Assuming there are monthly payments on the financing of those costs, with 10.5 percent annual finance charges and amortization over five years, the monthly service on debt and amortization of capital costs would be less than USD 30. Total costs can be captured by the following formulas:

A) The monthly payment on debt and amortization of computer equipment is calculated as $\frac{p(1+r)^t r}{(1+r)^t - 1}$ where p is the principal (USD 1300), r is the monthly interest rate (.105 / 12), and t is the length of the loan in months (12 * 5 years). This results in a monthly service on debt and amortization of capital of USD 28.

With the addition of monthly recurring costs of USD 40, on average, the total monthly expenditures could average less than USD 70. Revenues equaling this amount would allow the operation to break even, and those in excess could be booked as profit for the operator. Given a standard six-day work week, each tele-kiosk would have to take in daily revenues averaging roughly USD 2.70 (USD 75 divided by the number of work days in a month) to break even. At USD 4 per day, the facilities could be considered profitable and desirable business enterprises.[40]

Conservative ITU estimates indicate that residents of rural and poor communities might be willing to spend at least 1.5 percent of their incomes on information and communication needs. It is possible, then, that the economic viability of SARI operations could be realized in poor, rural villages of as few as 100 households. It should be noted, however, that the project currently does not provide voice services, and, given that restriction, sustainability has been reached only in collections of 800 or more households.

Using the same basic economic model described in Box 7.6, it may be instructive to study the potential impact on operational finances of certain changes in system deployment. These can then be reflected in recalculations of the estimated income per day required to break even. For instance, one could increase ISP charges or decrease the computer costs. Note that this exercise reveals the economic model's considerable sensitivity to any substantial change in the costs.

The SARI economic model assumes a break-even point at about USD 3 per day. But consider the following potential changes to the model:[41]

1. What if the Internet access device costs only USD 300 (for example, a handheld appliance such as the Simputer or a VoIP terminal) as opposed to USD 1000? The recalculated break even point would then be just a little more than USD 2 per day.

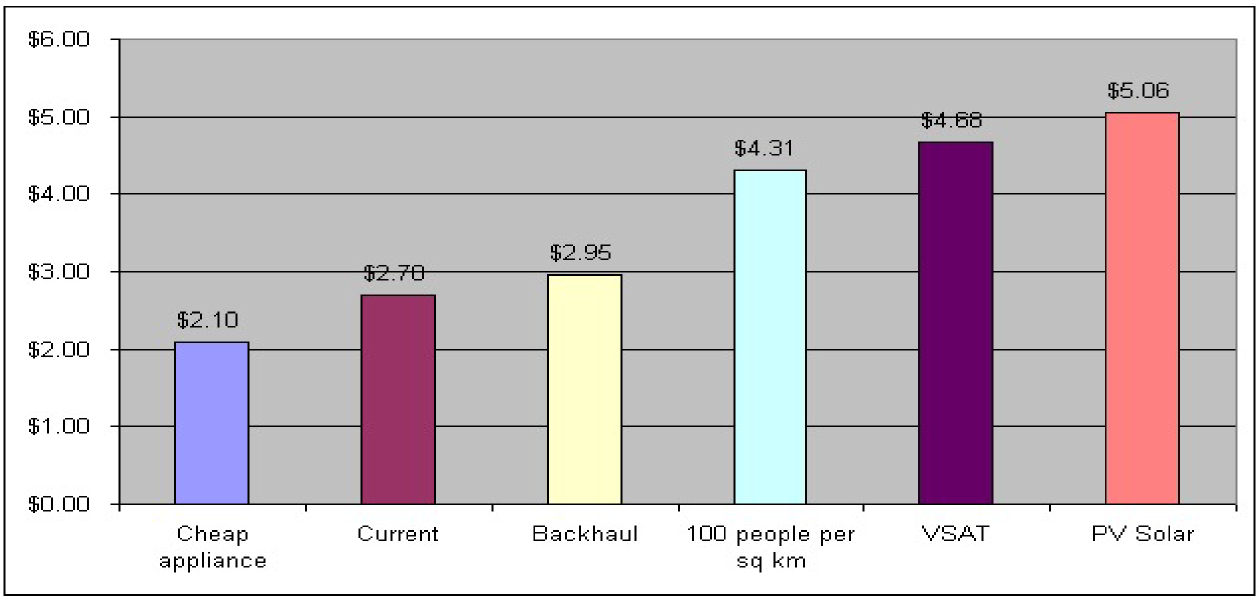
2. In the SARI pilot project, there is a fiber head end 40 kilometers or less from any one of the Internet facilities. Assuming instead that fiber facilities are farther from the base stations, what would be the added backhaul costs? The Canopy system, for instance, could provide an appropriate point-to-point backhaul capability. An estimated total cost for the necessary radio equipment is USD 5000, and a rough estimate for tower and ground costs is USD 10,000. Assuming just 50 subscribers, this could add roughly USD 300 in capital costs per subscriber. The new break-even point would be close to USD 3 per day[42].

3. Consider the added costs for satellite-provided backhaul through a VSAT system, which may be necessary if fiber is not accessible. A rough estimate for the additional capital costs would be USD 700 per subscriber, based on the cost of the least-expensive terminals currently available and assuming the equipment cost is shared amongst all the terrestrial wireless subscribers.[43] Recurring monthly costs, per subscriber, can be estimated at USD 50 if it is assumed that the bandwidth is shared among 50 subscribers. The new break-even point would be nearly USD 4.75.

4. Now assume that the population density is just 100 people per square kilometer. The network costs will increase, because there no longer the same economies of scale. If the existing network and ISP costs from the SARI pilot are divided among one-third the number of subscribers, the result is an additional USD 500 in per-subscriber capital costs and an additional USD 30 in monthly recurring costs. The break-even point would then be roughly USD 4.30.

5. Finally, consider the added cost of using photo-voltaic solar cells and a battery array to power each facility. This could add an estimated USD 3000 in capital costs, per subscriber. The model assumes monthly electricity charges of USD 5, based on the actual results of the pilot experiment. With those eliminated, the new break-even point would be just over USD 5.

Figure 7.7: A Comparison of Daily Break-Even Costs



Given our rough business model we can compare the daily break-even revenues if the deployment is changed. Above, we see the effect of the use of an inexpensive appliance as compared to a full-blown PC, the current deployment described above, the addition of a microwave backhaul, the impact in a reduction in population densities, the addition of a VSAT, and the addition of PV solar cells.

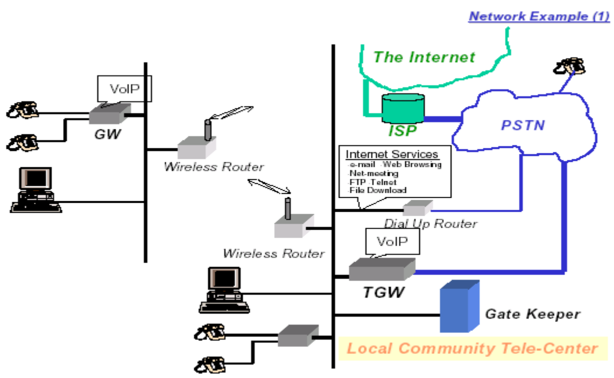
These estimates should not be viewed so much as static building blocks for a business plan, as costs, demand and other factors will vary over time and location. They serve to illustrate, however, that the economics are highly sensitive to additional capital and recurring costs, which can easily double the required break-even revenues. The same holds for licence fees, taxes, and other administrative costs. Similarly, large labour costs passed on by incumbent operators in service fees and tariffs can require the project operator to increase revenues to ensure profitability. It will be crucial for the small and micro-sized universal access providers to keep their cost structures low in order to reach and exceed their break-even points.

Box 7.7 ITU Pilot Projects: Wireless IP for Rural Connectivity

In its final report, New Technologies for Rural Applications, *ITU Focus Group 7, recommended pilot projects for packet-based wireless IP solutions for rural connectivity (See http://www.itu.int/ITU-D/fg7). The ITU is supporting the deployment of pilot projects using these new wireless IP technologies in rural and remote areas. Project funding has been secured and pilot projects are being launched worldwide. Partners are diverse in their scope and contribution to the each project.*

ARAB STATES: Rural Network extension using Wireless IP, Yemen

In conjunction with the rural connectivity strategy of Yemen, this low cost wireless IP access network is connecting a dozen rural communities with an ICT infrastructure. The project is supported by local and national government and industry under the leadership of the ITU. The Yemen Project proposes to use a wireless router system based on the following network parameters:



EUROPE: Rural Telecentre Network in Septemvri Region, Bulgaria

Advanced telemedicine applications are running on a wireless IP infrastructure in ten remote communities in the outlaying area of Septemvri, Bulgaria. The project is supported by the local community and community medical centers, the Bulgarian Academy of Sciences, local and national governments and local industry. It provides a rural extension to the European Union-PHARE funded telecentre network.

LATIN AMERICA: Rural Access to Multimedia Library Project, Guaratiba,Brazil

The Instituto EMBRATEL 21, together with the ITU, is seeking additional global partners to deploy rural connectivity and extend its Multimedia Digital Library project and existing community access facilities using wireless IP/RLAN networks into the remote fishing community of Guaratiba.

AFRICA: *Rural Extension of Community Access Points: Uganda*
This project is supported by government, industry, local NGO, and international institutions – under the stewardship of the ITU. It aims to extend connectivity into rural and remote areas using Wireless IP technologies. Uganda has developed a clear policy towards rural access and these new technologies can be seen in the context of a technological approach to universal access.

7.5 Conclusion

New technologies, business models, and public policies are fundamentally re-writing the equations of self-sustainability for ICT providers in poor and rural areas. Universal access may now be achievable through profit-driven, small-scale entrepreneurial operators. This chapter has described a set of new terrestrial wireless technologies that give rural and under-served communities network access for hundreds of dollars per subscriber. This is cheaper, by an order of magnitude, than traditional access networks.[44] In addition, many of these technologies enable broadband access.

As illustrated in the SARI example from southern India, deployments of wireless networks can be financially viable on revenues of only a few dollars a day. In return, this may allow small entrepreneurial and community-based operators to provide affordable and widespread basic and value-added services. Compared to the cost structures of large, traditional telecommunication operators, these micro and small enterprises have significantly reduced costs. Moreover, they may be more entrepreneurial and responsive to local needs and conditions.

Deployment of wireless technologies for universal access can be facilitated through implementing a basket of public policies. One approach may be to bundle these policies in a licensing process for "universal access providers." The critical elements in these policies are (1) low entry barriers (for example, licence exemptions or tax breaks); (2) permission to offer diverse value-added services with few or no regulatory restrictions (for example, a liberal allowance to use VoIP and other packet-switched services); and (3) encouragement of micro- and small-business models (for example, through USF subsidies, fair interconnection rules and/or zero-interest loans). With the combination of effective regulatory policies and innovative uses of wireless technologies, countries may be able at this juncture to make dramatic gains in introducing connectivity to their rural populations.

Of course, since many of the wireless Internet Protocol (IP) technologies described in this chapter are very new, more research into its practical use across a broad array of developing countries is needed. It is for this reason that ITU will be coordinating a series of pilot projects using wireless IP technology to further develop the knowledge in this field (See Box 7.7).

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[1] See Kofi Annan, “On the Digital Divide”, at http://www.un.org/News/ossg/sg/stories/sg-5nov-2002.htm.
[2] See the accompanying wireless glossary in Box 7.1 for definitions of some of these terms.
[3] The Institute of Electrical and Electronics Engineers is a leading engineering association and heavily involved in developing technical standards for network systems. See http://www.ieee.org.
[4] See http://grouper.ieee.org/groups/802/11/index.html.
[5] For instance the Wi-Fi Alliance. See http://www.wi-fi.org.
[6] Details and links to many vendor’s and their offerings can be found at http://www.wi-fi.org.
[7] Constant predictions on the future capabilities of Wi-Fi can be found in the popular press. For instance see Nick Wingfield, “Anytime, Anywhere”, Wall Street Journal Europe, 6 April 2003.
[8] See the Digital Gangetic Plain, Media Lab Asia Kanpur-Lucknow Lab, at http://www.iitk.ac.in/mladgp/home.htm.
[9] See the Village Area Network Box 7.2.
[10] Alvarion with the Swedish Space Corporation established a Wi-Fi link between a radio on the ground and a stratospheric balloon. See Kewney, G. “World Wi-Fi distance record – 310 km – acknowledge by Guinness”. NewsWireless.Net.
[11] See http://grouper.ieee.org/groups/802/16/.
[12] For both systems, this bandwidth is shared among all subscribers within the network. Moreover, substantial signaling overhead is present in these systems, which can consume over half of the available bandwidth. Thus it is not unusual for an 802.11b system to deliver only 2 mbps, which will then be shared among all systems on that WLAN.
[13] Offered by Motorola. See http://motorola.canopywireless.com/.
[14] See http://www.tenet.res.in/cordect/cordect.html and reviewed in Box 7.3 on corDECT below.
[15] Note that costs such as installation, grounding, transportation, etc. can vary considerably from location to location and influence these numbers.
[16] See http://www.simputer.org.
[17] See http://www.picopeta.com.
[18] The Sinsamut ICT computer is a 1 GHz computer, running Linux or Windows, costs approximately USD 250. Thailand expects to produce 1 million such computers. See Address of Dr. Nalikatibhag Sangsnit, Vice Minister of ICT, Royal

Government of Thailand at 10 July 2003 meeting of the Asia Pacific Forum on Telecommunications Policy and Regulation at http://www.aptsec.org/.

[19] Oficina Nacional de Estadistica. (2001). Poblacion del Censo 1993 y Estimada 1999- 2000 Segun Provincias y Municipios. See http://www.one.gov.do/proyecciones.htm and http://www.one.gov.do/html/sanjuan.htm.

[20] M.L. Best, L. Burnes, M. Escobedo & H. Shakeel. Village Area Network, Bohechio. In S. Krishna & S. Madon (Eds.), *Proceedings of the Seventh International Working Conference of IFIP WG 9.4* (p. 211-220). Bangalore, India. 2002.

[21] See http://www.lincos.net.

[22] At the time the Compaq IPAQ.

[23] The U.S. frequency allocation chart can be found at the Department of Commerce website, http://www.ntia.doc.gov/osmhome/allochrt.html.

[24] See Commission Recommendation 2003/203/EC of 20 March 2003.

[25] See Department of Telecommunications announcement at http://www.dotindia.com/wpcc/indoor_delicense.htm.

[26] See http://www.tenet.res.in.

[27] System specifications can be found in "corDECT Wireless Access System", Midas Communication Technologies Pvt. Ltd. See http://ww.midascomm.com.

[28] See Negroponte, N. "Being Wireless". *Wired*. 10.10. 2002.

[29] Jardin, X. Beyond Wi-Fi. *Wired* 11.05. 2003.

[30] When spread, a radio signal is transmitted across a range of frequencies rather than being packed into as narrow a band of radio spectrum as possible. This technique mitigates interference by either redundantly encoding the data across the frequency spread (called "direct sequence") or by hopping into new frequencies when interference is encountered (called "frequency hopping").

[31] Weinberger, D. The Myth of Interference. Salon.com. March 12, 2003.

[32] For instance, see Borisov, Nikita, Goldberg, and Wagner. "Intercepting Mobile Communications: The Insecurity of 802.11" at http:://www.isaac.cs.berkeley.edu/isaac/mobicom.pdf.

[33] See World Telecommunications Development Report 2002, ITU.

[34] See http://www.bta.gov.bt.

[35] Gillwald, Al Under-serviced Area Licences in South Africa: Steps to achieving viable operators. LINK Policy Research Paper Series No. 3, 2002.

[36] For basic telecommunications statistics for India and the rest of the world see *World Telecommunications Development Report 2002*, ITU.

[37] The author of this chapter is a Principal Investigator with the SARI project. The SARI specific figures contained here are based on his own primary research (in collaboration with research partners). Primary research methods include user and operator surveys, operator self-reports, analysis of Internet use logs, analysis of accounting books, and instrumentation of Personal Computer equipment.

[38] See Box 7.6 below.

[39] This data is available from the Government of Tamil Nadu website. See http://www.tn.gov.in.

[40] Note that all of these calculations are based on the figures and estimates, mostly from self-reporting by the local kiosk owners. Thus, there may be reporting errors. Nonetheless, the summary figures point to a break-even point below USD 3 per day and a profitability point that would certainly be reached at USD 4 a day. Moreover, some of the cost figures are going down. For instance, PC and corDECT costs are dropping to perhaps USD 1000 or lower, rent and electricity costs can be controlled or reduced (by co-locating with other businesses, for example) and there may be opportunities for low-interest or no-interest small-business loans. A combination of these cost savings could yield a break-even point of USD 2 a day and a potential profit at USD 3 per day.

[41] This model allows us to adjust the parameters to see the impact of various changes in the deployment (e.g. "What if we had to go to satellite?"). However, these calculations are all based on broad assumptions and subject to change as the markets and technology vary.

[42] And using broad assumptions on income levels (USD 1 per day per person) and willingness to pay, these figures could work in population densities as low as 15 people per square km.

[43] Huffman, B.D. Building a Wireless Bridge Over the Digital Divide. *Rural Development Dialogue*, 23(4), 2002/.

[44] Many of the costs described in this chapter are based on projects implemented by research institutes. Actual costs will vary as a function of commercially provided equipment costs, Internet backhaul costs and regulatory fees.