Wireless Networks and Rural Development: Opportunities for Latin America

Hernan Galperin

Annenberg School for Communication
University of Southern California

Prepared for the Latin American Studies Association Conference, Las Vegas, NV, October 7-9, 2004

- draft, please do not quote -

Correspondence:

Hernan Galperin
Annenberg School for Communication
University of Southern California
3502 Watt Way
Los Angeles, CA 90089
USA
hernang@usc.edu

Wireless Networks and Rural Development: Opportunities for Latin America

Abstract

Recent developments in wireless networking are raising new hopes for sustainable Internet diffusion in the rural areas of the developing world. These technologies allow drastic reductions in deployment costs, particularly for last-mile connectivity in low-density areas. More important, they make possible an infrastructure development model based on community-shared resources, small-scale investments, and user experimentation. This paper argues that the new generation of wireless technologies can significantly alleviate the constraints that limit Internet connectivity in Latin America to the wealthy, urbanized areas. Yet for this potential to be realized governments need to rethink current assumptions about spectrum management and universal access policies.

I. Introduction

It is widely accepted that new information and communication technologies (ICTs) can be used to alleviate a wide range of obstacles for economic and social development in the developing world. This is particularly true of the Internet. As a global platform for accessing and sharing information, the Internet offers unique opportunities to overcome a variety of informational deficits that handicap people, businesses, and communities in poor nations (Castells, 1999; Rodriguez and Wilson, 2000). Studies have shown that increased productivity, better health, education, and government services can all result from widespread Internet adoption (Grace, Kenny, and Qiang, 2001). However, many obstacles remain for widespread Internet adoption in the developing world, particularly outside the main urban centers (Norris, 2000; Sarrocco, 2002). A combination of poor telecommunications infrastructure, low population density, inadequate regulation, and high-cost technologies designed for urban markets makes Internet connectivity in many parts of the developing world a complex and costly proposition.

As a result, some researchers and donors have begun to question the cost-benefit rationale of extending Internet access to these high-cost, low-income areas. For example, Kenny (2002) argues that to address the informational needs of the rural poor, traditional technologies such as broadcast radio provide a more cost-effective alternative. Over the last decade, an abundance of demonstration project have been undertaken to demonstrate the benefits of Internet connectivity for a variety of rural development goals. However, long-term sustainability and wider-scale replication are rarely obtained (James, 2003; Caspary and O'Connor, 2003). The reasons are complex, but most researchers point to a combination of poor design and implementation that does not properly account for local conditions, and the use of technologies developed for urban markets.

Recent developments in wireless networking are nonetheless raising new hopes for sustainable Internet diffusion in the rural areas of the developing world. These technologies allow drastic reductions in deployment costs, particularly for last-mile connectivity in low-density areas. For example, remote rural villages can be serviced by asynchronous wireless systems that take advantage of local caching and existing transportation infrastructure (e.g., roads) for long-distance traffic backhaul. Such systems can be gradually scaled-up or adjusted following actual demand for ICT services, thus enhancing long-term sustainability. But more important, new wireless technologies make possible an infrastructure development model based on community-shared resources, small-scale investments, and user experimentation (Best, 2003; Bar and Galperin, 2004). While we often think of Internet deployment as an undertaking for large commercial or government organizations, these technologies allow infrastructure to be built from the bottom-up by a variety of local actors, from municipalities to user cooperatives. This also enhances sustainability for systems grow more closely tied to local contexts and community needs.

This paper argues that a new generation of wireless technologies can significantly alleviate the constraints that limit Internet connectivity in Latin America to the wealthy, urbanized areas. However, for this potential to be realized, a number of obstacles need to be overcome. The first part of the paper provides a brief overview of the new breed of wireless networking technologies that are fundamentally changing the cost structure of Internet deployment – in particular the family of wireless standards known as Wi-Fi. The second part discusses the implications of these changes for strategies to promote Internet diffusion in rural Latin America, and more generally to alleviate the endemic poverty that characterize these regions. The conclusion argues that more rigorous evaluations of demonstration projects are needed to reveal the potential of new wireless technologies to bridge development gaps for the rural poor.

II. The Wireless Revolution: Development Implications

The deployment of telecommunications infrastructure has traditionally been associated with hefty investment programs undertaken by large entities such as telecommunications operators and government agencies. The reason is simple: only these entities were able to amass the sizeable capital and bear the sunk costs involved in laying down copper wires and fiber optic cables to reach households and businesses over a large geographic area. Over the past decades, however, technological progress in key areas of wireless communications and cost reductions in core equipment components have fundamentally changed the cost equation in favor of wireless solutions, particularly in the last-mile segment. This has made possible a connectivity boon for developing nations by significantly reducing the capital costs and the operational complexity involved in deploying basic telecom infrastructure, particularly where no legacy wired networks existed. Of the countries where penetration of mobile telephony first surpassed that of fixed lines, most where in Africa and Latin America (ITU, 2003).

A similar process is now under way with respect to the delivery of Internet access services. Today, the level of Internet connectivity in the developing world is far below that of developed nations, and highly concentrated in urban areas (World Bank, 2004). A number of studies have demonstrated that cost remains a major obstacle for Internet diffusion in these nations. In Latin America, the cost of Internet use as a percentage of average monthly income is about 30 times higher than in the developed world.[1] The reality is that traditional Internet connectivity (i.e., residential connections via wireline dial-up or broadband technologies) remains out of reach for all but a small privileged urban minority. Aside from low per capita income, there are several contributing factors. The preexisting telecommunications infrastructure is generally poor and unevenly distributed in favor of urban centers. Leased-line costs and international connectivity, two key components of Internet access prices, are typically higher than in the developed world. In many cases, regulation discourages competition in the provision of backhaul services and last-mile connectivity (Wallsten, 2003). Finally, in most rural areas low population density and high deployment costs discourage private investments, creating a negative feedback of limited capacity, high prices, and low service demand (Sarrocco, 2002).

[1] Source: ITU. This is calculated as the monthly price of 20 hours of use for residential users.

A new generation of wireless networking technologies is poised to have an impact in the delivery of Internet services in the developing world comparable to that of cellular technology for basic telephony. The technology that is having the greatest impact is the suite of IEEE 802.11 standards also known as Wi-Fi. This technology was originally conceived as a wireless alternative for connecting computers in local area networks (LANs) within homes and offices. However, it soon became clear that it could also be used to extend the reach of LANs into public spaces. Moreover, both equipment vendors and wireless enthusiasts also realized that with the appropriate hardware and clever tinkering, point-to-point connections could be made over several miles.

Wi-Fi networks have experienced extraordinary growth since 1997, when the IEEE finalized the original 802.11 standard. This encouraged further improvements to the original specifications. Today, Wi-Fi comes in three basic flavors: 802.11b, which operates in the 2.4GHz frequency range and offers speeds up to 11Mb/s; 802.11a, which operates in the 5GHz frequency range and offers speeds up to 54Mb/s; and the most recent 802.11g, which is backwards compatible with 802.11b but offers speeds up to 54Mb/s. While the signal range of Wi-Fi networks is limited to a few hundred meters, next generation variations such as IEEE 802.16 (known as Wi-Max) promise speeds up to 70Mb/s over several kilometers. Moreover, work continues on new variations of the standard that will improve the range, security and functionality of wireless local area networks (WLANs).

Among the many factors that explain the success of Wi-Fi, three are particularly noteworthy. First, Wi-Fi networks can deliver high-bandwidth without the wiring costs, which makes it an effective replacement both for last-mile delivery as well as for backhaul traffic where the installation and maintenance cost of wired infrastructure is prohibitive. Second, there is widespread industry support for the Wi-Fi standard, coordinated through the Wi-Fi Alliance, an industry organization including over 200 equipment makers worldwide. The Wi-Fi Alliance was formed in 1999 to certify interoperability of various WLAN products based on the IEEE 802.11 specifications. Since the beginning of its certification program in 2000, the group has certified over 1,000 products. As a result, equipment prices have dropped rapidly, and users can expect compatibility between Wi-Fi client devices and access points (APs) made by different vendors. A third key to the technology's success resides in the lack of regulatory overhead: Wi-Fi networks have blossomed on unlicensed bands, namely, thin slices of the radio spectrum reserved for low-power applications in which radio devices can typically operate on a license-exempt basis (though as we shall see this is not always the case in the developing world). This has allowed for a wide variety of actors to build local wireless networks without any of the delays and expenses traditionally associated with obtaining a radio license from the telecommunications authority.

It is easy to grasp the cost advantages of Wi-Fi for promoting connectivity in a developing world context. Wi-Fi networks do not need reliable wired infrastructure, which is scarce in developing nations. Equipment and installation costs are considerably lower since wireless dispenses of wiring expenses, which typically comprise up to threequarters of the upfront costs of building telecom networks. Finally, Wi-Fi takes advantage of a natural resource typically underutilized in rural areas: the radio spectrum. Yet the challenge of Internet diffusion in the developing world is not only economic in nature. There are also implementation models linked to legacy wired technologies that tend to discourage investments outside wealthy urban centers.

Laying telecom wires is not unlike paving roads. It typically requires large upfront investments, and the architecture of the network has to be carefully planned in advance because resources are not easily redeployed. As a result, centralized planning by large organizations is typically how telecom infrastructure is deployed. This involves making many ex ante assumptions about how the services will be used and by whom. Such assumptions are easier to make in the case of well-understood, single-purpose networks (such as roads and sewage) than in the telecom case, where applications and uses often result from “learning by doing.” Furthermore, in the rural areas of the developing world demand for connectivity is complex to aggregate and difficult to predict. These factors not only discourages private investors but also create sustainability problems as well-intentioned donors and governments often miscalculate the long-term viability of pilot initiatives (Heeks, 2002).

New wireless technologies encourage a different model of infrastructure development better suited to the challenges of extending Internet connectivity to rural areas. Unlike fixed technologies, wireless solutions are flexible and scalable, both in terms of their physical layout and their logical architecture.[2] Also, because of the cost advantages associated with wireless and the use of unlicensed spectrum bands, infrastructure investments are within the reach of local organizations that better understand local conditions. Pilot initiatives with information kiosks in rural India have demonstrated that a variety of services can be provided by local entrepreneurs with minimal capital outlays (Best and Maclay, 2002). The infrastructure can therefore expand from the bottom-up, without a preconceived plan, and linked to the needs and attributes (geographical, demographic, economic) of local communities.

The new breed of wireless technologies thus allows developing nations to leapfrog the first generation of Internet access technologies much like mobile telephony has allowed leapfrogging of traditional telecommunications networks. Moreover, it allows for development strategies to bridge the access gap within these nations by removing technology and regulatory bottlenecks that make traditional connectivity prohibitively expensive outside the main urban centers. The foundation for such strategies is the deployment of inexpensive WLANs by local entrepreneurs and governments for shared access in underserved rural communities. Yet, as discussed in the next section, a number of obstacles remain for such potential to be realized in Latin America and elsewhere.

III. Opportunities and Obstacles for Wireless Deployment in Latin America

[2] A good example is the system known as DakNet, which combines Wi-Fi with a mobile access point mounted on and powered by a public bus to provide email and video message capabilities to rural villages in India (Pentland, Fletcher, and Hasson, 2004).

Latin America is a continent of stark inequalities with respect to income and access to a variety of basic services, and the case of ICT services is no exception. While important gains have been made over the last decade with respect to basic telephony (as noted, largely because of the growth of mobile services) and Internet access, the region as a whole still lags significantly with respect to the developed world on the major ICT indicators (Hilbert and Katz, 2003). Furthermore, evidence from within the continent reveals great disparities between urban and rural regions, regardless of the expected gaps by education and income. Long-dated regional gaps in access to basic telecommunications services have now been magnified in terms of access to new ICT services in most Latin American nations. In Brazil, among the urban residents 12.4% are regular Internet users, while only 1% of rural residents are online.[3] In Chile, the regional leader in ICT development, while 11,5% of urban households have Internet connections, only 1,8% of rural households are connected.[4] In most rural areas there are few to none ISPs, which translates into costly access charges due to lack of competition or long-distance charges for basic Internet connectivity.

Closing these infrastructure gaps between urban and rural areas is critical for raising living standards in the region. While the continent has undergone a rapid process of urbanization over the past decades, almost a quarter of Latin Americans still live in rural areas, and they are disproportionately poor.[5] Lifting rural residents out of poverty is a

[3] Source: CPS/IBRE/FGV, Mapa da Exclusão Digital (2003).
[4] Source: Subsecretaría de Telecomunicaciones, Análisis de Estadísticas por Hogar del Sector Telecomunicaciones (2003). It should be noted that household statistics tend to underestimate the urban/rural connectivity gap since urban residents also connect through public access points (e.g., cybercafés) that are readily available in most Latin American cities but hardly exist in rural areas.
[5] According to CEPAL, 54% of rural households in the region are poor, compared to 30% in urban areas.

complex undertaking that involves a variety of development strategies, all of which presuppose better ICT access. First, several studies have demonstrated that ICTs can help improve productivity for the rural poor by reducing transactions costs and enhancing information flows in agricultural product and factor markets, including credit and information relevant to agricultural activities (Torero, 2000; Eggleston, Jensen, and Zechhauser, 2002). Second, the reality of rural communities in Latin America is that they increasingly depend on non-farm activities, and attracting these requires reliable communication links to urban centers and a more educated workforce, both of which presuppose improved ICT access (de Janvry and Sadoulet, 2000). Third, the administration and delivery of government services, and in particular of social assistance programs for the poor, can be improved dramatically through the use of ICTs. Finally, improved access brings about local empowerment, an important precondition of sustainable rural development strategies.

New wireless technologies, as discussed, offer exciting new opportunities for addressing the lack of connectivity in rural Latin America, both in terms of reduced cost per connection and in terms of allowing local organizations and entrepreneurs to become active participants in (rather than just recipients of) of infrastructure development projects. Yet for such potential to be realized, renewed policy effort is needed on a number of fronts. As Navas-Sabater, Dymond and Juntunen (2002) note, the challenge of extending connectivity to the rural poor requires policy action that addresses two different access gaps. The first is the gap between the level of penetration under the current regulatory structure and the one that could be achieved should reforms allow for a well-functioning ICT services market in these areas (the market efficiency gap). The second gap refers to those who simply cannot be served profitably even under perfect market conditions, and for whom some form of public subsidy is needed (the affordability gap). The advent of new wireless networking technologies calls for rethinking public action on these two fronts.

With respect to the market efficiency gap, there is much to be done to facilitate the deployment of local wireless networks in the continent, whether by entrepreneurs, public entities, or civil society organizations. A pervasive concern are the rules that govern the use of unlicensed bands. As noted, Wi-Fi networks have flourished on the basis of rules that provides for designated slices of the spectrum where anyone can build a network without the need to obtain a radio license. Unlicensed bands were pioneered by the FCC, which in 1985 decided to allow low-power radios to operate on the so-called Industrial, Scientific and Medical (ISM) bands (at 900MHz, 2.4GHz, and 5GHz) on a license-exempt basis (Carter, Lahjouji, and McNeil, 2003). Since then, more frequencies have been made available, and other regulators have followed on the FCC's footsteps by establishing rules for the operation of WLANs in these bands. Unlicensed bands have also been endorsed by the International Telecommunications Union (ITU), most recently in the 2003 World Administrative Radio Conference (WARC) which recommended primary allocation of a sizeable amount of spectrum (455MHz) in the 5GHz band for WLANs.[6]

[6] Although some of these frequencies were recommended for indoor use only due to interference concerns with radar systems operating in the same frequencies.

Developing nations, however, have been much slower in adapting spectrum policies to enable deployment of WLANs over unlicensed bands. Overall, analysts estimate that in the developing world less than 50% of the nations have established rules for license-exempt bands (Leblois, 2003). This is confirmed by a survey of African nations conducted by Neto (2004). The survey found significant heterogeneity across the continent in the regulation of the 2.4GHz and 5GHz bands in terms of licensing requirements, power and range limitations for WLANs, equipment certification rules, and service restrictions. More important, the results revealed that the majority of African nations (54% in the case of the 2.4GHz band and 57% in the case of the 5GHz band) still require a license for the operation of low-power devices in these frequencies. While no comparable survey of the Latin American regulatory environment for WLANs exists, the examples below reveal that, much like in Africa, legacy spectrum regulations create obstacles for the deployment of Wi-Fi networks across the continent.

Take the example of regulations concerning the 2.4GHz band (where the popular 802.11b standard operates). To begin with, as shown in Table 1, licensing rules typically relegate Wi-Fi systems to secondary status, which means that these systems must both accept interference from and avoid interference to primary band licensees (these vary from country to country, ranging from fixed wireless data services to broadcasting news operations). In the case of Brazil, there are also power limitations for the operation of Wi-Fi devices in cities with over 500,000 inhabitants.[7] In Chile, power restrictions are even

[7] ANATEL Resolução No. 365 (2004). These rules limit the output power of unlicensed WLAN systems to 400 mW, which is less than half the power allowed by FCC Part 15 rules.

more severe, and the operation of unlicensed WLANs is restricted to indoor spaces.[8] Similarly, power restrictions drastically limit the use of Wi-Fi systems in Mexico, and outdoors operations are restricted to a small portion of the 2.4GHz band.[9] In Peru, the operation of Wi-Fi devices is also restricted to indoor spaces, and power restrictions severely limit the range of possible applications.[10] In the case of the 5GHz band, the regulatory environment is even more restrictive, although this is changing following the WARC 2003 agreement discussed above.

Table 1: The Regulation of WLANs in the 2.4GHz Band in Selected Countries

	Brazil	Chile	Mexico	Peru
Licensing basis	Secondary	Secondary	Secondary	Secondary
Power restrictions	400mW in large cities, 1W for rest	100mW	650mW	100mW
Range restrictions	None	Indoor use only	Indoor use only in 2,400-2,450MHz	Indoor use only

The heterogeneity in rules across the continent and the overly restrictive rules for the operation of Wi-Fi devices in some key nations represent significant regulatory obstacles for the deployment of a technology that, as discussed, offers significant opportunities for reducing access costs and reaching areas neglected by the major ISPs in the region. Different rules discourage investments by regional players and prevent the realization of economies of scale in equipment supply and services strategies. Licensing on a secondary

[8] SUBTEL Resolución No. 991 (2003).
[9] NOM-121-SCT1-2000.
[10] Article 25 of the Reglamento General de la Ley de Telecomunicaciones.

basis similarly discourages investments for no interference protection is afforded not only from peer low-power users but more critically from higher-power primary licensees. Output power restrictions and in some cases the ban on outdoor use effectively limit the functionality of WLANs to indoor applications such as the replacement of Ethernet cabling in homes and offices or "hotspot" access in hotels and airports. This is very significant because, contrary to the case of developed nations where the growth of Wi-Fi is being driven by applications for mobile Internet access in restricted spaces (Bar and Galperin, 2004), there is evidence that some of the most valuable applications for Wi-Fi in the developing world are based on fixed outdoor systems for the carriage of backhaul traffic or the provision of last-mile access.

Take the example of backhaul connections. Local wireless networks provide, as the name suggests, local connectivity. But the provision of true Internet access requires that these networks be linked (interconnected) to the global Internet via wired or wireless high-speed links. These services, called IP (Internet Protocol) backhaul services, are typically provided by telecom operators through dedicated lines or satellite connections. There are a number of factors that often make IP backhaul services prohibitively expensive in developing nations. Some relate to the existing arrangements for international IP traffic that typically favors large operators in developed nations at the expense of those in the developing world.[11] Yet others stem from legacy regulations that protect the monopolistic provision of Internet backhaul services in many Latin American nations (Estache,

[11] Unlike in the telephony world, where ITU-mandated rules require that the costs of international calls be shared between operators, international IP connectivity arrangements are market-driven private contracts. Given the smaller customer base of most developing-country operators, these will typically have to pay to interconnect with its larger counterparts in the U.S. or Europe. This is also significant for regional IP traffic which in the case of Latin America is generally triangulated through the U.S. (Cavalli, Krom, Kijak, 2003).

Manacorda, and Valletti, 2002). New wireless technologies allows potential bypassing of such high-cost backhaul links. In Africa, Wi-Fi systems are often used to carry backhaul IP traffic (Neto, 2004). Yet, by restricting the operation of Wi-Fi to indoor spaces, spectrum regulations create a significant barrier to entry for small entrepreneurs, local governments, and other non-traditional actors that reduces competition and in many cases perpetuates the neglect of rural, low-income communities by incumbent ISPs.

For some regulators, the concern is that the mushrooming of Wi-Fi networks coupled with new technologies that enable new applications over these networks such as VoIP (voice over Internet Protocol) will wreak havoc to the ongoing process of telecom industry reform. Such concerns are not completely unfounded: in many developed world markets the unexpected success of Wi-Fi has indeed created much market turmoil and put wireless industry incumbents on the defensive (Bar and Galperin, 2004). Yet, such turmoil has fostered innovation, encouraged investments, and delivered many benefits to the public, including not only mobile connectivity for wealthy users but also better and cheaper access in previously underserved rural and inner-city areas (Johnston and Snider, 2003). Revisiting legacy spectrum rules that obstruct the development of WLANs is thus an important task for regulators in the region, for such rules tend to protect corporate privileges at the expense of innovation and broader opportunities for connectivity in the most disadvantaged areas of the continent.

Given the appropriate regulatory environment, new wireless technologies can therefore significantly reduce the affordability gap and encourage the entry of new actors in the provision of ICT services. Yet it is likely that such market-led policies will not suffice to bring about universal connectivity in the continent because the delivery of Internet access in certain areas will remain unprofitable. Generally speaking, the main public policy instrument used to promote network deployment in areas with negative private returns are universal service obligations (USOs) imposed on telecommunications operators. During the industry reforms of the 1990s, Latin American nations established different USO regimes that varied widely in terms of general definition, coverage, retail scheme, and funding mechanism (Navas-Sabater, Dymond, and Juntunen, 2002). While traditionally these obligations only encompassed the extension of basic voice telephony, several nations have recently expanded the definition of universal service to include advanced ICT services, and governments are increasingly channeling USO funds to subsidy ICT kiosks in rural or low-income areas. In Chile, the Telecommunications Development Fund was modified in 2001 to allow funding of a program that has to date subsidized the creation of almost 300 community telecenters in rural areas through competitive tenders (Wellenius, 2001). In Colombia, a similar program (called Compartel) has to date financed the installation of over 900 community telecenters across the country.[12]

The increasing use of public funds to subsidize community telecenters in unprofitable areas is encouraging. However, these programs are generally based on a top-down approach in which public officials select the locations and administer a competitive tender for the deployment of community access centers with clearly defined parameters in terms of what technology will be used, which ICT services will be made available, how the center will be operated, and so on. The result is that, as evidenced by the

[12] Reporte de Internet en Colombia (2003), Comisión Regulación de Telecomunicaciones.

aforementioned programs in Colombia and Chile, most contracts are awarded to large telecom operators or service aggregators, with little participation from community organizations.

As discussed, new wireless technologies make it easier for a variety of local actors to participate in the deployment of ICT infrastructure. This opens the door to another option based on micro-financing programs to public or private local entrepreneurs. Micro-financing programs for network infrastructure deployment, pioneered by the Rural Electrification Authority (REA) in the U.S. in the 1930s, have been successfully applied to ICTs in several cases, most notably in the Grameen Phone project (Prahalad and Hammond, 2002). Though further research is needed, anecdotal evidence suggests that such programs represent an effective way of channeling public funds into ICT development projects since local actors are often best positioned to understand the characteristics of local demand for ICT services and integrate them with local information needs. Moreover, these programs also contribute to build local entrepreneurial capacity, a much needed skill for the diversification of economic activities in rural Latin America.

IV. Conclusion

Extending Internet connectivity to marginalized areas in the developing world involves a delicate cost-benefit balance. The price of access has to be low enough to be affordable to low-income residents. At the same time, the gains derived from connectivity must be high enough to enable long-term sustainability as well as the realization of social development goals. The costs and deployment models associated with the first generation of Internet access systems based on wireline technologies have often proved inadequate to address this problem. New wireless technologies, on the other hand, offer new opportunities for network deployment in areas currently neglected by the existing operators. These technologies are powerful, flexible, and inexpensive. Moreover, they enable local actors to regain an important role in the roll-out of network infrastructure and ICT services. As such, these technologies are poised to redefine the terms of the debate about the sustainability and cost-effectiveness of strategies to promote Internet diffusion in developing nations.

Yet much remains to be done before these opportunities are realized in Latin America. One of the main challenges is to reform existing spectrum rules that restrict the deployment of Wi-Fi systems over unlicensed bands. Another is to rethink universal service policies in a way that reflects both the economic realities of rural Latin America and the development opportunities associated with community access to ICT services. Yet another is to educate government and donors about these opportunities. For this, demonstration projects that illustrate the benefits associated with community network initiatives under a variety of different local conditions are critical.[13] Ultimately, the goal is to demonstrate that new wireless technologies significantly broaden the range of alternatives for addressing the existing connectivity gaps inside the region.

[13] For disclosure, the author is involved in a project funded by the Institute for Connectivity in the Americas (ICA-IDRC) that will evaluate a number of Wi-Fi pilot projects in rural areas of Latin America.

References

Bar, François, & Galperin, Hernan. 2004. *Building the wireless Internet infrastructure: From cordless Ethernet archipelagos to wireless grids*. Presented at the European Communications Policy Research Conference, Barcelona, March.

Best, Michael, & Maclay, Colin. 2002. Community Internet access in rural areas: Solving the economic sustainability puzzle. In *The Global Information Technology Report 2001-2002: Readiness for the Networked World*. New York: Oxford University Press.

Best, Michael. 2003. The wireless revolution and universal access. In *Trends in Telecommunications Reform*. Geneva: ITU.

Carter, Kenneth, Lahjouji, Ahmed, & McNeil, Neal. 2003. *Unlicensed and unshackled: A joint OSP-OET white paper on unlicensed devices and their regulatory issues*. Washington, DC: FCC.

Caspary, Georg, & O'Connor, David. 2003. *Providing low-cost information technology access to rural communities in developing countries: What works? What pays?*. Paris: OECD.

Castells, Manuel. 1999. *Information technology, globalization and social development*. UNRISD Discussion Paper No. 114, September.

Cavalli, Olga, Krom, Jorge, & Kijak, Alejandro. 2003. *Desarrollo de NAPs en Sudamérica*. Montevideo: ICA-ICRD.

De Janvry, Alain, & Sadoulet, Elizabeth. 2000. *Making investment in the rural poor into good business: New perspectives for rural development in Latin America.*

Presented at the Conference on Developing the Rural Economy and Reducing Poverty in Latin America and the Caribbean, New Orleans, March.

Eggleston, Karen, Jensen, Robert, & Zeckhauser, Richard. 2002. Information and communication technologies, markets, and economic development. In *The Global Information Technology Report 2001-2002: Readiness for the Networked World.* New York: Oxford University Press.

Estache, Antonio, Manacorda, Marco, & Valletti, Tommaso. 2002. Telecommunications reforms, access regulation, and Internet adoption in Latin America. *Economica* 2: 153-217.

Grace, Jeremy, Kenny, Charles, & Qiang, Christine. 2001. *ICTs and broad-based development*. World Bank Global Information and Communications Technology Department, Washington, D.C.

Heeks, Richard. 2002. *Failure, success and improvisation of information systems projects in developing countries*. Institute for Development Policy and Management, Development Informatics Working Paper #11.

Hilbert, Martin, & Katz, Jorge. 2003. *Building and information society: A Latin American and Caribbean perspective*. Santiago de Chile: CEPAL.

International Telecommunications Union (ITU). 2003. *World telecommunications development report*. Geneva: ITU.

James, Jeffrey. 2003. *The global information infrastructure revisited*. Third World Quarterly 22(5): 813-822.

Johnston, James, & Snider, James H. 2003. *Breaking the chains: Unlicensed spectrum as a last-mile broadband solution*. New America Foundation Spectrum Series Working Paper #7.

Kenny, Charles. 2002. Information and communication technologies for direct poverty alleviation: Costs and benefits. *Development Policy Review* 20(2): 141-157

Leblois, Axel. 2003. A global standard meets local policies and politics. In *The Wireless Internet Opportunity for Developing Countries*. Boston: Wireless Internet Institute/infoDev.

Navas-Sabater, Juan, Dymond, Andrew, & Juntunen, Niina. 2002. *Telecommunications and information services for the poor*. World Bank Discussion Paper No. 432.

Neto, Isabel. 2004. *Wireless networks for the developing world: The regulation and use of license-exempt radio bands in Africa*. Unpublished Ph.D. dissertation.

Norris, Pippa. 2000. *The global digital divide : Information poverty and Internet access worldwide*. Presented at the International Political Science World Congress, Quebec City, August.

Pentland, Alex, Fletcher, Richard, & Hasson, Amir. 2004. DakNet: Rethinking connectivity in developing nations. *IEEE Computer Outlook* 37(1): 78-83.

Prahalad, C.K., & Hammond, Allen. 2002. *Serving the poor, profitably*. Washington, DC: World Resources Institute.

Rodriguez, Francisco, & Wilson, Ernest J. III. 2000. *Are poor countries losing the Information Revolution?* infoDev Working Paper, May.

Sarrocco, Claudia. 2002. Improving IP connectivity in the least developed countries: Breaking the vicious circle. *info* 4(3): 14-28.

Torero, Maximo. 2000. *The access and welfare impacts of telecommunications technology in Peru*. ZEF-Discussion Papers on Development Policy No. 27.

Wallsten, Scott. 2003. *Regulation and Internet use in developing countries*. AEI-Brookings Paper, May.

Wellenius, Bjorn. 2001. *Closing the gap in access to rural communication: Chile 1995–2002*. Washington, DC: World Bank.

World Bank. 2004. *World development indicators*. Washington, DC: World Bank.