Network Connectivity Architectures in Developing Regions: a Survey
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Introduction

Modern theory in anthropology claims that in this increasingly small world there is no area untouched by modern technology. The question, therefore, is no longer that of how to leave developing cultures untouched, but it has increasingly become one of how to make resources available to these areas, where the disparity between technology’s haves and have-nots have exacerbated the “digital” divide between the rich and the poor.

The United Nations has especially embraced this issue, where Secretary-General Kofi Annan has of late called for the use of information and communication technologies to bridge the digital divide to create “a truly global, inclusive and human development-oriented information society.” Annan also called for information and communication technologies to act as key catalysts for social, economic, and cultural development in developing countries. Increased access to knowledge is “rapidly becoming a potent tool for empowering the people and communities in their quest for new opportunities, dignity and a better life.”1 With technological innovations permeating all aspects of human life and improving living standards, the same benefits are necessary for sustainable development.2

Finding wireless or networking technologies to connect these remote areas of the world are becoming increasingly important for the equity of opportunities. Networked communities will work to offset brain drain, as well as create new opportunities through distance learning. In conflict areas, these distance-learning initiatives may offer a new channel in which to teach nonviolent conflict resolution.

Concerns have been raised about being “foolhardy to throw money at fancy computers and Internet links” for people who are living on less than a dollar a day, whose basic focus is survival.3 While there is some verity in this statement, that people in the bottom rungs of poverty have other priorities and do not have the capacity to consume goods and services, there is also a “middle-tier” of poverty that is largely ignored, underserved by IT, and have not seen the benefits of IT because of a lack of local language services, affordability of access devices, and the lack of a communications infrastructure.4

In developing a network for these areas, great improvements are likely in the following goal applications: core communication, government (e-government), commerce (e-commerce), education (distance learning), health (e-health), entertainment, and training. Research has shown that people in these regions are more than willing to pay to have communication services. This shows a potential for new markets.

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1 Chand [12]
2 World Bank [59]
3 The Economist [5]
4 Gopal [24]
Data and Statistics

According to the 2002 data from the World Bank Group, 15.6% of the world’s population (from fifty-four countries) held 80.6% of the world’s income, as represented in the user distribution chart below (Figure 1).\(^5\) It is this same high-income class that composes roughly 70% of all Internet users.\(^6\) Meanwhile, people from the sixty-one countries in the low income class only compose 3.8% of the world’s Internet users, even though they account for 37.7% of the world’s population and 3% of the world’s GDP.\(^7\) Even worse off are the people at the very bottom of the rung, in the least-developed nations, as determined by the UN, whose population only account for 0.3% of the world’s Internet users.

Figure 1: Internet User Distribution by Income Class, 2002

Further, by dividing the world into income-related regions, we can see that eighty percent of the world’s GDP is concentrated in North America, Western Europe, and Oceania (Figure 4), and that while Internet usage and PC ownership has been steadily growing in the US and Europe/Central Asia, regions like sub-Saharan Africa and South Asia have been stagnant in their growth.

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\(^5\) World Bank [59]
\(^6\) World Bank [59]
\(^7\) Sachs [49]
Running a t-statistic on the data accumulated from the CIA Factbook\(^8\), it is clear that there is a strong positive correlation between GDP per capita and Internet usage per capita \((t=28.571, pr<2\times10^{-16}, df=210)\). The variance is 79.54\%, which suggests that there is a very strong association between the GDP per capita of a country and the percentage of the population who use the Internet (user penetration). This affirms the assumption that in this high-speed digital world, citizens of many lower-income nations are suffering from information poverty, inability to access information that would otherwise inform their decisions.\(^9\)

That is not to say that people in the developing world are not interested in technology. Considering the prices rural populations are willing to pay for community access to pay phones and TV sets, given the opportunity, there is a market for network connectivity.

### Priorities in Architecture

David Clark’s Design Philosophy\(^{10}\)

| 0.  | Connectivity – connecting multiple networks |
| 1.  | Survivability – network (link & router) failures transparent from endpoints |
| 2.  | Support multiple services – everything-over-IP |
| 3.  | Accommodate a variety of networks – IP-over-everything |
| 4.  | Distributed management of resources – multiple administrations |
| 5.  | Cost-effective – in terms of wasted bytes |
| 6.  | Host attachment with low level of effort – fate-sharing |

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\(^8\) CIA factbook [60]  
\(^9\) WiderNet [56]  
\(^{10}\) Clark [13]
The ideals of the design were placed in order within a military context, so that networks could be rapidly deployed by mustering resources even in a hostile environment. I have modified the importance for a developing country as follows:

Table 2

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<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>0.</td>
<td>Connectivity</td>
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<td>1.</td>
<td>Cost-effective</td>
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<td>2.</td>
<td>(Accountability)</td>
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<tr>
<td>3.</td>
<td>Host attachment with a low level of effort</td>
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<tr>
<td>4.</td>
<td>Accommodate a variety of networks</td>
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<tr>
<td>5.</td>
<td>Distributed management of resources</td>
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<tr>
<td>6.</td>
<td>Survivability</td>
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<tr>
<td>7.</td>
<td>Support multiple services</td>
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<tr>
<td>8.</td>
<td>Accountability</td>
</tr>
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</table>

The most important criteria should be connectivity, cost-effectiveness, host attachment with a low level of effort, accommodation of a variety of networks, and distributed management of resources.

**Connectivity:** Connectivity was placed with the highest emphasis in the initial design for “multiplexed utilization of existing interconnected networks.”\(^{11}\) Packet switching was selected for the Internet architecture to accommodate this feature. Connectivity is still placed with highest emphasis as the main target of these initiatives, in connecting pre-existing networks (ex. A remote region with the nearest hub (likely in a city)). Although reliability of the connection varies between methods, connectivity neither implies a synchronous or always-on characteristic.

**Cost-effective:** The main factor in achieving connectivity in developing regions is the cost. Because not-for-profit institutions usually fund these initiatives, not only does deployment need to be cost-effective, the main objective must be sustainability at a low cost.

**Host Attachment:** Host attachment was given little priority in the initial design. In the initial design the ease of host attachment was sacrificed for connectivity. The mechanisms to provide the desired types of service are implemented in the host rather than in the network, resulting in a high cost of attaching a host to the Internet. In the developing world, priority needs to be given to host attachment. To invest in a last-mile network, there must be enough traffic or demand to make the effort worthwhile. Sustainability. Moreover, because the need for network connectivity is not yet defined,

**Accommodate a variety of networks:** The hosts need to be flexible, that is, the hardware set up in the hosts need to accommodate whatever networks are available.

**Distributed Management of Resources:** It would be better that when local organizations take over these architectures, that there be decentralized organizations managing the service. Success may depend on small local firms rather than big ones.

**Less important goals:** Survivability was given a very high priority in the initial design because the design was created to serve military purposes. Undisrupted flow control was important in transmitting military messages on, say, a battlefield. Meanwhile, in developing countries where electric power faces frequent outages, survivability of a network would not be considered top priority. Some of the methods proposed are

\(^{11}\) Clark [13]
asynchronous, and require latencies and delays of a few days. The only solution would be if the endpoints could fate-share and track state information, since the network will not be able to do so. Supporting multiple services is not really important, since most of these proposals only deal with a few basic services anyway. Accountability is not important in methods like wireless local loops and satellites. However in methods using mobile access points and couriers where digital storage acts as a datagram packet, accounting becomes more essential, since it is harder for the endpoints to simply “retransmit” another.

Survey of Techniques

With the majority of the developing world population in rural areas, a wide area network infrastructure needs to be deployed. Cost and landscape pose the greatest challenges in deployment. In the past several approaches have been proposed as possible infrastructures in developing areas. Because of these two hurdles, cable landlines are out of consideration, as their coverage area is limited and cannot span expansive rural areas, as well as mountainous regions.

Table 3: Comparison of possible solutions

<table>
<thead>
<tr>
<th>Factors/Link Technology</th>
<th>ADSL</th>
<th>Cable Modem</th>
<th>Broadband WLL/FWA</th>
<th>Satellite WLL/FWA</th>
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</thead>
<tbody>
<tr>
<td>Type of Link</td>
<td>Twisted pair</td>
<td>Coaxial cable</td>
<td>Terrestrial microwave</td>
<td>Satellite microwave</td>
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<tr>
<td>Deployment Cost</td>
<td>High</td>
<td>High</td>
<td>Low-Med</td>
<td>Very High</td>
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<tr>
<td>Deployment Time</td>
<td>Med</td>
<td>Med</td>
<td>Low</td>
<td>Med-High</td>
</tr>
<tr>
<td>CPE (equipment) Cost</td>
<td>US $50</td>
<td>$50</td>
<td>$100</td>
<td>$2500</td>
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<tr>
<td>Data Rate per Location</td>
<td>Up to 6 Mbps</td>
<td>Up to 10 Mbps</td>
<td>Up to 100 Mbps</td>
<td>Up to 20 Mbps</td>
</tr>
<tr>
<td>Coverage Area</td>
<td>3-5km from central office</td>
<td>3-5km from cable endpoint</td>
<td>2-10km per cell</td>
<td>large</td>
</tr>
</tbody>
</table>

Source: Rural Wireless Broadband Access Initiative powerpoint presentation

A few different approaches have been proposed. Below I have covered a few proposals that are currently in existence.

Courier Methods, which physically transport digital storage for asynchronous connectivity. Latency can be a major problem, but total bandwidth has a potential to be massive.

Drishtee (sneaker net), an e-government platform, has started using “sneaker net,” an asynchronous transfer of floppy disks from the village to the government center and back

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12 Wanichkorn [53]
again. Sneaker net has met with success because Drishtee’s revenue-generating applications require only intermittent connectivity.\(^{13}\)

*Postmanet*, Princeton University. A major research project is the Postmanet project at Princeton University, which proposes to use the existing postal system as a high-bandwidth alternative to the Internet. A major proposal is to use the postal system as a generic and transparent communication channel to send and receive digital storage media (such as DVDs).\(^{14}\)

*Wizzy Digital Courier*, South Africa. Offline Internet access is used to allow students to browse pre-cached web pages. Emails and requested websites are downloaded overnight, when dial-up rates are cheaper, then delivered with a digital USB storage device, or by a mobile access point.

**Mobile Access Points**, using carriers for intermittent access.

*First Mile Solutions (DakNet)* group, MIT Media Lab, India. Couriers on motorbikes, buses, or even ox carts act as mobile access points to wirelessly transport data from a networked base to a remote host. This project has been deployed in a village near Calcutta, India, and in schools in northern Cambodia.\(^{15}\)

*Sámi Network Connectivity Project*, Sweden. Swedish researchers combined sensor networks with remote Internet access for the Saami tribe of reindeer herders. Email, cached web access, reindeer herd tracking telemetry and basic file and data transfer services are available to the nomadic tribe even during migration, via sensor networks that are attached to snowmobiles.

*Delay Tolerant Networking Group*
A research group dedicated to developing architectures for challenged networks, with intermittent connectivity. The architectures introduces a new “bundle” layer into the existing seven-tiered OSI architecture, where packets could be cached until bundles can be exchanged or at locations where Internet gateways are available (store-and-forward).

**Mobile ad-hoc/Sensor networks**

*Sámi Network Connectivity Project*, Sweden. See above.

*ZebraNet*, Africa. is a sensor network using a herd of zebra. Zebras are equipped with sensors, which flood or use historical data to send information to other sensor hardware to eventually transmit data to the final arbitrary destination where the researchers are. Plans to deploy in Kenya (lions, zebras, hyenas) and in the U.S. (wild horses).

\(^{13}\) Pentland [42]  
\(^{14}\) Wang [52]  
\(^{15}\) Pentland [42]
Long-distance wireless multi-hop

*Digital Gangetic Plains*, Media Lab Asia Kanpur-Lucknow Lab, India. Deployment of IEEE 802.11b as a point-to-point, multi-hop, long-distance wireless network, using towers to extend the range over long distances to rural areas. 16

*HPWREN*, University of San Diego, San Diego, California. 802.11b wireless point-to-point links between mountain peak nodes serve as a backbone to create a 2500-square mile, wide-area network architecture at unlicensed high frequencies. 17

Wireless Local Loop (WLL)

*corDECT*, India. A wireless local loop technology developed by researchers at the TeNeT group at IIT-Madras, employing Multi-Carrier Time Division Multiple Access (MC-TDMA), a technique in which the frequency can change from one time slot to another. 18 Telephone networks are used to carry signals over long distances, then the signals are transmitted wirelessly to hosts. A system usually consists of a central unit based at a local exchange, and around twenty transmitters, each with a transmission radius of 10km, 25km with the help of solar-powered relay stations. 19

*n-Logue*, India. A private company that is a spin-off from the India Institute of Technology, providing corDECT service to local areas. They expect to serve between five to seven hundred subscribers within a twenty-five-kilometer radius.

*SARI (using corDECT)*, IIT-Madras; MIT Media Lab; Berkman Center for Internet and Society, Harvard University Law School; and the I-Gyan Foundation. Carried out jointly with n-Logue Communications Pvt. Ltd., India. Existing telephone networks (PSTN) are used to carry signals over long distances. Local exchanges split voice and Internet traffic, and the Internet signals are converted to radio waves and sent to radio access-enabled homes.

Satellites

*WiderNet*, University of Iowa, Nigeria. A non-profit project with Nigerian universities providing Internet access in many countries in Africa. They rely heavily on satellite communications to avoid the telecommunications monopoly in the region, and since no Internet backbones run through Africa.

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16 Bhagwat [8]
17 Baker [2]
18 CorDECT [26]
19 Sari article [31]
TARAhaat, India. A for-profit business enterprise using existing phone lines and vSat satellite links to bring Internet to rural areas in India. Their most profitable programs include those related to education, training, and government.

Analysis of the methods

Couriers

Pros: The start-up cost for this method is very low. While other methods require a hefty deployment fee in outfitting radio access with each host, couriers use a method that is already in existence. Over time, however, the price of combined postage and digital storage may outweigh the costs of network links. However, the postal service is a physical layer link that has proved over the years to be both reliable and scalable (can handle holiday traffic), although the degrees to which they are either reliable or scalable vary greatly by area. Throughput itself is very large.

Cons: Latency. Postal delivery of media is worse than a store-and-forward application, as each digital storage device takes a few days to deliver. Moreover, the process requires manual labor in actually burning the data onto a DVD or copying data into a digital storage medium, and a physical hand-off, that is, users at the endpoints must be present in order to send/receive. Most importantly, couriers only offer a temporary solution to the infrastructure problem. Because human intervention is required in these projects, the projects are only sustainable as long as there are equipment and qualified volunteers overseeing and guiding the execution of the project.

If couriers are to be implemented in actuality, a “TCP” must be implemented. Currently, flow-control and reliability, error detection/correction, tracking the state, and multiplexing is the responsibility for the users at the endpoints, and can become tedious and challenging, especially at high data volume. Because packet loss with couriers is more expensive than with a digital packet (in terms of monetary cost of the digital storage media and physical time and labor spent in creating the packet), packet loss must be kept to a minimum. Also, the latency is large, and the content is severely limited. It cannot become a reliable alternative to connectivity. However, the immense bandwidth can be very useful in communication modules that do not require real-time, like a digitized book delivery service, or distance learning. Couriers will meet success as a supplement to the Internet, which is the intention of Postmanet in the first place. However, in the case of Postmanet, we are operating under the assumption that a postal system is available and reliable. That is not the case in many places. The postal system does not exist in many places, can be very inefficient, and theft of mail is not uncommon.

Mobile Access Points

Pros: Mobile Access Points are a relatively cheaper solution for providing basic asynchronous communication service. It is also a better use of resources. Moreover, this
method is adaptable, in that the hosts can keep using the same equipment when upgrading to an always-on network. With a few projects underway, it has proved effective and successful. It is sustainable because the method is maintained mainly by locals, but maintenance may become a problem when the funding disappears, these areas may return once again to its pre-digital state.

Cons: The initial cost for deployment is a little high, as multiple transportation vehicles must be equipped with radio access. Vehicles and electricity is essential in operating a mobile access point. The method is reliable when the MAP is fixed to public transportation, like buses, but less reliable when hiring couriers or ox carts. Most importantly, the design is not scalable. The design makes use of a centralized system in order to make the access points available. The design requires that people be at the dispatching end to download and inseminate data. It does not seem like a solution that will integrate into the social fabric for an extended amount of time, because of its unnatural setup. The buses are already a part of the community, so that may be a viable mobile access point, but hiring people to operate vehicles to essentially “deliver” data may become an unnatural service that is not lucrative enough to continue once the foreign funding disappears.

The WiderNet initiative in Africa pushed for direct access because they believed that a store-and-forward connectivity was not enough to take advantage of the business opportunities in linking with the rest of the world. However DakNet quoted a McKinsey report that stated that short-term, email, scan mail, voice mail and chat were likely to be only revenue-generating applications, and thus, an asynchronous mode of communication may be more practical and socially appropriate. With deployment being scheduled in a few regions, the mobile access point method is a very viable one that is relatively easy to implement. It is also relatively adaptable, with varying modes of transportation (ox carts, motorcycles) to accommodate different topology and terrains. Again, a transport layer needs to be implemented in the design for retransmission. Moreover, because mobile access points are transported by a physical carrier on roads, if there is a link failure, routing may not always be efficient. If the buses were equipped with a map and a routing algorithm to find the shortest path, this task would become more efficient. Although, speed and survivability are not high on the list of priorities for developing regions.

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**Mobile ad-hoc/Sensor networks**

Pros: Connectivity via sensor networks is not developed enough yet for deployment in developing areas, but there is a lot of potential. A good scalable design minimizes use of centralized elements, and wireless mesh networks is exactly that. The intermittent connectivity is well-suited for the environments where this method was deployed. No fixed base station.

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*20 WiderNet [56]*

*21 Pentland [42]*
Cons: Need a network or a migratory herd of some sort that is capable of existing for a long time. Affixation of sensors is also costly in terms of time and effort. Depending on how wide the area is, the signals may never reach the destination.

New routing algorithms and protocols are being developed to take advantage of the forwarding opportunities presented by periodic chance encounters. This method is ideal for areas possessing a migratory network or in high-density urban centers.

**Long-distance wireless multi-hop**

Pros: Cost of initial deployment. The Digital Gangetic Plains project was able to extend its transmission radius to over 37km. The projects were successful in extending the range over a wide area network, serving many villages. HPWREN, especially, was successful in extending a broadband network out to reservations, ecological researchers in remote mountainous areas, and most of San Diego County.

Cons: Long-distance wireless links suffer from low adaptability. The wireless signals are sensitive to wind and weather because the 802.11 standard was meant for indoor use. Signal towers require electricity, which may be costly for areas that are already poor. Furthermore, governmental regulations limit the range of frequency that is available for wide use, so that they do not interfere with other signals. For that reason HPWREN used the 2.4-GHz frequency, which severely affected the signal’s resiliency to natural factors such as wind.

Most practical in mountainous terrains and wide areas. The towers need to be at high elevation, since they cannot have interference by buildings. Although the initial setup is costly, once established, there is a good chance at sustainability and will serve a considerable population with synchronous high-speed service.

**Wireless Local Loop (WLL)**

Pros: Relatively low cost for users and providers. Ease of set-up, use, maintenance. Relatively high bandwidth. The set-up cost is one-third that of a copper/fiber landline.

Cons: The challenges that may arise in dealing with new networks are due to the limited range of wireless technology, and federal regulations curbing the frequencies that are available for use. However government regulations are only in place in countries where the mobile phone infrastructure is more or less established, and thus in a few developing countries these do not need to be taken into consideration. Also, a point-to-multipoint link can be unreliable and unadaptable. The method requires a high population density and user base to make up for the costs.

*Satellites*
Pros: Vast coverage area. The bandwidth is less than that of wireless local loops.

Cons: Cost of deployment and cost of maintenance (charges per packet) is very high. Some low-earth orbit satellites only offer connectivity while overhead? Moreover, in order to justify the cost of satellite connectivity, a satellite ground station must generally be combined with other network technologies to distribute the available bandwidth and services to a large user base.

Satellites offer a constructive solution for countries that require higher bandwidth, that do not have a reliable telecommunications infrastructure. But otherwise, the bandwidth that is available does not compensate for the high costs associated with deploying, maintaining, and extending the reach of this service.
### Table 4: Comparison of different methods

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Bandwidth</th>
<th>Latency</th>
<th>Robustness</th>
<th>Scalability</th>
<th>Reliability</th>
<th>Adaptability</th>
<th>Sustainability/Manageability</th>
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</thead>
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<tr>
<td><strong>PSTN</strong></td>
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<td>MOD-L</td>
<td>MOD</td>
<td>LOW</td>
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<td>MOD-L</td>
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<td>MOD-L</td>
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</table>

### Conclusion

Since there are so many different wireless technologies it is important to select one that most suits the region. The different methods must be tailored for each region depending on deployment costs, population density, topography, distance of the ‘last-mile,’ literacy, the possible degree of benefits from the applications made available from the network connection.
The discussion really comes down to whether connectivity should be asynchronous or synchronous, and whether the demand can be established. Advocates of asynchronous methods such as DakNet would argue that non-real-time infrastructures and applications, providing basic communication and information services will be less costly while not sacrificing functionality. They would claim that these methods are more practical, socially appropriate, and more helpful than providing more sophisticated services.

At the same time, we should not invest in technology that will become obsolete quickly. Investing in outdated technology or hand-me-downs negates the purpose of spending capital to “catch up” these developing regions. If we are investing in technology that will help the livelihoods and economies of the people in these regions, it must be ongoing technology that will stimulate growth in the region.

Of course, different methods of connectivity are better suited for some areas than others. Although real-time connectivity of the region with the rest of the world should be a concern, a higher emphasis should be placed on the ability for people of developing communities to gain access to the information and resources that would not be available otherwise. While universal real-time connectivity would be ideal, this is just not realistic, in that there is just not enough funds or researchers to set up this kind of network.

The biggest challenges, then, are in cost (in building infrastructure and maintenance), resiliency to power failures, sustainability. In any given connection, the costs should not exceed lower-cost information that is already available, or the content needs to be very appealing information or a service that is not already available. Once the networks are deployed, the applications that will go supplement these network architectures will also influence the survival of networks in these areas. Already villages with a SARI connection are using webcam and email to communicate with distant hospitals. The villages use the connection for patients in the village to receive check-ups remotely. Practical applications providing a new service such as the aforementioned ensure the continued existence of the network in these areas.

The key to investing in wireless technology is to make sure that the deployment is sustainable. Because there is no on-going financial aid, there must be a focus on enabling businesses. The key to sustainability may be in the private sector: franchises, small local businesses and entrepreneurs, local service providers. The initial setup may be government-motivated, but then there must be a seamless transfer from a government-motivated e-government application to a market-driven universal broadband connectivity that local users will pay for (user adoption). In order to achieve this, researchers must first introduce a basic need by providing affordable service, then aggregate demand, while brokering information service. Technology must offer relevant support to the agricultural, informal, and business sectors. From there, they can see how technology can support and streamline service and locals. When demand increases the cost per user falls creating a double incentive. A few ideas have been raised for shared-use PCs for community use, or pay-per-use, as well as offering for-profit training or education.

Another concern is that the network cannot be unnatural. It cannot be an inorganic design that foreign investors impress upon these areas. A few surveyed in a village in India where non-profits have established an Internet center have never used the center. They were skeptical of technology’s ability to affect their lives and they just could not find a need for it. Whatever the initiative, it cannot be handed out as a solution and expected to take hold on its own. If there is to be a demand, the momentum must come from within; the local universities and government must

22 Best [7]
23 The Economist [5]
be the ones mobilizing this initiative. This is probably why the SARI project, executed in coordination with the Indian Institute of Technology, has gained so much credibility and a stronghold in recent years.

Increased connectivity can undoubtedly lead to increased economic opportunity, new channels for learning, better communication with government, and improvements in health. But in order for this to be possible, different institutions – business, government, academia, non-profits – must cooperate to organize a long-range strategy to efficiently plan for network connectivity. Because, after all, innovations in technology will inevitably lead to a development of a cost-efficient, long-range service, such as WiMax, a wireless long-range technology that was recently unveiled. Technology, business models, capital, policy, capacity, aggregating demand, are just a few things that must be solved in order to sustain the network access, to include developing communities in the networked world.
Appendix

Clarification of Terms in Table 3

*Cost* is in terms of time & money.

*Bandwidth* = The amount of data that can be transmitted in a fixed amount of time.

*Latency* = amount of time it takes a packet to travel from source to destination.

Speed (latency) + capacity (bandwidth) of network should measure strength of network.

*Robustness* = The ability of the network to either recover quickly from or hold up well under exceptional circumstances.

*Scalability* = how well network can handle increased demands/hosts.

*Survivability* = ability to make link failures transparent to endpoints.

*Reliability* = Robustness + Survivability.

*Adaptability/Flexibility* = how well network can adapt to environmental or architectural constraints.
Figure 3  Source: www.worldbank.org/data

Figure 4  Source: www.worldbank.org/data
Figure 5

Internet Users (per 1000) 1999-2003

Source: www.worldbank.org/data
Figure 6

Personal Computers (per 1000 people), 1999-2002

Source: www.worldbank.org/data
References


