DakNet: A Road To Universal Broadband Connectivity

Wireless Internet UN ICT Conference Case Study

Amir Alexander Hasson	Dr. Richard Fletcher	Dr. Alex (Sandy) Pentland
Founder, First Mile Solutions amir@firstmilesolutions.com	Founder, First Mile Solutions rf@firstmilesolutions.com	Founding Director, Media Lab Asia and Co-founder, Center for Future Health sandy@media.mit.edu

Background: The Wireless Revolution & The Developing World

Recent advances in wireless computer networking have led to huge commercial success and very low pricing for broadband networks. While these networks are thought of as mainly for offices, they have been shown to be a practical means for providing broadband access to even the most remote areas at very low prices. They thus offer developing countries with an opportunity to "leap-frog" over wire line infrastructures to the forefront of communications.

Wireless data networks (Wide Area Networks and Local Area Networks) based on the IEEE 802.11 or "WiFi" standard are perhaps the most promising wireless technology. Given its popularity in developed nations, it is reasonable to consider the use of WiFi in developing countries as well. The forces driving the standardization and proliferation of WiFi in the developed world could also stimulate the communications market dynamic in the developing world. These features include: its ease of set-up, use, and maintenance; its relatively high bandwidth; and, most importantly, its relatively low cost for both users and providers.

Standard WiFi connectivity (IEEE 802.11b) provides up to 11Mb/sec data rates, and operates in a band near 2.4Ghz that is generally unlicensed in Europe and the Americas. Newer versions of WiFi provide 22Mb/sec in this band, and versions that operate at higher frequencies provide up to 54Mb/sec. Tests in rural settings show that a standard WiFi card (such as commonly used with laptop PCs) can provide good connectivity given line-of-sight. With the addition of antennas and repeaters, it is possible to achieve point-to-point connectivity at distances of up to 20 kilometers. WiFi access points (devices commonly used to provide a WiFi network) currently retail for $120, and WiFi cards retail for under $60.

WiFi technology opens up new possibilities for rural connectivity in developing countries. However, the successful implementation of this technology and the choice of usage model should be guided by an intimate knowledge of rural communities and their information- and communication-related needs. Our vision is that, provided a conducive regulatory environment, local entrepreneurs within developing countries will leverage WiFi-based technology to: (a) solve the chicken-and-the-egg problem of the simultaneous need for both a market and an infrastructure; and (b) create a `viral' wireless infrastructure that grows seamlessly with the rural communications market, ultimately scaling up to universal broadband connectivity.

The Problem: The Need For A Shared Seed Communications Infrastructure

Rural ICTs are typically introduced as a communications channel that is *shared* across the community. Whether through a PCO or a public computer kiosk, users are introduced to ICTs as shared utilities intermediated by a technically-literate operator.

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In this shared-use model, many ICTs have relied on *real-time* communications, such as land-line telephone, cellular phone, or satellite radio links. These real-time technologies can be useful for immediate interactivity and accessing highly time-sensitive information. Successful examples include India's Public Call Offices (PCO), and the Grameen Phone initiative (http://www.grameenphone.com/).

The strategy of deploying shared, real-time communications, while successful at providing basic services, also has serious drawbacks. One of the main problems is the large capital investment of real-time infrastructure, which requires a high level of user adoption to achieve cost recovery. However, the average villager cannot even afford a personal communications device (i.e. a telephone or computer), let alone a subscription fee for access to the communications infrastructure. Hence, sharing of the communications infrastructure is required in order to support the costs. This limits the all-important added value due to network effects. For example, a typical response from a villager when considering the possibility of making a telephone call is: *"Who am I going to call? I don't know anybody who owns a telephone."*

In this sense, the real-time aspect of telephony can also be a disadvantage: both intended parties have to be present at each terminal to capture the full value of the infrastructure. If a caller wishes to contact someone who does not possess (or is not present at) a telephone, then the communication is asynchronous despite the real-time infrastructure. Some kind of additional messaging mechanism (be it a messenger or an answering machine) is required to deliver the caller's message to its destination.

As a consequence, real-time telephony can reinforce gaps among rural populations since it encourages users to communicate mainly with people who have private phone lines, typically those of higher economic status located in more urban areas. In the Grameen Phone initiative, women were chosen as the community operators to help reduce this effect.

Until widespread private ownership of ICT devices becomes economically feasible for end-users, it may be useful to consider non-real-time infrastructures and applications such as voice mail, email and electronic bulletin boards. Also known as store-and-forward or asynchronous modes of communication, these technologies can be significantly lower in cost and do not necessarily sacrifice the functionality required to deliver valuable end-user services. They may also be more practical and socially-appropriate for end-users where communications infrastructure is shared.

The Goals: Rural ICT Seed Infrastructure

To make the goals of the project more concrete, we will use the example of the rural ICT (Information and Communications Technologies) market in rural India. It is estimated that 5-6% of GDP per capita is spent on communications related services in rural India. According to a recent report from Harvard's Center for International Development, which surveyed hundreds of household involved in the Sustainable Access for Rural India (SARI) project in Tamil Nadu, India,[i] each 1% increase in per-capita income has resulted in a 1.4% increase in communications-related expenditures among rural households. This disproportionate rise in expenditures implies that there is a latent demand for information and communication services such as newspapers, cable-TV, telephone calls, mail, and access to information.[ii]

In dollar terms, this means that the typical villager in rural India spends about $20/year on media and communications services. This, however, does not mean that a village of 1,000 people could

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support or provide a timely economic return on a $20,000 communications infrastructure investment, for the following reasons:

(a) *User adoption takes time*: existing market data suggests that user adoption may only reach 10% within a village in 1 year, and that it may take up to 5 years to reach 20% penetration.

(b) *Service adoption also takes time*: given the social and economic costs of switching to new information and communication services, it will be quite some time before a villager switches his/her annual expenditure over to the new infrastructure.

(c) *Adoption Incentives*: villagers may only switch over to new ICT services if these services represent *lower cost substitutes* for existing information, transportation, and communication expenses. Therefore in the short term, a villager's annual spending on rural information and communication services may be less than their current expenditure of $20/year.

Given these considerations, we believe that the goal for an initial ICT infrastructure investment for a typical village in rural India should not exceed $1,000 in order to provide economically motivating model for investors and operators. This cost should include the communications network as well as the terminal (i.e. a PC computer) and should require minimal recurring costs. This would enable cost recovery within one year of operation assuming a user adoption rate of 10%, a service adoption rate of 50%, and a 10% cost savings over traditionally-used services. In the longer term, if rural ICTs can deliver on their promise of economic development, then, as indicated by the latent demand seen in the SARI project, villagers will have more disposable income and therefore spend more than $20/year on information and communication services. This, in turn, could catalyze further investment, deployment, and adoption of rural ICTs.

Describe Available Solutions : DakNet

As an implementation of very low cost asynchronous communications infrastructure, we have developed a store-and-forward wireless ad-hoc network for rural connectivity known as *DakNet* (www.daknet.net). The name derives from the Hindi word "dak" which means "post" or "postal". The DakNet wireless network takes advantage of existing communicationsand transportation infrastructure to distribute digital connectivity to outlying villages lacking digital communications infrastructure. DakNet combines physical means of transportation with wireless data transfer in order to extend the Internet connectivity provided by a central uplink or Hub (e.g. a cybercafe, VSAT, or post office) to kiosks in surrounding villages.

Instead of trying to relay data over a long distance (which can be expensive), DakNet transmits data over short point-to-point links between kiosks and portable storage devices called Mobile Access Points (MAPs). Mounted on and powered by a bus, motorcycle, or even bicycle, the MAP physically transports data among public kiosks and private communications devices (as an intranet) and between kiosks and a Hub (for non-real-time Internet access). Through the use of low-cost WiFi radio transceivers, the data carried by the MAP is automatically and wirelessly transferred at high-bandwidth for each point-to-point connection. The operation of the network can be described as follows:

1. The MAP devices are mounted on specific transports that regularly pass through a series of villages.

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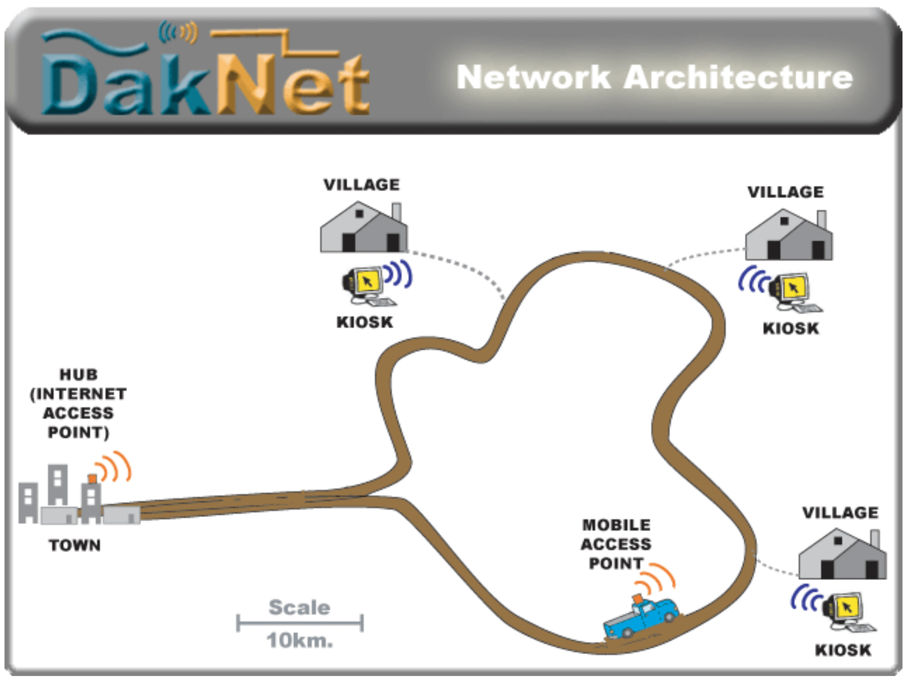
2. As the vehicle carrying the MAP comes within range of each village they automatically sense a wireless connection with a kiosk and deliver and collect data at relatively high bandwidth.
3. Whenever a MAP comes within range of another kiosk or a Hub, data is automatically uploaded to and downloaded from the intranet/Internet.
4. This cycle is repeated for every vehicle carrying a MAP unit, thereby creating a low-cost wireless network and seamless communications infrastructure. Even a single vehicle passing by a village once per day is sufficient to provide daily information services.



Although the data transport provided by DakNet is not real-time, a significant amount of data can be moved at once. As a result, it is interesting to note that physically transporting data from village to village by this means generally provides a higher data throughput than other low-bandwidth technologies, such as telephone modems.

By employing short-distance radio links, DakNet allows for small low-cost low-power radio devices to be used. Perhaps more importantly, the use of short-distance radio links also ensures high-data rates and does not have the interference problems, security problems, and maintenance costs associated with long-distance wireless links.

The store-and-forward wireless network represented by DakNet can be used for a wide variety of applications that require automated low-cost distribution and collection of information. Examples of application domains are:

Internet/intranet messaging: This can include e-mail, video/audio messaging, mobile e-commerce.

- ***Information distribution/broadcasting:*** this can include community bulletin boards, transfer of educational materials, public health announcements, news, music and video broadcasts.
- ***Information collection:*** This can include collection of environmental sensor information, voting, census/polling, health records, and land records.

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- ***Rural supply chain management:*** By incorporating Global Positioning Systems the DakNet network can also function as a means of tracking the movement of vehicles and shipment of goods in a geographical area.
- ***Information searching, web services:*** By incorporating new types of Internet applications that are designed for non-real-time access (such as the TEK web-search engine mentioned previously), many new web-related applications can be developed for the rural market.

DakNet provides a seamless method of upgrading to universal broadband connectivity. As a village increases its economic means, the *same* hardware, software and user interface used for DakNet can be used to provide real-time information access through the deployment of fixed-location wireless antennas and towers. For the end-user, this change is entirely transparent as he/she would not be required to learn any new skills or buy any new hardware or software. The addition of fixed transceivers would provide real-time connectivity, thus enabling new, more sophisticated services, such as Voice over IP (VoIP), which allows "normal" real-time telephony.

Business Model: Services Come First

The business model for DakNet depends on the specific applications and services that use it as a platform. In some cases DakNet may be deployed by governments to cost-effectively meet Universal Service/Access Obligations, and as an infrastructure for enabling and improving public services (i.e. eGovernance). In other cases, DakNet is a connectivity solution for local entrepreneurs or organizations who have developed services for the rural market. These rural service providers (RSPs) have achieved significant revenues and even profitability by offering lower-cost substitutes for a villager's existing information, communication and transportation expenses. Drishtee (www.drishtee.com) provides a digital platform that enables villagers to send/receive information to/from Drishtee's Web server from a remote village kiosk brokered by a kiosk operator. A variety of services such as checking local market prices, applying for a loan, and requesting a driver's license are generating up to $2,000/year/kiosk for Drishtee.[iii] The significant demand for these services results from a sound value proposition: saving villagers time and money. According to a villager who filed a complaint using a Drishtee kiosk:

> *A visit to Sirsa costs Rs 50* [$1, for travel], *plus I waste a day. I will happily give Rs 10, even Rs 30 at the telecenter* [kiosk] *if I can save this.*

Drishtee's success suggests that the introduction of ICTs in rural areas may not have anything to do with technology *per se*. In contrast to many rural ICTs which start with a specific technology and then test out a variety of information and communication services to see which ones get accepted (a "push" approach), a better approach may be to start with a basic service – in Drishtee's case, aggregating demand and brokering information exchange between the villager and the government – and then see what/how technology can support and streamline that service – in Drishtee's case using computers and available connectivity to capture, send, and receive information electronically.

RSPs such as Drishtee, however, are constrained by the lack of a viable communications infrastructure throughout India. For instance, many of the villages that Drishtee operates in Sirsa, Haryana do not have working phone lines due to poor line maintenance and delayed installations. As a result, Drishtee has resorted to an asynchronous approach to connectivity: physically transporting and swapping floppy disks from the village to the panchayat and back again –

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otherwise known as "sneaker net". This is viable since Drishtee's most revenue-generating applications only require intermittent connectivity.

Project Economics: Broadband For Less Than $300/Village

The total cost of the DakNet MAP equipment used on the bus is US$580, which includes: a custom embedded PC running Linux with 802.11b wireless card and 512MB CF memory; a 100mW amplifier, cabling, mounting equipment, and 14" omnidirectional antenna; and a UPS that is powered by the bus battery. The average total cost of the equipment used to DakNet-enable a village Kiosk or Hub is US$185. Assuming that each bus can provide connectivity to approximately 10 villages, the average cost of DakNet-enabling each village in this pilot was US$243 ($185 at each village plus $580 MAP cost/ 10 villages).

A back-of-the-envelope calculation for DakNet suggests that a capital investment of $15M could equip 50,000 rural vehicles with a $300 MAP and thereby provide intermittent broadband connectivity to most of rural India. This is orders of magnitude lower in cost than current alternatives for rural communications.

Costs for interactive user devices supported by DakNet are also far more affordable than PCs or traditional WLL equipment. New PDA-like devices using a DakNet-like wireless protocol retail for $100, with a manufacture cost of approximately $50 (www.cybiko.com). These costs are being further reduced by "system on a chip" technology, with prototypes of wireless PDAs achievable at prices as low as $25 (www.mobilesolv.com).

How the project is being deployed: The DakNet Bhoomi Pilot

Currently there is a fully operational implementation of DakNet as an affordable rural connectivity solution for Bhoomi by Media Lab Asia. Bhoomi is a computerization of land records initiative pioneered by the State Government of Karnataka in India. It has been recognized as the first national eGovernance initiative in India as it has been successfully implemented at district headquarters across the State to completely replace the physical land records system.

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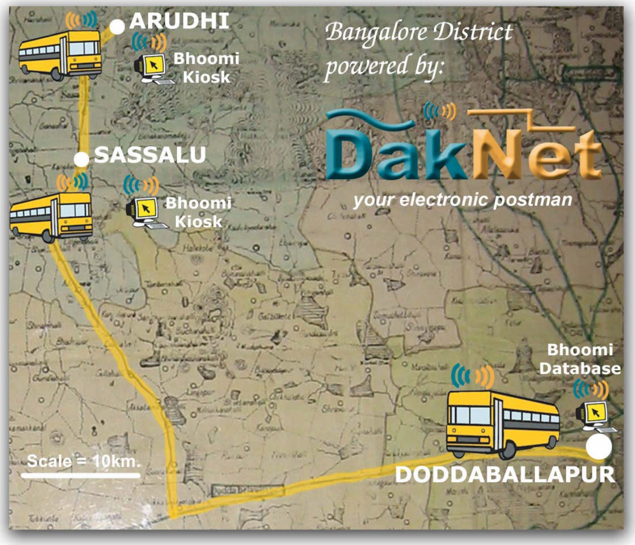

Figure 3: Map of DakNet-Bhoomi Pilot in Rural India

DakNet has enabled Bhoomi to decentralize its land records database to villages up to 40km away from its district headquarters or "taluka" in Doddaballapur. This pilot takes advantage of existing transportation infrastructure by outfitted a public government bus with a DakNet Mobile Access Point to transport land record requests from each village kiosk to the taluka server. The server processes requests and outputs land records which are then delivered back to each village kiosk for printing and payment of 15 rupees (US$0.32) per land record. The bus passes by the Hub and stops at each village six times per day (three round trips per day).

Figure 4: DakNet-Enabled Public Bus

Each time the MAP on the bus comes within range of a kiosk to transfer data it is referred to as a "session". The average length of a session is 02:34 (MM:SS) during which an average of 20.9MB can be transferred uni-directionally (from Kiosk to MAP) and up to twice that amount bi-directionally (from both Kiosk to MAP and MAP to Kiosk). The average Goodput (actual data throughput) for a session, during which the MAP and Kiosk go in and out of connection due to mobility and obstructions, is 2.47Mb/sec. These averages are based on repetitive testing in a sample group of villages that reflect the range of different antenna configurations. Both omnidirectional and directional antennas with differing gains were used according to the orientation of each Kiosk with the road and the bus stop.

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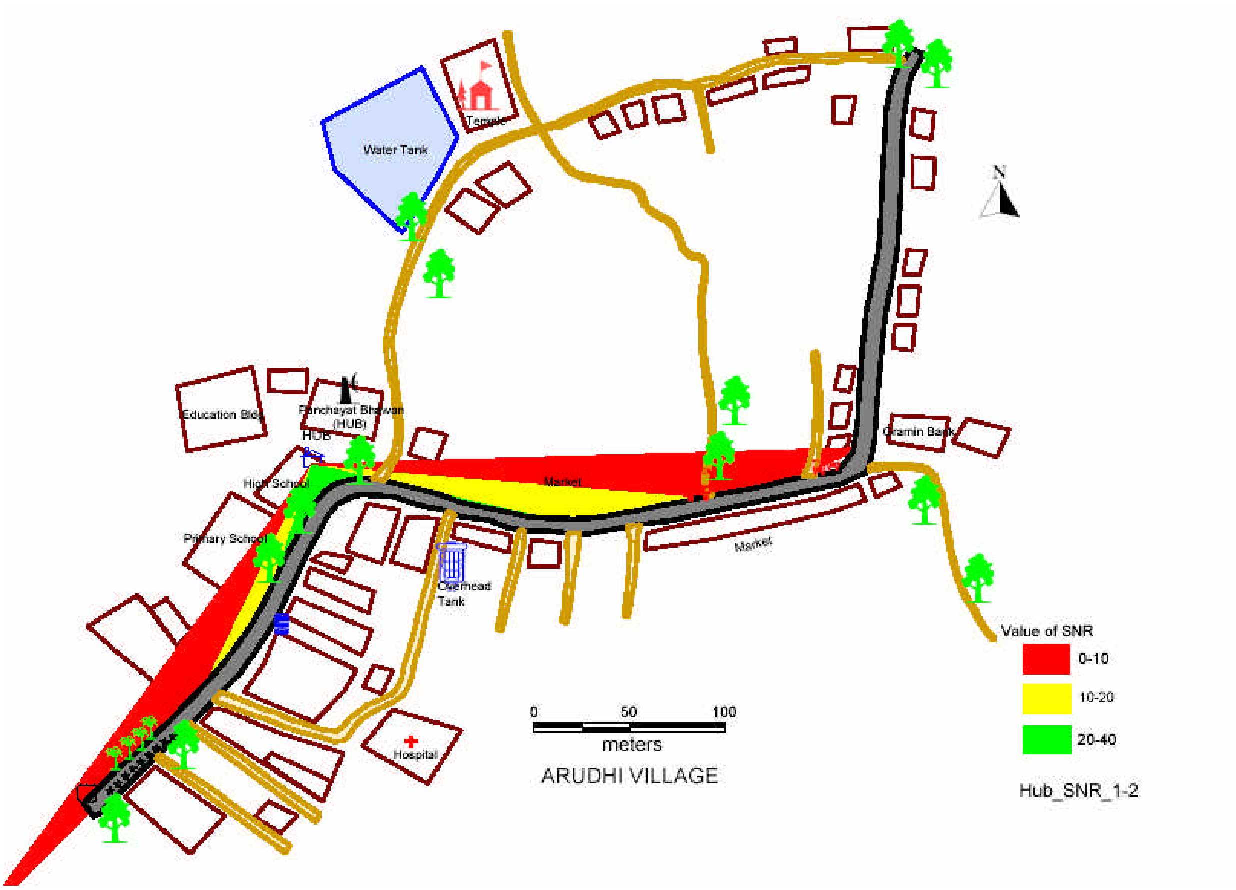
The figure below illustrates the radiopropagation cloud for the village kiosk's relative to the Mobile Access Point as it travels along the road during a session. The quality of the connection between the MAP and the kiosk is suggested by the Signal-to-Noise Ratio (SNR), indicated by the three different colors red, yellow, and green. These SNR values roughly correspond to the three different data rates of the 802.11b protocol: 2 Mb/s (red), 5 Mb/s (yellow), and 11 Mb/s (green). This wireless network visualization map was produced by correlating the SNR values with longitude and latitude positions using standard GPS technology, enabling an iconic map of the village and visual representation of a live DakNet-enabled environment.



Impact analysis: Creating New Value For Existing Transportation Infrastructure

Conclusions on the impact of the DakNet implementation for Bhoomi would be premature since the project has just recently been launched. However, it is likely that the Bhoomi application will not exploit the broadband capacity of the DakNet network since land record requests are only 2KB and electronic land records are approximately 20KB. Furthermore, given a sense of the actual conditions of roads in rural areas, the need for ruggedness of the required Mobile Access Point hardware cannot be overstated. The most important anticipated impact of the DakNet pilot for Bhoomi has been the use of a public bus as an existing transportation infrastructure to enable the network.

Lessons learned: Local WiFi Capacity & Ugly, Robust Hardware

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The principal lessons learned have been that:

- Although WiFi is simple to deploy relative to other radio/telecommunications equipment, developing countries often lack the local talent required to implement and operate WiFi networks.
- Customs duties and processes for certain WiFi equipment such as amplifiers and high gain antennas can create a major time and cost barrier to deployments.
- Hardware should be as unattractive and possible and must be secured using locks.
- Power is more of a constraint than expected. Villages were without power for at least 4 hours everyday. DakNet was adapted for this constraint by using a dedicated access point at the client which can run for up to 3 hours on a UPS that can power a desktop for only 20 minutes.
- A reliable, high-bandwidth backbone is difficult to find, making the Internet uplink the bottleneck (i.e. 28.8Kb/s) for rural connectivity as opposed to DakNet's broadband local distribution capacity. Furthermore, intranet applications appear to be a more natural and compelling starting point for rural connectivity before introducing Internet connectivity.
- 2.4Ghz should be delicensed for remote rural applications to encourage entrepreneurship in developing countries.

Next Steps: Scaling It Up

DakNet is going to be deployed and tested in larger implementations with applications that exploit is broadband capabilities. The current R&D focus is on further lowering the costs of the required hardware and developing a highly interoperable and cross-platform software module so that deployment processes can be streamlined.

REFERENCES

[i] Harvard's Center for International Development, Christopher Blattman, Jensen, Robert, Roman, Raul, "Assessing the Need and Potential of Community Networking for Developing Countries: A Case Study from India", February 2002, Unpublished, p. 9. Increased communications-related expenditures include: News (2.33%); Cable-TV (1.26%); Phone (1.11%); and Mail (.81%).
[ii] Ibid.
[iii] The Boston Consulting Group, "*Drishtee* Case Study", March, 2002, PowerPoint presentation.

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