DakNet: Rethinking Connectivity in Developing Nations

DakNet provides extraordinarily low-cost digital communication, letting remote villages leapfrog past the expense of traditional connectivity solutions and begin development of a full-coverage broadband wireless infrastructure.

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As a government representative enthusiastically talks about the new telephone for a village in remote rural India, a villager asks, "Who am I going to call? I don't know anybody who owns a telephone." Yet, despite this sensible observation, a phone is dutifully installed as part of the current government mandate to connect villages to neighboring towns. Although some villagers do use the phone occasionally, most still travel sometimes days to talk to family or to obtain the forms and other data that citizens in developed nations can call up on a computer in a matter of seconds.

In short, the goal of "broadband connectivity for everyone" has been shelved in favor of cutting back to the minimum possible standard telephone service in the mistaken belief that this is the cheapest way to provide connectivity. This compromise is particularly tragic given recent advances in wireless technology, which make running a copper line to an analog telephone far more expensive than broadband wireless Internet connectivity. Rather than backpedal on the goal of connecting everyone, society should be thinking, How can we establish the kernel of a user network that will grow seamlessly as the village's economics develop? In other words, what is the basis for a progressive, market-driven migration from government seed services—e-governance—to universal broadband connectivity that local users will pay for?

DakNet, an ad hoc network that uses wireless technology to provide asynchronous digital connectivity, is evidence that the marriage of wireless and asynchronous service may indeed be that kernel—the beginning of a road to universal broadband connectivity. Developed by MIT Media Lab researchers, DakNet has been successfully deployed in remote parts of both India and Cambodia at a cost two orders of magnitude less than that of traditional landline solutions. Villagers now get affordable Internet services—and they're using them. As one man in a small village outside of New Delhi remarked, "This is better than a telephone!"

THE WIRELESS CATALYST

Recent advances in wireless computer networking—particularly the IEEE 802 standards—have led to huge commercial success and low pricing for broadband networks. While these networks are viewed as mainly for offices or for hotspots in urban areas, they can provide broadband access to even the most remote areas at a low price. Today, wireless cell phone and wireless local loop (WLL) service costs roughly a third of copper or fiber landline service, while packet-based broadband computer networks cost roughly a ninth of the landline service—and they are far friendlier to data services and to lower-grade voice service such as voice messaging. These new technologies thus offer developing countries an opportunity to leapfrog over wireline and WLL telephony infrastructure to the forefront of broadband communications technology.

Wireless data networks based on the IEEE 802.11, or WiFi, standard are perhaps the most

Published by the IEEE Computer Society

promising of the wireless technologies. The forces driving the standardization and proliferation of WiFi in the developed world have resulted in features that can stimulate the communications market in the developing world. These features include ease of setup, use, and maintenance; relatively high bandwidth; and, most important, relatively low cost for both users and providers.

As one demonstration of the practicality of this new technology for rural connectivity, researchers from the Indian Institute of Technology at Kanpur, working with Media Lab Asia (www.medialabasia.org), have "unwired" a 100-sq km area of the Gangetic Plain in central India. Figure 1 shows the corridor. This project provides broadband connectivity along a corridor with almost one million residents, at a projected one-time cost of under $40 per subscriber. Other experiments have shown the practicality of the technology in mountainous terrain and in city centers. Indeed, several cities in the US have begun to deploy free Internet connectivity using IEEE 802.11b.

Even with advances such as those demonstrated in the Digital Gangetic Plain project, the cost of real-time, circuit-switched communications is sufficiently high that it may not be the appropriate starting point for rural connectivity in developing nations. Market data for information and communication technology (ICT) services in rural India strongly implies that asynchronous service—voice messaging, e-mail, and so on—may be a more cost-effective starting point for rural connectivity projects.

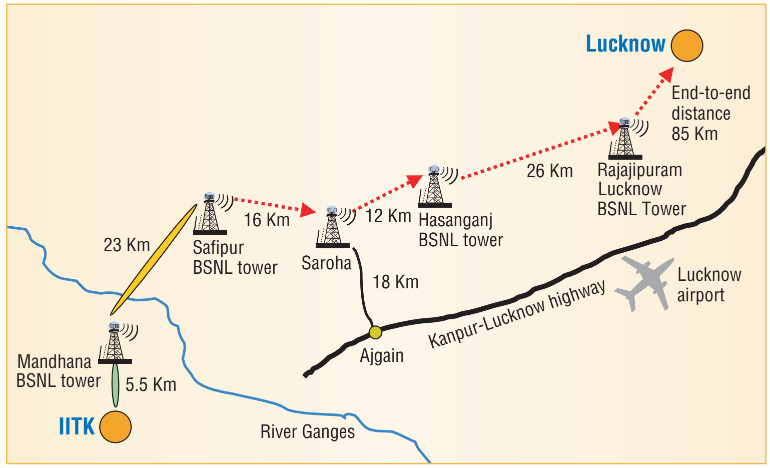

Figure 1. Digital Gangetic Plain project. Map shows the corridor of wireless technology in central India.

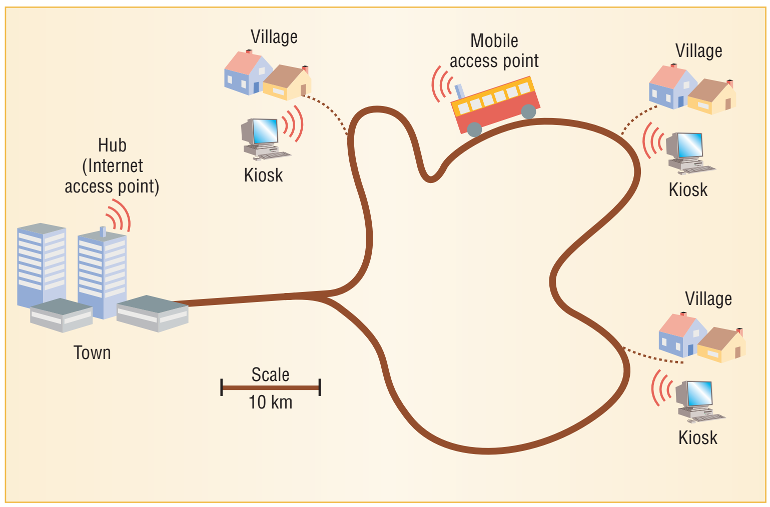

Figure 2. DakNet concepts. Physical transport, in this case a public bus, carries a mobile access point (MAP) between village kiosks and a hub with Internet access. Data automatically uploads and downloads when the bus is in range of a kiosk or the hub.

MOBILE AD HOC CONNECTIVITY

The DakNet wireless network takes advantage of the existing communications and transportation infrastructure to distribute digital connectivity to outlying villages lacking a digital communications infrastructure. DakNet, whose name derives from the Hindi word for "post" or "postal," combines a physical means of transportation with wireless data transfer to extend the Internet connectivity that a central uplink or hub, such as a cybercafe, VSAT system, or post office provides.

As Figure 2 shows, instead of trying to relay data over a long distance, which can be expensive and power-hungry, 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, a motorcycle, or even a bicycle with a small generator, a 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). Low-cost WiFi radio transceivers automatically transfer the data stored in the MAP at high bandwidth for each point-to-point connection.

DakNet operation thus has two steps:

- As the MAP-equipped vehicle comes within range of a village WiFi-enabled kiosk, it automatically senses the wireless connection and then uploads and downloads tens of megabytes of data.
- When a MAP-equipped vehicle comes within range of an Internet access point (the hub), it automatically synchronizes the data from all the rural kiosks, using the Internet.

The steps repeat for every vehicle carrying a MAP unit, thereby creating a low-cost wireless network and seamless communications infrastructure.

Some Common Myths about Rural Information and Communication Technology

***Myth:* The village telephone is the best model for poor communities.**
***Truth:* Giving everyone access to digital messaging—voice mail, digital documents, e-mail, and so on—is better than installing a community telephone.**

Rural information and communication technology (ICT) is typically introduced as a communications channel that the community shares. Whether through a public call office (PCO) or a public computer kiosk, users are introduced to ICT as shared utilities with a technically literate operator acting as an intermediary.

In this shared-use model, much ICT has relied on real-time communications, such as landline 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 PCOs and the GrameenPhone initiative (www.grameenphone.com/).

While successful at providing basic services, the strategy of deploying shared, real-time communications also has serious drawbacks. One is the large capital investment in a real-time infrastructure, which requires a high level of user adoption to recover costs. The average villager cannot even afford a personal communications device such as a telephone or computer, let alone a subscription fee for access to the communications infrastructure. Hence, to recover cost, users must share the communications infrastructure. This limits the all-important value added from network effects. A villager who finds no use for a phone is typical, and this is perhaps why so few of the world's poor have used a telephone.

The real-time aspect of telephony can also be a disadvantage: Both intended parties must be present at each terminal to capture the infrastructure's full value. If a caller wishes to contact someone who does not own (or is not present at) a telephone, 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 GrameenPhone initiative, women were chosen as the community operators to help reduce this effect, since it was socially acceptable for women to deliver messages to everyone in the village.

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, e-mail, 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 user services. They might also be more practical and socially appropriate for users than a shared real-time communications infrastructure.

***Myth:* Poor people don't need computers.**
***Truth:* The poor not only need digital services, but they are willing and able to pay for them to offset the much higher costs of poor transportation, unfair pricing, and corruption.**

Some rural service providers (RSPs) have achieved profitability by offering lower-cost substitutes for a villager's existing information, communication, and transportation expenses. For instance, Drishtee (www.drishtee.com) provides an e-government platform that lets villagers interact with local government offices remotely from a kiosk in their village that is managed by a trained operator. A variety of services such as filing a complaint, applying for a loan, and requesting a driver's license are generating up to $2,000 per year per kiosk for Drishtee.[1] The significant demand for these services results from a sound value proposition: Save villagers time and money. According to a villager who filed a complaint using a Drishtee kiosk,

> A visit to Sirsa costs Rs 50 [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 ICT in

Even a single vehicle passing by a village once per day is sufficient to provide daily information services. The connection quality is also high. Although DakNet does not provide real-time data transport, a significant amount of data can move at once—typically 20 Mbytes in each direction. Indeed, physically transporting data from village to village by this means generally provides a higher data throughput than is typical with other low-bandwidth technologies such as a telephone modem.

Seamless scalability

In addition to its tremendous cost reduction, a critical feature of DakNet is its ability to provide a seamless method of upgrading to always-on broadband connectivity. As a village increases its economic means, its inhabitants can use the same hardware, software, and user interface to enjoy real-time information access. The only change is the addition of fixed-location wireless antennas and towers—a change that is entirely transparent to end users because they need not 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, which allows "normal" real-time telephony.

Thus, as the "Some Common Myths about Rural Information and Communication Technology" sidebar describes, asynchronous broadband wireless connectivity offers a practical stepping-stone and migration path to always-on, broadband infrastructure and end-user applications. Together with rural areas might not have anything to do with technology per se. Much rural ICT starts with a specific technology and then tests out a variety of information and communication services to see which get accepted (a push approach). A better strategy might 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 how technology can support and streamline that service. Drishtee determined that computers and available connectivity were enough to capture, send, and receive information electronically.

Like other RSPs, however, Drishtee is constrained by India's lack of a viable communications infrastructure. Many of the villages that Drishtee operates in lack working phone lines because of poor line maintenance and delayed installations. As a result, Drishtee has resorted to "sneaker net," an asynchronous approach to connectivity that involves transporting and swapping floppy disks from the village to the government center and back again. Despite this labor-intensive approach, sneaker net is successful because Drishtee's applications that generate the most revenue require only intermittent connectivity.

Myth: Connectivity must be real time.
Truth: Asynchronous ICT services are sufficient to meet most rural community needs.

The Sustainable Access for Rural India (SARI) project in Tamil Nadu, India—a joint endeavor by the MIT Media Lab, the Harvard Center for International Development, and the Indian Institute of Technology, Madras—recently collected data about the communications needs, habits, and costs in hundreds of rural Indian households to gauge the desire for and perceived affordability of household communications.[2] The study found that the current market for successful rural ICT services does not appear to rely on real-time connectivity, but rather on affordability and basic interactivity:

> [Rural ICT companies] should start their operations by first focusing on providing basic communication and information services rather than more sophisticated applications.

Another SARI analysis done by McKinsey Consulting[3] indicates that although the universe of potential applications is large, "in the short-term only e-mail, scan-mail, voice-over-e-mail and chat are likely to be revenue-generating applications."

The McKinsey report also found that most of SARI's applications do not require real-time connectivity. It estimates that 50 percent of all existing rural mail will convert to e-mail, and people often preferred voice messaging to a real-time voice channel. Both e-mail and voice messaging are non-real-time applications.

In addition to these non-real-time applications, providers can use asynchronous modes of communication to create local information repositories that community members can add to and query. For example, a villager can access information from a computer somewhere outside the community and store that information in a village repository so that others can use it. This approach is particularly viable because the cost of digital storage is decreasing faster than the cost of most communication technologies.

Moreover, users are apt to find the information in a local repository highly relevant, which further decreases their reliance on a real-time infrastructure and international bandwidth. Users could search and browse the Web in non-real time through applications developed for low-connectivity environments such as TEK (http://tek.sourceforge.net/).

References

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2. C. Blattman, R. Jensen, and R. Roman, "Assessing the Need and Potential of Community Networking for Developing Countries: A Case Study from India," Feb. 2002; http://edevelopment.media.mit.edu/SARI/papers/CommunityNetworking.pdf.
3. A. Pentland, R. Fletcher, and A.A. Hasson, "A Road to Universal Broadband Connectivity;" http://thinkcycle.org/tc-filesystem/?folder_id=37675.

the development of two other key rural communication components—robust, low-cost terminals and local user-interface design and applications—DakNet makes it practical for individual households and private users to get connected.

Economics

A back-of-the-envelope calculation for DakNet suggests that a capital investment of $15 million could equip each of India's 50,000 rural buses with a $300 MAP and thereby provide mobile ad hoc connectivity to most of the 750 million people in rural India. This figure represents a cost that is orders of magnitude lower than other rural communication alternatives.

Costs for the interactive user devices that DakNet supports—including thin-client terminals, PDAs, and VoIP telephones—may also soon become far more affordable than traditional PCs or WLL equipment. PDA-like devices using an IEEE 802-like wireless protocol retail for $100, with a manufacturing cost of approximately $50 (www.cybiko.com). System-on-a-chip technology is lowering these costs even more, potentially enabling wireless PDAs at prices as low as $25 (www.mobilesolve.com).

DAKNET IN ACTION

Villages in India and northern Cambodia are actively using DakNet with good results. As Figure 3 shows, local entrepreneurs currently are using DakNet connections to make e-services like e-mail and voice mail available to residents in rural villages.

One of DakNet's earliest deployments was as

Figure 3. A local entrepreneur using a DakNet connection to sell e-services like voice mail and e-mail to residents in a rural Indian village.

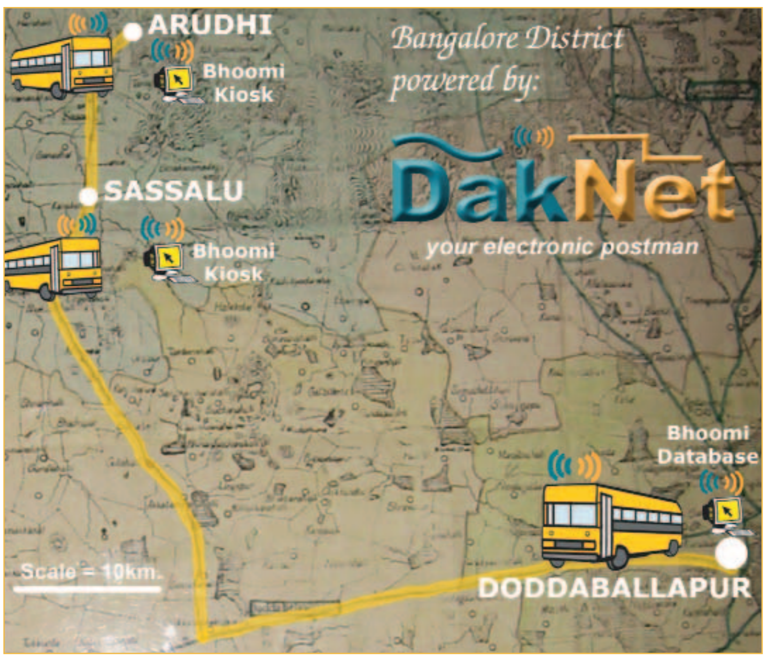

Figure 4. DakNet support of the Bhoomi e-governance project. Map shows route between Bhoomi database and village kiosks.

an affordable rural connectivity solution for the Bhoomi e-governance project. In September 2003, we also implemented DakNet in a remote province of Cambodia for 15 solar-powered village schools, telemedicine clinics, and a governor's office.

Bhoomi initiative in India

Bhoomi, an initiative to computerize land records, is recognized as the first national e-governance initiative in India. Pioneered by the State Government of Karnataka, Bhoomi has been successfully implemented at district headquarters across the state to completely replace the physical land records system.

As Figure 4 shows, DakNet makes Bhoomi's land records database available to villages up to 40 km away from Bhoomi's district headquarters, or "taluka," in Doddaballapur. In this deployment, we outfitted a public government bus with a DakNet MAP to transport land record requests from each village kiosk to the taluka server. The server processes requests and outputs land records. The bus then delivers the records to each village kiosk, where the kiosk manager prints them out and collects a 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).

A "session" occurs each time the bus comes within range of a kiosk and the MAP transfers data. The average length of a session is 2 minutes and 34 seconds, during which the MAP transfers an average of 20.9 Mbytes unidirectionally (kiosk to MAP or MAP to kiosk) and up to twice that amount bidirectionally (from 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 because of mobility and obstructions, is 2.47 Mbps. These averages are based on repetitive testing in a sample group of villages that reflect the range of different antenna configurations. The team used both omnidirectional and directional antennas with differing gains according to the orientation of each kiosk with the road and the bus stop.

The total cost of the DakNet MAP equipment used on the bus is $580, which includes

- a custom embedded PC running Linux with 802.11b wireless card and 512 Mbytes of compact flash memory;
- a 100-mW amplifier, cabling, mounting equipment, and a 14-in omnidirectional antenna; and
- an uninterruptible power supply powered by the bus battery.

The average total cost of the equipment used to make a village kiosk or hub DakNet-ready was $185. Assuming that each bus can provide connectivity to approximately 10 villages, the average cost of enabling each village was $243 ($185 at each village plus $580 MAP cost for 10 villages).

Villagers along the bus route have enthusiastically received the DakNet-Bhoomi system. They are grateful to avoid making the long, expensive trip into the main city to obtain land records.

Figure 5. The Internet Motoman project in Cambodia. (a) The main hospital, with its VSAT connection to the Internet, acts as the hub. (b) Because the roads are so bad during rainy periods, MAP-enabled Honda motorcycles are used to connect schools to the hub. (c) For locations with particularly challenging terrain, there is even a MAP-equipped ox cart.

E-mail for Cambodian schools

CambodiaSchools.com operates 225 rural schools throughout Cambodia with funding from private donors and the World Bank. Our aim was to provide students with Internet access by providing asynchronous connectivity to the backbone or hub—a satellite dish in the provincial capital of Ban Lung, which has a 256-Kbyte per second link.

As in the Bhoomi project, we used public transportation, but, as Figure 5 shows, the terrain in northern Cambodia is so difficult that we had to place MAPs on Honda motorcycles instead of buses. For one particularly remote area, we even affixed the MAP to an ox cart. The results of the project, which we dubbed the Internet Village Motoman, were once again gratifying. For the first time, students in these Cambodian schools could send e-mail, request Web pages, and feel connected to the rest of the world.

DakNet's low deployment cost and its enthusiastic reception by rural users has motivated dozens of inquiries for further deployments. We are already working on versions for Nigeria, Jordan, and Colombia, as well as developing plans for offering a turnkey solution that will let users deploy DakNet themselves (www.firstmilesolutions.com). This should provide millions of people their first possibility for digital connectivity, and, as study after study has shown, increasing connectivity is the most reliable way to encourage economic growth.

The larger goal is to shift the policy focus of the government's universal-service-obligation funds from wireline village telephones to wireless ad hoc networking. The shift will probably require formal assessment of user satisfaction, resulting economic growth, and of course system reliability. If we can clear these bureaucratic hurdles, however, governments might be able to connect the world's poor to the Internet far sooner than anyone believed possible. ■

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