

*WiFi, Roads, VOIP, & Prepaid Cards:
Leapfrogging Rural Communications Beyond the Economic Reach of Cellular*

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Abstract

Cellular phone technology has revolutionized communications throughout the developed and developing world and, for many developing countries, has offered a way for telecommunication companies to “leapfrog” over wireline communications infrastructure directly to wireless communications services. Cellular infrastructure, however, is still too expensive for the billions of people living in areas with low population densities and per-capita incomes. Leveraging existing communications and transportation infrastructures, DakNet combines WiFi, VOIP, and Prepaid Cards to provide an economically viable solution to provide villagers with an email address and phone number today while creating a migration path to future wireless communications infrastructure.

The Economics of the Digital Divide

In the developing world the cost of digital connectivity using traditional communications technologies becomes increasingly prohibitive outside of urban areas. As one moves further away from existing backbone communications infrastructure, the costs of connectivity rise dramatically while population density and income per capita decrease dramatically. Available income per square kilometer therefore drops by orders of magnitude from an estimated \$4,500,000 per square kilometer/year in urban areas (1,500 people per square kilometer with an average annual income per capita of \$3,000) to just \$77,000 per square kilometer in rural areas (220 people per square kilometer with an average annual income per capita of \$350). This is the underlying reason why telecommunications companies have not been able to economically service many rural areas, which are referred to as the ‘last mile’, i.e. the problem of delivering connectivity from a communications backbone to the premises of end-users. This is also one of the main causes of the urban-rural Digital Divide in developing countries.

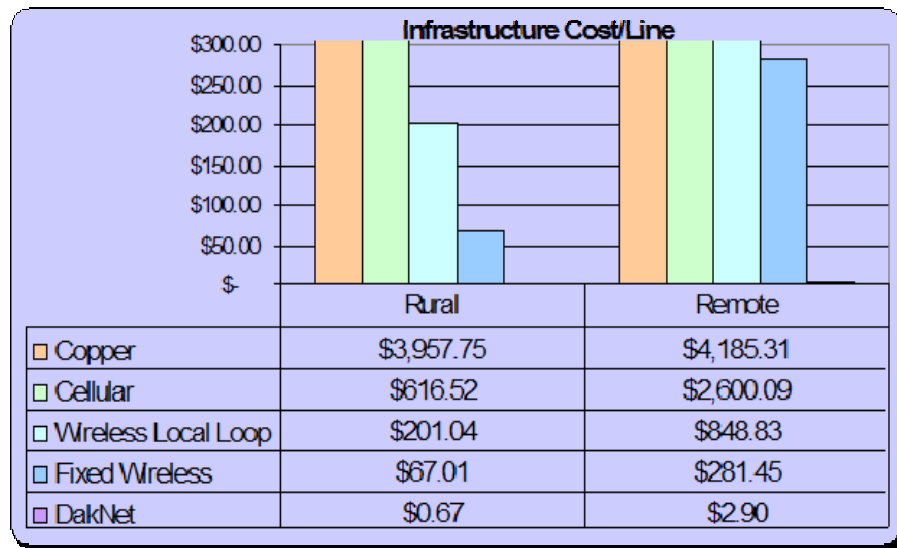


Figure 1: Comparison of Infrastructure Costs/Line Comparison for Rural & Remote Areas

So how can the billions of people living in rural areas beyond the economic reach of cellular or wireline communications infrastructure use phones and the Internet? Without resorting to satellite-based communications, which have not proven to be economically sustainable for rural areas, *DakNet* is a new hybrid technology that combines WiFi, VOIP, prepaid cards, and transportation infrastructure to create a store-and-forward wireless broadband network that is economically viable for rural areas. Figure 1 provides a chart (developed by United Villages, Inc.) comparing the infrastructure cost per line in rural areas (at least 40 kilometers from backbone communications infrastructure) and remote areas (at least 80 kilometers from backbone communications infrastructure) for five types of communications infrastructure: Copper, Cellular, Wireless Local Loop, Fixed Wireless Broadband, and DakNet, which is at an order of magnitude lower in cost than the alternatives.

Village Area Networks & The DakNet Solution

A Village Area Network (illustrated in Figure 2) is a hybrid wireless network that combines real-time and store-and-forward data transport to help solve the last-mile problem in rural areas of developing countries. The reliable (and preferably high-bandwidth) Internet connection is called a Hub. Subscribers within an initial radius of the Hub can access the Internet on a standard real-time wireless Local Area Network (wLAN). Depending on population density, topography, regulatory restrictions on amplification and spectrum usage, this wLAN can be expanded into a broader coverage area using 802.11 repeaters and existing points of elevation. These real-time point-to-multipoint and “mesh” wireless networks, however, are restricted by the limited availability and high cost of broadband data backbones in most parts of the developing world. For instance, a 512KB/s VSAT link in rural Cambodia costs over \$400/month, and over \$750 in Nigeria, in addition to the associated capital costs. It therefore becomes difficult and costly

to ensure even low quality of service levels as the number of real-time wireless broadband nodes/subscribers scales.

Village Area Network

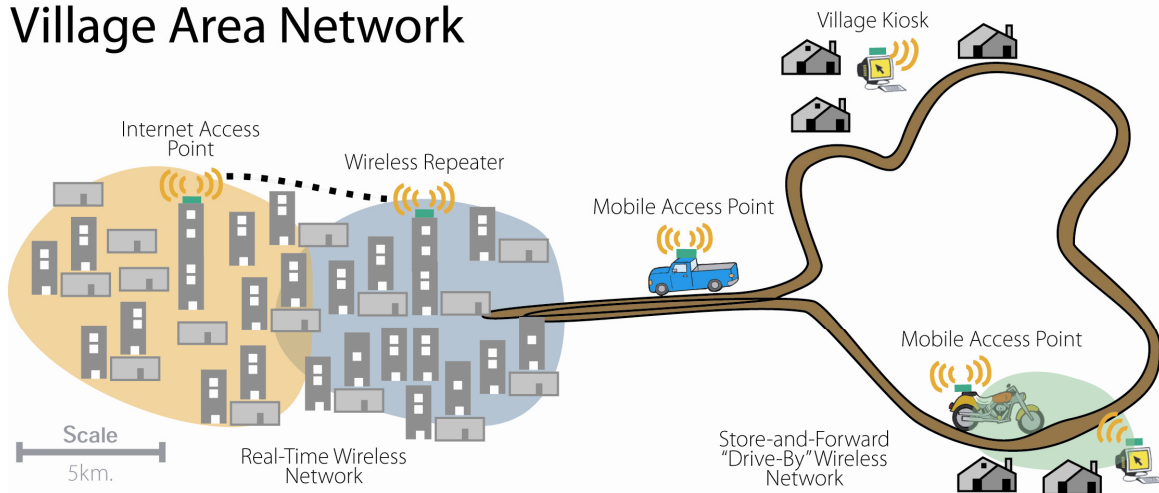


Figure 2: Village Area Network (VAN)

DakNet provides a way to cost-effectively distribute the Hub's bandwidth as far as the road goes, leveraging existing communication backbones and transportation infrastructures to provide store-and-forward "drive-by" connectivity for rural communities. A Mobile Access Point (MAP) is mounted on any vehicle that passes by the Hub and neighboring villages with some reliable frequency (e.g. buses, motorcycle taxis, boats... aircraft). The MAP physically transports data to/from surrounding rural areas using a store-and-forward drive-by WiFi connection. In each village a PC is deployed to provide email, voicemail, SMS, Web searches, and other services to end-users, typically delivered through a service operator who is trained to use the village PC.

The village PC communicates with the MAP and completes the store-and-forward network. Each village PC can support additional access sites, some of which may be mobile, such as a cordless phone or a WiFi-enabled PDA. As the MAP comes within approximately 500 meters of an antenna connected to the village PC, it automatically communicates with the village PC via WiFi and transfers that village PC's data. The MAP travels its route, repeating this process for typically 10 village PCs per MAP. Upon its return to the Hub, the MAP connects to the real-time Hub network via WiFi and transfers all of the collected data to and from the Internet. MAPs may also connect to the Internet directly through cellular data networks, which are being deployed in urban and sub-urban areas of developing countries. Figure 3 provides a photograph of Mobile Access Points that were mounted on motorcycle taxis in rural Cambodia.



Figure 3: Internet Village Motoman Project in Rural Cambodia with Mobile Access Points

VoiceMail Over IP

In addition to email and cached Web searches, the DakNet technology also enables villagers to use a phone and phone number to send and receive voice messages and text messages to and from any phone by leveraging a combination of Voice Over IP telephony, traditional wireline telephony, and SMS gateway services. This VoiceMail Over IP (VMOIP) solution turns each village PC into a virtual phone booth and local exchange for limited mobility handsets. VMOIP enables users to create VoiceMail boxes through which they can send and receive VoiceMails to and from cellular and wireline phones.

Using the simple numeric interface of a standard telephone handset, users can communicate in their mother tongue with everyone they know who has a phone number. Since it does not require a PC interface, the VMOIP system reduces the user literacy requirements for digital communications while plugging users into traditional phone networks. Figure 4 shows a photo of a user in rural Cambodia sending his first VMOIP message to his uncle's mobile phone in a nearby town.



Figure 4: First VoiceMail Over IP Message Sent from Sre Ankrong Village in Ratanakiri, Cambodia

Users can send and receive VoiceMails through a publicly available phone at each village PC and also use \$12 cordless phones to access their VoiceMail within a limited radius from each village PC. Village PCs route VoiceMails in a store-and-forward mode until they reach a real-time Internet link, at which point each VoiceMail is routed to a server that delivers the VoiceMail to its destination phone number. For VoiceMails sent to mobile phones, SMS messages can be sent to notify recipients to call a number to retrieve the VoiceMail.

For VoiceMails sent to landline phones, VoiceMails can be delivered over the phone in their entirety to the recipient, or just a preview can be delivered with notification of how to retrieve the complete VoiceMail. Typically, VoiceMails for local numbers are delivered over standard telephony networks, and national (where legal) and international VoiceMails are delivered using VOIP. VMOIP users can also have phone numbers in each of the locations where a server is maintained in order to be reachable on a more local phone number. Village PCs with real-time broadband connections can also support standard VOIP communications. Figure 5 below provides an overview of an embodiment of this VMOIP system:

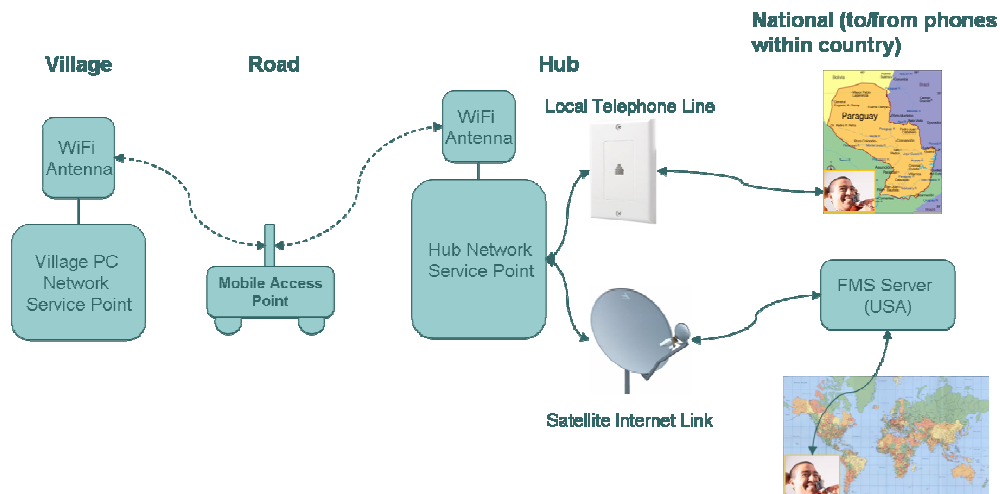


Figure 5: VMOIP System Architecture

Prepaid Cards

United Villages is a rural wireless ISP that has deployed Village Area Networks in developing countries such as India, Cambodia, Rwanda, Costa Rica, and Paraguay. United Villages sets up the networks and sells Prepaid Cards to village PC operators who then sell them to end-users and provide VoiceMail, email, SMS, Web search and other services. Prepaid Cards have been critical to the success of cellular operators in developing countries where banking and credit infrastructure is poor and post-paid billing is risky.

To register for an email address and phone number, users buy an Identity Card which has a scratch-off password on the back that activates the account. Users then purchase Recharge Cards and scratch-off a 16-digit recharge code on the back to credit their account. The denominations, currencies, and formats of the Prepaid Cards are fully customizable as is the tariff structure for services. The Prepaid Card system can be integrated with existing billing systems such as a cellular carrier's prepaid billing system. Additional services can also be integrated into the Prepaid Card system, such as eCommerce, micro-credit and telemedicine. The Prepaid Cards essentially provide villagers with a digital stored value account which can be used to facilitate a variety of transactions via the village PC.



Figure 6: DakNet Prepaid Cards Sold by United Villages in rural India

Ultimately, the Prepaid Cards enable last-mile network operators to ensure the sustainability of their networks whether they are for-profit or not-for-profit.

DakNet in Action

DakNet has been used by village schools in Cambodia, Rwanda, and Paraguay to teach children about the Internet and provide access to broader educational resources. It has also been tested by *Bhoomi*, a program run by the Government of Karnataka in India which has digitized all land records in the state, to provide villagers with a computer-generated print-out of their land records. United Villages has deployed DakNet as a commercial ISP in India. Below is some feedback from DakNet users, and Figures 7 and 8 provide some photographs of United Villages DakNet Service Providers and users in Orissa.

"We have two options for accessing the Internet for sending emails. Either we go to Khurda which is 35 kms from here and which has some cyber cafes offering broadband connectivity at Rs. 20 per hour. Second option is to access dial-up internet from one cyber café in Kalapathar, but the charges here are very high at Rs. 40 per hour and composing and sending one email can take as much as 10 to 15 minutes, because of the slow speeds, costing us Rs. 15 to 20. Therefore, we feel that the DakNet email at Rs. 1 per email and Rs. 3 per email with attachment which is now being offered in Kalapathar is a very good alternative."

- Students in Kalapathar village, Orissa

"A large number of relatives work in the state of Gujarat. Making STD calls to Gujarat costs us about Rs.15 to 20 for a 5 minute call. With the VoiceMail service, we can communicate more frequently and get to know about their well being at much lesser the cost."

- Villager in Nayagarh village, Orissa



Figure 7: United Villages DakNet Service Provider and Users in Orissa, India

"I have to send daily report to my branch office in Bhubaneswar. Currently I am sending a CD, which has the soft copy of the report, along with a hard copy by courier, every evening. The charge per courier is Rs. 5 and the courier reaches the branch next day in the afternoon. With the DakNet email service now available in the village, I can explore the option of sending the report through email to my branch office. The cost of one email would be Rs. 3 and I can expect the email to reach either the same day in the evening or latest next day morning. So there is saving in both cost and time."

- Bank Manager of UCO Bank branch in Gania village, Orissa

"We have to travel to Khurda for getting our railway ticket bookings done. The travel time is about 3 hours and one way ticket is Rs. 35. In addition, it takes about 1 hour in the queue to buy the railway ticket. We have got to know that using DakNet we can book railway tickets by just visiting the premises of the DakNet Service Provider in our village and the charge of Rs. 40 per ticket is much less than the cost of traveling to Khurda. In addition, the convenience of not having to travel all the way to Khurda."

-Villager in Kantilo village, Orissa



Figure 8: DakNet Service Provider Selling Prepaid Cards

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