The Last Inch of the Last Mile Challenge

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ABSTRACT

In this talk, I will discuss a promising solution to the "last mile" problem of providing Internet connectivity in underserved rural areas of developing countries. The solution leverages existing road and vehicle infrastructure to create a digital wireless network by installing custom WiFi access points on vehicles already travelling between rural areas lacking Internet connectivity and urban areas where Internet connectivity is present. We will review how this technology was implemented in rural areas of five developing countries, citing technical results and challenges. While the technology seemed to have solved the last mile problem by reducing the connectivity cost per capita to a few cents, it failed to address what I refer to as the "last inch" problem: the need to identify the data and interface that users are willing to pay for in order to sustain the connectivity infrastructure without donations and grants. I will explain how we adapted to address this last inch problem by migrating to a new mobile infrastructure with a more specific market focus. I will explore what lessons can be learned from our experiences as well as highlight areas for further research.

Technology is easy, humans are hard.
- John Gage, Former Chief Researcher at Sun Microsystems

Categories and Subject Descriptors

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1. STORE-AND-FORWARD DRIVE-BY WIFI

In the Fall of 2001 at MIT, Professor Alex Pentland, Dr. Richard Fletcher, and I conceived of a way to provide digital wireless broadband access for rural areas in developing countries for approximately $25 per village of communications infrastructure cost: store-and-forward "drive-by" WiFi. We proposed to install custom WiFi access points onto vehicles already travelling between rural and urban areas that would transmit cached data to and from WiFi-enabled devices within range of the vehicle's normal route, and then upload and download data to and from the Internet when within range of Internet-enabled hotspots. In this way, a $200 WiFi access point powered by a 12v vehicle battery could transmit large quantities of data on a daily basis for approximately ten villages, which would each have a digital device with a $50 WiFi adapter and antenna. Assuming an average village population of 1,000, the communication infrastructure cost of this type of Village Area Network (see Figure 1, below) would be approximately $0.03 per capita -- orders of magnitude lower than alternatives available at that time. We imagined that this kind of low-cost, delay-tolerant network could be deployed internationally to solve the last mile problem that prevented poor rural communities from receiving the benefits of information and communication technologies.

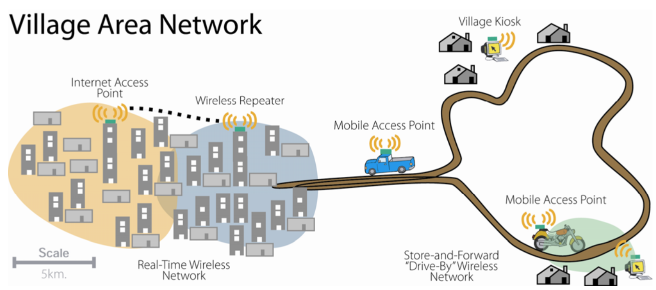

Figure 1: Store-and-Forward Drive-By WiFi Architecture

2. PILOT TESTING IN INDIA

In the Spring of 2002, we submitted a patent application and demonstrated this concept in rural India. Based on the results, I decided to pursue the idea as a full-time research project for MIT's lab in India, Media Lab Asia, and I moved to New Delhi in the summer of 2002. We set up a pilot network for the State Government of Karnataka's digital land record program, called *Bhoomi*. We installed embedded computers running Debian on Compact Flash cards with 802.11b chipsets and omni-directional antennas onto public government buses to create a "DakNet" -- *dak* means "post" or "postal" in Hindi. DakNet enabled villagers to request and receive print outs of their digital land records at village kiosks. Land record requests were picked up wirelessly by the DakNet bus as it drove by the kiosks, and were then fed to the Bhoomi database in the district headquarters. The Bhoomi database automatically transmitted the corresponding land record to the DakNet bus, which then relayed the land record back to the

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corresponding kiosk where it was printed out. Villagers were willing to pay Rs. 12 to receive their land record print out in the village where they lived because it was something that they needed and they didn't have to pay for travel to obtain it.

During the Bhoomi project, we also collected some compelling technical data, indicating that the DakNet bus would begin transmitting data anywhere between 200m to 1.5km from village kiosks, and would remain within range for a total of two to four minutes. However, due to environmental obstructions, network overhead, and other factors, the DakNet bus only experienced 72 seconds of effective connectivity above the minimum WiFi beacon threshold. Nevertheless, during an average "drive-by" session, DakNet transmitted 21 MB of data (in each direction), resulting in a "goodput" of 2.3 Mb/s.

3. THE LAST MILE IN CAMBODIA

On the strength of the Bhoomi pilot, we decided to spin-out a company called First Mile Solutions ("FMS"), based in Cambridge, MA, to develop and distribute this DakNet technology internationally. Our first customer was an N.G.O. called American Assistance for Cambodia ("AAFC"), which operated over 300 primary schools located throughout rural Cambodia. Each of these schools had solar panels, a computer, and a teacher (trained by AAFC's orphanage in Phnom Penh) who taught children English and basic computing skills. The vast majority of these schools lacked communications infrastructure and grid-based electricity, however, they did have moto-taxis that travelled between the villages and district headquarters on a frequent basis. In the remote province of Ratanakiri, we installed our access points on the back of five moto-taxis that provided drive-by WiFi access for eighteen schools five days per week. The moto-taxis connected to a hub access point at a hospital in the provincial capital that had a VSAT uplink. The schools could send and receive emails and perform offline, cached web searches using an open source MIT research project called Time Equals Knowledge ("TEK"). We later integrated a Voice Mail Over IP ("VMOIP") service we developed that enabled the schools to send and receive voice messages through a standard cordless phone that plugged into the school's kiosk. These services could be used at any time by the teachers and students, and then the data would be synchronized whenever the moto-taxi drove by. We trained the school teachers how to run the kiosks as well as a network administrator at the hospital how to manage the hub access point, mobile access points, and village kiosk software.

The "Internet Village Motoman" project in Ratanakiri was launched on September 1, 2003 and AAFC decided to expand the project to over 100 schools in four other rural Cambodian provinces. We partnered with and trained an IT company in Phnom Penh to provide in-country technical support for these additional hubs, however, several software and network patches as well as manual interventions on our part were required to keep the networks running.

4. PUBLICALLY FUNDED NETWORKS

From 2003-2006, we implemented similar not-for-profit projects in rural Paraguay, Rwanda, and Costa Rica for organizations such as the United Nations Development Program and the Institute for Connectivity of the Americas. These projects were similar in two ways: (a) they all used the same store-and-forward technology to provide email, voicemail, and cached web searches for village kiosks; and (b) they were all funded by non-commercial organizations for educational objectives that were not-for-profit in nature. Our technology served as a lower cost alternative to other technologies and services (such as VSAT) while still meeting those organizations' basic connectivity needs. These projects did not require real-time, international Internet access; they required an affordable means to route and transmit digital information between rural and urban areas. Apart from developing, customizing, and iterating the technology, our primary challenges in these projects were:

- finding reliable, high-frequency transports for the mobile access points;
- training the local network and kiosk operators how to deploy the access points, position antennas, and use the services;
- providing adequate local technical support to troubleshoot errors, re-install software, replace hardware, and communicate major problems to us.

5. BECOMING A RURAL ISP

After implementing and supporting several of these projects we decided to pursue a service model: rather than selling our technology to other organizations, we would use it to create rural communications infrastructure and provide services commercially to villagers. We started a new company called United Villages, Inc. ("UV") and established a subsidiary in India where we obtained an ISP license. We set up a network for twenty villages in the state of Orissa using the same technology we had implemented in other countries. We partnered with local rural bus operators to transport our mobile access points for a small monthly fee. We provided the same set of services (email, voicemail, web search, and SMS) through village kiosks operated by village entrepreneurs (typically shopkeepers). We integrated a custom prepaid transaction platform and sold prepaid cards to the kiosk operators at a discount, who then resold them to users in their villages at a profit. Users were charged for each transaction and purchased prepaid cards to recharge their accounts.

While the kiosks became popular for specific groups within each village (such as former college graduates who wanted to communicate with their friends), only a small segment of the broader village population was willing to pay for the kiosk services. Cellular voice and SMS coverage was spreading rapidly, and the demand for email and web services was very limited, even at Rs 1.5 ($0.03) per email. The kiosks also consumed a lot of electricity, so the kiosk operators were reluctant to keep them on enough of the time. This resulted in network downtime (if the kiosk was not on when the bus drove by) and unhappy customers. While our technology was successful in providing last mile rural connectivity for our other not-for-profit projects, we struggled to develop services that villagers were actually willing to pay for. We realized that villagers do not want "bytes"; rather, they want services and information that are directly relevant to them. The technology that we had developed didn't really matter to them because they didn't care how their data was transmitted. In short, although our technology provided digital connectivity for the last mile in rural areas, it failed to address the "last inch" question: what is the data and interface that users are willing to pay for that can thereby sustain the communications infrastructure?

6. DELIVERING THE LAST INCH

We performed village market research surveys and organized focus groups to help answer this question. We discovered that villagers cared about things like: finding a job; selling their crops or crafts; reserving a train ticket; buying a text book or a mobile phone; and matrimonial listings. We developed a kiosk-based portal to these services based on these needs: a job search service; a classifieds service; and an eCommerce service. While the job search and classifieds services generated some interest, the eCommerce service quickly became popular. Through the kiosk, villagers could order approximately 30 different products that they wanted but that were not typically stocked in their village and for which they would have to travel to a city or town to procure. This included products such as watches, branded personal care items, mobile phones, sunglasses, and so forth. We received their orders and arranged for delivery of the products to the corresponding kiosk operators using space on the same buses that were transporting our mobile access points. A villager would place his or her order and receive the goods within 60 hours on average.

Word spread about our “E-Shop” service within the villages and soon we were receiving orders for items that were not in our catalogue, such as an order for 40 Kit Kats. Although we did not carry Kit Kats, we fulfilled the order and later discovered that it was one of the village retailers who had run out of stock on Kit Kats and was going to have to pay to travel to procure more, so he ordered from us instead. More retailers began ordering from us, however, rather than using the kiosk (on which their order would have to wait for the bus to pick up), the retailers would call us directly and hang up before we could answer the phone, knowing that we would pay for the cost of the call to ring them back and take their order.

By the end of 2008, we had become a call-center-based distribution company for retailers in small villages. Many of our “kiosk” operators began visiting the retailers in their villages to solicit orders. One of our main challenges was that we had to pay for most calls and negotiate most transactions on a case by case basis with the retailers. Our market research indicated that retailers in villages with a population of less than 10,000 people had to leave their village to procure 81% of their inventory value. Based on this research and our success with E-Shop, we decided to refocus the business entirely on the rural supply chain opportunity. We shut down our kiosks, removed our mobile access points, and, since our sales team and most of our customers already had mobile phones, we developed an SMS-based transaction platform for our products. We did not recognize orders unless they were generated by the phone via SMS -- and our mobile phone E-Shop application did not negotiate.

7. LESSONS LEARNED & FUTURE RESEARCH

Although we successfully developed and deployed a low-cost wireless network to provide delay-tolerant, digital connectivity in rural areas, we were unable to identify an application or service that generated significant commercial demand and required large amounts of data to be transmitted between rural and urban areas. We were not alone in this regard: the lack of a “killer application” for village computing has been a contributing factor to the demise of many village kiosk based projects and ventures. Over an eight year period, we migrated from store-and-forward drive-by WiFi kiosks providing data services for villagers to SMS on mobile phones providing inventory for village retailers. In essence, although it seemed as though we had solved the rural last mile connectivity problem, we underestimated the importance of the critical last inch, which has much less to do with connectivity and much more to do with human factors such as appropriate interfaces, social and cultural preferences and interests, and indirect costs.

Today, our subsidiary in India supplies over 200 products to hundreds of village retailers every week, and all of the transactions are integrated into a digital supply chain management system. Demand for information and communication in rural areas of countries like India seems to center on frequent transmissions of small quantities of data that are highly localized using the mobile phone as the interface, not on large quantities of data requiring PCs with international, broadband connectivity.

While our experience with addressing the challenge of last mile rural connectivity represents just one approach to one type of “challenged network”, there are some broader conclusions that one may consider:

- leverage existing infrastructure to reduce costs and increase sustainability;
- connectivity is just one piece of the puzzle -- think holistically as you design your network and don't forget the “wetware”;
- research the human factors related to your proposed solution early on in the development process;
- conduct surveys with the intended users of the network early on -- see what they think about your solution;
- carefully assess connectivity requirements: do users actually require real-time international broadband connectivity or would a store-and-forward narrowband intranet suffice?

As mobile phone networks are becoming increasingly ubiquitous and capable of transmitting both voice and data at declining costs, mobile networks and phones provide a fertile platform for further research. We were able to address the last inch problem that we faced by leveraging mobile networks for SMS connectivity and mobile phones as a flexible platform for a massive existing installed base. We are currently developing a mobile phone based application enabling our retailers to post classified listings that can be accessed by users through multiple media channels. Preliminary research indicates that this application is just “the tip of the iceberg” of potential mobile phone applications for rural communities. Mobile operators can be major obstacles if applications do not integrate with standard network protocols and security policies; however, the proliferation of mobile phone hardware and software seems to be resulting in more open platforms that welcome third-party application development. As the propagation of mobile networks and the evolution of mobile phones continue to reduce the last mile problem, we can focus more on the most challenging part of our networks: the human part.

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