Final Summary report for

Wireless Internet Post Office:
Providing Rural Access to Text based Digital Communication using Wireless Multi-hop Mesh Networking

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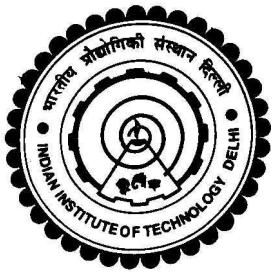

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1 Project Synthesis

With one-third of the world population living without electricity, providing digital connectivity is a distant dream for many. Cost, lack of infrastructure, and complexity of computer technology create a large digital divide between networked and unconnected citizens. However advancements in technology and mass commercialization of handheld computers (PDA) and wireless networking (WLAN) now offer the opportunity to break down these traditional barriers to digital communication. This project aims to couple advances in consumer electronics and digital communication with to design a system that can provide text based communication to remote/outlying areas underserved by traditional Internet/communication infrastructure.

The main output of the project is an end-to-end design of a Wireless Internet Post Office capable of delivering text-based messaging services to remote villages thorough a mesh network of wireless relay stations. Cost and complexity is minimized by using off-the-shelf commodity components. WLAN radios (802.11b) operating in the international license-free band (2.4 GHz) combined with directional antennas provide long range (kilometers) inexpensive wireless networking. Medical and aid workers, teachers and government employees can synchronize a low-cost PDA (¡USD$100) at a wireless relay stations, much like dropping off and picking up mail at a post office, then bring the PDAS into the field. Other potential applications include enterprising villagers who purchase a PDA can go into business as "scribes", reading and writing email to the illiterate, and "information workers", providing crop and fertilizer pricing, pest and health alerts, and matching sellers with distant buyers.

1.1 Project Status

Complete design of a Wireless Internet Post Office system has been made and based on the design, a working concept demonstrator of the Wireless Internet Post Office has been setup at IIT Delhi campus.

The setup comprises of three relay nodes spread over the IIT campus communicating over 802.11b network using long range antennas. Three parabolic and three Yagi Antennae have been used in the current setup. The system has been used to validate the design and also to carry out some performance tests.

The project website located at **http://genie.iitd.ernet.in/wipo/** has been updated to include the final integrated designs, current setup and the results obtained. A complete software package(including the installer script) of the system is also available from the website.

A simulation using the Network Simulator [1] has also been done. The results obtained from the simulation are also available from the project webpage.

2 Research problem and Findings

The major research problem faced in the proposed application context were how to design a network which is

[1] available from http://www.isi.edu/nsnam/ns

- low cost using commodity hardware components,
- resilient to node failures since the application environment is such that even power availability is limited to possibly a few hours in a day,
- easy to deploy and configure,
- uses public domain software modules to ensure software licensing does not become a bottleneck and
- does not lock in to any specific equipment model or manufacturers.

In our design we have been able to address most of these issues. These issues have also been tested on the current setup to validate the solutions proposed in the design.

The technical design for the project consists of the following four components:

- Design of the Internet Gateway Station,
- Design of Wireless Network Architecture,
- Design/selection of Wireless Communication Protocols to be used,
- Design of Application Modules for:
  - Handheld devices,
  - Internet Gateway Station and
  - Wireless relay stations.

2.1 Design Decisions vis-a-vis Observations

Some of the more important design decisions taken during the design phases of the four components and the actual observations using the pilot set-up:

Design Use Ad-Hoc On Demand Vector Routing (AODV) for routing amongst the wireless relay stations. This protocol has been borrowed from Mobile Ad-Hoc Wireless Networks model and was modified to suit the requirements of this project. This protocol was selected considering the requirements to make the system resilient to frequent power failures as the on-demand nature of the algorithm, the routing overheads are considerably lower as compared to any standard routing scheme used in the Internet.

Observed The results obtained using the test setup for WIPO show that the modified version of AODV performs very well even when one of the three nodes is temporarily shutdown.

Design In order to make the system interoperable with the existing Internet infrastructure, we decided to provide IP based network connectivity to all the nodes in the mesh network formed by the wireless relay stations.

Design Use standard email as a base platform for text messaging. Email distribution will be done using the domain name allocation. A Domain Name Server for this purpose needs to be setup on the Internet Gateway Station. Simple Mail Transfer Protocol (SMTP) is used for email exchange. This ensures that the system is operable with existing email services on the Internet. Internet Gateway Station will also serve as the mail server for receiving mails.

Observed Two of the three nodes were also connected to the existing LAN's at the respective locations. One of the nodes was used as the gateway, and all the mails destined for the WIPO subsystem were handled by this node. For outgoing messages from the WIPO system, this gateway used the existing mail servers on the LAN to relay these mails to appropriate addresses on the Internet.

Design Make the system independent of any specific PDA device. Since the PDA technology is evolving rapidly, we should not lock into a particular PDA hardware and operating system. The proposed design will work on different hardware platforms (iPAQ, Palm, Zaurus) and operating systems (WinCE/Linux/PalmOS) alike. The main choices to make it operating system platform independent are as follows:

1. Use POP3 (supported by almost all operating system platforms) on PDA for email retrieval from mail server(s).
2. All the platforms normally support an email client capable of email retrieval using POP3. The other option is to provide a web based email access from the mail servers. This can be done using Squirrelmail software provided with the RedHat distribution being used for the mail server(s).

To make the system hardware independent we chose to use:

- Communication using Infrared interface (IrDA) with the wireless relay stations. Optionally, we also plan to support communication between the PDA and the wireless relay stations over USB ports as a part of the ongoing work in the project.

Observed The system was tested using WinCE platform and Linux Familiar Distribution on an iPAQ and using POP3 for email retrieval. Both IrDA and USB communication between the relay stations and the handheld device were tested for transfer of emails.

3 Project Output and Implementation

A complete implementation of the basic WIPO system (v 2.0) has been done and tested in the IIT campus. The current implementation is based upon

- Linux operating system running on standard low-end PC hardware for
  - wireless relay stations,
  - mail server(s), and
  - Internet Gateway Station

This has the advantage of easy hardware availability and maintainability since any computer technician can build/repair such systems. Indeed we do not need new PC's, the nodes can be 3 year old PC's which may have been discarded by mainstream users and may be available as a donation.

- The implementation of AODV available from National Institute of Standards and Technology(NIST) has been used. This implementation has been modified for the purpose of this application. A comprehensive patch incorporating these modifications is available from the project webpage.
- HP iPAQi, PDA's have been used for development and testing purposes using both WinCE and Linux platforms. We chose WinCE and Linux since they are quite popular and available on various hardware platforms from HP, Toshiba and many others, and since support for HP IPAQ's was readily available. Again we do not foresee any problems in using any PDA that supports POP3 email.
- For the wireless relay stations, 802.11b wireless network adapters available from Cisco (Cisco Aironet 350 Series). We used Cisco network adapters because of their easy availability and widespread support, though any other network adapter which is supported in Linux (such as Orinocco, Intel, Netgear, LinkSys, D-Link) should work equally well.
- Of the 3 links between the three relay station nodes, for two of the links we have worked with parabolic antennas and for one link, Yagi Antenna's have been used for increasing the transmission range of the off-the-shelf 802.11b hardware. Both the parabolic and Yagi antenna for this case provide a very cost effective solution to increase the transmission range of the 802.11b network adapters to the desired range.

3.1 Solutions to open issues

Initially we faced some issues in the implementation of the project, however during the course of the project the same have been sorted out. The current deployment at IIT campus uses the solutions to these issues.

1. During the first phase, we faced some problem due to the interference due to communication over multiple links originating from the same node. However the problem was solved by using non-overlapping frequency channels available in 802.11b for each such communication links. The driver for the Cisco Aironet 350 Series cards on Linux was modified to incorporate this. In the current setup, different channels are being used for two different links originating from the same node.
2. The issues faced initially with setting up Yagi antennas over long ranges was also sorted out. We also experimented with parabolic antennas for very long links. The current setup uses a mix of Yagi and parabolic antennas (3 yagi + 3 parabolic).
3. Some vendors in Delhi itself were also located who supplied the necessary antenna and cabling equipment required. Though initially we had faced some problems in sourcing these, however on exploration we found that some of these vendors also manufacture some of these antennas locally, which makes it much more cost effective for large scale deployments.

4 Impact

The project has been completed and our research has demonstrated that the technical goals are achievable and the cost of the infrastructure required is fairly low. The stable test-bed deployed at IIT campus has also proved the worthiness of the technology in real world. This would enable others who wish to deploy such a system on a larger scale to evaluate our technology from a application perspective and see its practical viability in remote areas.

5 Overall Assessment

We have been able to meet the technical goals satisfactorily and the pilot implementation shows that the design provides a viable and effective means of bridging the digital divide and bring low cost communication to the most needy in remote locations in a cost effective manner. We believe that the technology developed as a part of this project can form a basis for business solutions for remote areas which can be offered as services to the people in rural areas at very low cost. The revenue model can be based upon a fixed fee or a transaction based fee.

6 Recommendation

It may be advisable to consider identifying an implementation agency who may be interested in deploying a commercial/full scale implementation in a remote area with possible technical support from us in a follow up project.