Addressing the Digital Divide
in Philippine Education

Manuel C. Ramos, Jr.
Department of Electrical and Electronics Engineering
College of Engineering, University of the Philippines
Diliman, Quezon City 1101
Tel: +632 9252957, Email: manuel@eee.upd.edu.ph

Abstract: Education is a powerful instrument in poverty alleviation and economic growth. Improving information access is critical in supplementing standard education techniques and improving the state of education in the country. In remote parts of the country, information access is very limited, with access to the digital information in Internet even more limited. To bridge the information access problem, we propose using 802.11b wireless links to link remote underserved areas. In particular, we study the issues in deploying the wireless network in the Batanes islands. We look at the technical viability of deploying wireless routers in the challenging Batanes environment, using solar to power our equipment and the resulting network usage by the schools.

1 Introduction

The phrase bridging the digital divide usually appears in articles and press releases to refer to the disparity between people and communities with and without access to digital information. With the wealth of information available in digital form, gaining access to this information is very more important now than ever. More often, the phrase refers to the task of providing Internet access to unconnected communities, usually in rural areas. The problem of bridging the digital divide is especially relevant to rural communities here in the Philippines were access to the Internet is either not available or very costly.

The impact of information access to communities has all to well been argued and documented. In general, the underpinning assumption is that information access is critical to economic and social activities that comprise the development process. Simply put, information access is needed for development.

In the Philippines, government agencies and NGOs are all too familiar with the need for information access. These agencies and organizations have different programs to address bridging the digital divide. One particular area of concern is rural areas. Although, there is still much to be done even in local urban areas when it comes to information access, rural areas present an additional challenge. In urban areas, communication infrastructure is at least accessible. Providing information access in this case would basically involve putting in reasonable effort to activities such as deploying kiosks or personal computers to schools and other centers. However, in rural areas, the communication infrastructure may be absent or very expensive for large volume access. Connection solutions such as mobile (such as GPRS and 3G) and satellite would definitely be too expensive for a small rural school or a small fishing town to afford much less sustain.
One sector very much in need of access to information is education. Education is usually seen as a powerful instrument in poverty alleviation and economic advancement. Getting rural schools connected to the Internet may have a large impact on not only the students of the schools but also the teachers. Access to additional information through the Internet can improve the competencies of the teachers; this in turn impact the students. One report on Philippine public education [1] mentions that rural areas and the countryside are the worst affected by the deteriorating quality of public education in the Philippines. However, in rural areas, the communication infrastructure may be absent or very expensive for large volume access. Connection solutions such as mobile (such as GPRS and 3G) and satellite would definitely be too expensive for a small rural school or a small fishing town to afford much less sustain.

There are already different groups in the country trying to address the information access problem to rural areas. One such group is GILAS (Gearing up Internet Literacy and Access for Students). GILAS is an NGO targeting to provide computers along with Internet connectivity to all public high schools in the Philippines. GILAS typically supplies a school with a package of about ten or twenty sets of computers, and also arranges for Internet connectivity with local ISPs for one year. Depending on the location of the school, Internet connectivity may be provided through either the basic dial-up, DSL, or wireless broadband. DSL providers are usually through one of the three big telecommunications company, while only one company is currently offering wireless broadband. With these providers, GILAS can connect most of the public high schools in the country. Schools in urban centers should present the least problem as at least one of the mentioned providers will surely have a presence. Schools within the vicinity of a major city or town can also easily get Internet connections through these providers. However, some areas are a bit more challenging to connect and requires novel and custom solutions.

There are also individuals, who on their own time, support connectivity initiatives of schools in the region. Surely, there are more efforts here in the country that may not be as well publicized as the GILAS efforts.

This paper will focus on the efforts of our group TACTIC (Technology affecting communities, technology improving communities) in addressing the digital divide in education. In particular, we will be highlighting the results of efforts to interconnect public high schools in the Batanes islands, a group of islands in the northermost region of the country. The report will discuss our network topology and performance, our solar power setup, and the resulting web traffic through the network.

TACTIC is a group from the University of the Philippines, Electrical and Electronics Engineering department which aims to address socially relevant issues in rural communities with the use of technology. The group currently focuses on using wireless connectivity as a last mile option for connecting rural schools to the Internet. On a bigger scale, it studies different aspects of technology use for rural communities.

The group has interconnected several sites all over the country primarily using hardware and firmware setups similar to UC Berkeley’s TIER (Technology Infrastructure for Emerging Regions) group [2]. The most challenging site encountered to date is the deployment in Batanes.

2 Initial Deployments

The very first rural deployment attempted by the group was to connect Malakimpook HS in San Pascual, Batangas to the Internet. This connection effort was primarily driven by GILAS. Wireless was the only cost-effective option to provide connectivity to
Malakimpook since the school is located in a remote part of Batangas (80 km south of the capital) where landlines are not even available. The source of Internet connection for Malakimpook is Alalum HS, which is another school in San Pascual, Batangas about 2 km away from Malakimpook. Alalum HS is fortunate enough to be an area where landlines which support DSL are available. Equipment used in the interconnection is a pair of WRAP boards with 200 mW wireless cards hooked up to 15 dB antennas. Even with the short distance, the deployment proved challenging. The San Pascual area is covered with tall coconut trees which necessitates high mast heights to get good line of sight. Due to budget constraints, mast heights where limited to 10 meters. This results in large signal losses between the links. We were getting -81 dBm received signal level and a 5 Mbps stable throughput both ways. This bandwidth is acceptable given that our DSL connection bandwidth is only 500 kbps.

Another site connected to the Internet with the help of the TACTIC group is Guisguis National HS in Zambales (180 km north of the capital). The source of the Internet connection for Guisguis is the Lipay National HS, some 8 km away. Although 8 km is very much within the range of the wireless equipment installed, due to the contour and vegetation of the region between the two schools, antennae masts about 10 meters high needed to be used. Constructing antenna masts higher than 5 meters becomes an issue when cost is a primary factor. The masts needed to be inexpensive but at the same time able to support the wireless equipment and the person who will be climbing up to install the equipment. With the 5 meter masts, we were able to get -86 dBm signal level. For this setup, we were able to get 2 Mbps stable throughput; similar to the Batangas setup, this is acceptable since our DSL source bandwidth is only 384 kbps.

3 Batanes Deployment

The most challenging site encountered to date is the deployment in Batanes. With initiatives from the local government of Batanes and the Department of Education, and the coordination of GILAS, plans for interconnecting a total of six schools scattered across the three Batanes islands were started in mid-2006.

3.1 Network Setup

For the Batanes network shown in Figure 1, the only available Internet source is located at the Basco National Science HS in Basco, Batanes. The Batanes deployment posed several new challenges such as longer link distances (as compared to other sites), multihop configurations, solar powered relays and very tall antenna masts. A 20 meter mast needed to be constructed in order to provide links to the islands of Sabtang and Itbayat. Locals with their experience with harsh Batanes storms did their part here in constructing a stable and tall mast in Vayang (batanes relay 7), about 1.5 km North-east of Basco. Due to the remote location of Vayang, the wireless equipment needed to be solar powered. Using experience learned in a solar testbed for wireless routers in the university, a reliable solar power system was designed and deployed in Batanes to power some of the wireless routers. In conjunction with an energy aware wireless router configuration, the solar power system deployed will provide two days of power even with minimal sunlight. This design is especially useful in a place like Batanes where good sunlight may not be available for several days during stormy periods. The wireless router in Vayang links Itbayat Agricultural NHS to the Internet. The link from Vayang to Itbayat is approximately 40 km (see Figure 2), and is the farthest single link
deployed by the group outside of the university testbed. The Vayang link also provides Internet connection to the Sabtang island where Sabtang National School of Fisheries is located. From Sabtang, the wireless connection is distributed to three other schools located in the southern part of the main island. Two of the schools are Ivana NHS and Batanes General Comprehensive HS which are about 6 km from Sabtang across the Sabtang channel. The third school linked from Sabtang is Itbud Integrated School. Connecting Itbud is challenging due to its location in a valley region and the surrounding mountainous areas. Two solar powered remote wireless relay sites needed to be established to get the link from Sabtang to Itbud. This part of the deployment provides valuable data on the performance of the multihop configuration as well as solar power. The sixth school connected in Batanes is Mahatao National HS. Another solar powered remote relay needed to be installed to get the Internet connection to Mahatao.

In the Batanes deployment, the primary hardware used were WRAP boards with 400 mW EMP-8602 wireless cards. In some network endpoints such as the schools in Mahatao, GCHS and Itbud, Linksys WRT54GL boards were used. The WRAP boards are running TIER distribution of linux, while OpenWRT were loaded into the Linksys boards. Antennas used are all 24 dBi mesh parabolics. Table 1 shows details about the wireless network such as link distances, channel settings, actual signal levels, and bit rates.

All the link pairs are setup in adhoc mode with the exception of the short links around Sabtang which are setup in infrastructure mode with the Sabtang router acting as the master. Table entries with received signal levels in pairs show the signal levels at each
Table 1: Network Details

<table>
<thead>
<tr>
<th>Link Pair</th>
<th>Distance</th>
<th>802.11b Channel</th>
<th>Received Signal Level</th>
<th>Bitrate Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basco - relay 7</td>
<td>1.65 km</td>
<td>1</td>
<td>77 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>Basco - relay 2</td>
<td>3.43 km</td>
<td>6</td>
<td>-82 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>relay 7 - Itbayat</td>
<td>38.43 km</td>
<td>6</td>
<td>-77 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>relay 7 - Sabtang</td>
<td>17.49 km</td>
<td>11</td>
<td>-85 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>relay 2 - Mahatao</td>
<td>1.00 km</td>
<td>11</td>
<td>-82 dBm / -65 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>Sabtang - Ivana</td>
<td>5.76 km</td>
<td>1</td>
<td>-66 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>Sabtang - GCHS</td>
<td>7.00 km</td>
<td>1</td>
<td>-75 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>Sabtang - relay 4</td>
<td>7.78 km</td>
<td>1</td>
<td>-53 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>relay 4 - relay 3</td>
<td>0.91 km</td>
<td>11</td>
<td>-56 dBm</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>relay 3 - Itbud</td>
<td>1.72 km</td>
<td>1</td>
<td>-67 dBm / -53 dBm</td>
<td>2 Mbps</td>
</tr>
</tbody>
</table>

end of the link. These highlight the difference in power and sensitivity of the EMP-8602 wireless cards and the Linksys boards.

3.2 Solar Setup

Solar is used to power the wireless routers at five sites within the network, namely, relay 7 in Vayang, relay 2, relay 3, relay 4 and in Sabtang. The solar setups are identical with each site utilizing an 80 W solar panel and a 30 AH gel type, deep discharge battery. The system was sized to provide two days of continuous operation for the wireless router even with minimal sunlight. Figure 3 shows the typical setup. The panel and battery are mounted at the base of the antenna mast. Due to strong winds and rain in the mountainous areas, the panel needs to securely fastened to the ground with large metal
poles.

Figure 3: Solar Setup

In all of the solar-powered sites with the exception of Sabtang, solar power was the only option. For the Sabtang site, electricity is available but intermittent. Since the Sabtang site is a main link to the three other sites in the south of the main island, it is crucial that the Sabtang router is always powered. For this reason, solar power was installed in the Sabtang site.

4 Testbed

A very important lesson learned in these deployments is that careful planning goes a long way. The successful outcomes of the deployments would have been very hard to achieve without the a good study of the site to be deployed to and the test of a mock setup in the university. To aid in performing different tests on multihop links and long distance links, the group has setup a testbed (Figure 4) consisting of sites in the university and areas in Antipolo (14 km from the university) and Tagaytay (60 km from the university. The testbed allows single links of distances 1 km, 10 km, 14 km and 60 km and multihop links of up to three hops to be tested.

Another feature of the testbed is the solar power setup. The setup allows testing of different solar configurations, especially those configurations appropriate for our wireless routers. The solar setup features solar panel sizes of 40W, 50W and 80W. A primary use of the solar testbed is the continuous testing of the solar controller (Figure 5) being developed based on the TIER Solar Controller [3].

Only after the wireless equipment is properly configured and thoroughly tested is when a deployment to the actual site is attempted. This careful planning and testing minimizes problems that may be encountered in the site deployment. The careful planning also helps in simplifying the actual setup which allows the possibility of the locals involved in doing the deployment themselves.
The board in Figure 5 mainly functions as a charge controller and a system status monitor; its main functional blocks are shown in Figure 6.

5 Solar Charge Controller

The board in Figure 5 mainly functions as a charge controller and a system status monitor; its main functional blocks are shown in Figure 6.
The microcontroller block consists of the PIC16F88 and associated support circuits for the PIC. The PIC16F88 microcontroller coordinates the different functions of the board. It talks to the voltage and current sense circuits to determine the voltages and currents of the solar panel, battery and the load. It also interfaces to the switch mode power converter to set the appropriate power conversion factor, and the Ethernet and serial ports to report system status.

The voltage and current sense block is built around the PIC’s analog-to-digital inputs and the LM3813 current sense ICs. Currents for the solar panel, battery and load are sensed directly using LM3813-10 current gauges. Both PIC A/D converter and LM3813 current sense have 10-bit conversion resolutions.

The switch power conversion block is built around the LTC1624 switching regulator controller. The power converter is designed to switch between different conversion ratios in order to achieve maximum power point tracking. Depending on conditions such as solar intensity and battery voltage, the PIC microcontroller sends signals to the power converter to adjust the conversion ratio so as to maximize power extraction from the solar panel.

The Ethernet and serial ports block provides external Ethernet and serial interfaces to enable the board to report system status to the router. The Ethernet interface is built around the ENC28J60 SPI Ethernet chip; the interface operates at 10 MBps full-duplex. The serial interface is standard RS-232 at 19.2 kbps.

The board charge controller functions are similar to typical commercial controllers, namely, maximum power point tracking, low voltage disconnect, and trickle charging.

The significant capabilities of the board beyond commercial controllers in this power handling range are related to system monitoring.

### 5.1 Voltage and Current Sensing

Voltages and currents for the solar panel, battery, and router are continuously monitored every 250 ms. Voltage is sensed using the internal A/D converters of the PIC microcontroller. Voltage monitoring range is from 0-36 V with 10-bit resolution. Current is sensed using three separate current gauges which report current magnitude as well as current flow direction. Knowing the current flow direction is especially important in monitoring whether the battery is charging or discharging. The current sense circuit is rated up to 10 A with 10-bit resolution.

The voltages and currents sensed are used by the PIC in power calculations to implement power tracking, for low voltage disconnect, and for trickle charging. The voltage and current values are also reported through the Ethernet and serial ports.
addition, the power conversion setting and trickle charge status are also reported.

5.2 Ethernet Reporting

With the current implementation, Ethernet reporting begins only after receiving an ARP request for a specific range of addresses. This allows the board to determine the subnet it is on and report on this subnet appropriately. Basically, an ARP request for the address x.y.z.123 will set the board to use x.y.z subnet in its reporting. The system status is reported by the board using ARP replies to nine consecutive IP addresses starting at address x.y.z.123. The data is reported using last two bytes of the MAC addresses for the mentioned IP addresses. Using the ARP replies and last two bytes of MAC addresses to communicate the system status report simplifies extracting the reported data. A short tcpdump and awk script is all that is needed to get the data from the board to the router.

To give the system maximum flexibility, all data reported through the Ethernet is similarly echoed through the serial port. Additional reports are also sent out the serial port for debugging during initial system setup.

Since the board was designed to simplify wireless router setup with solar power, having power over Ethernet is crucial. The onboard Ethernet jack supplies 12 V across pins 4/5(+) and 7/8(-) to implement POE. The POE pins are tied to the low voltage disconnect circuit, which powers down the router if voltage drops below the critical level.

6 Discussion

The Batanes wireless network was completely operational in mid-2007. Logs are periodically sent to the university to keep track of the performance of the links and the usage of the different schools of the network. Due to the low bandwidth of the upstream broadband link, logs for web traffic are collected for one hour periods at a time and then sent to the university. Logs for link status are sent every twenty minutes.

Table 2 shows the TCP throughput of different segments of the link as gathered using iperf. The table shows that throughput is dependent on distance and the number of hops. It can be observed that throughput of 484 kbps is achieved between the farthest point of the network (Itbayat) to the broadband gateway. Although the achieved throughput is low compared with other links, it is actually sufficient to bring the entire available bandwidth (384 kbps) of the gateway to the school in Itbayat.

<table>
<thead>
<tr>
<th>Endpoints</th>
<th>Link Segments Traversed</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basco - relay 2</td>
<td>1</td>
<td>1.40 Mbps</td>
</tr>
<tr>
<td>Basco - relay 7</td>
<td>1</td>
<td>1.59 Mbps</td>
</tr>
<tr>
<td>relay 7 - Itbayat</td>
<td>1</td>
<td>721 kbps</td>
</tr>
<tr>
<td>Sabtang - relay 4</td>
<td>1</td>
<td>1.44 Mbps</td>
</tr>
<tr>
<td>relay 4 - relay 3</td>
<td>1</td>
<td>1.62 Mbps</td>
</tr>
<tr>
<td>Sabtang - relay 3</td>
<td>2</td>
<td>1.43 Mbps</td>
</tr>
<tr>
<td>Basco - Itbayat</td>
<td>2</td>
<td>484 kbps</td>
</tr>
<tr>
<td>relay 2 - Itbayat</td>
<td>3</td>
<td>222 kbps</td>
</tr>
</tbody>
</table>

Table 2: Network Throughput

In order to assess the schools usage of the network, transparent proxies where installed in the WRAP-based wireless routers. The proxy setup allowed us to monitor and log
the number of web connections through the wireless routers. Table 3 shows a snapshot of the number of distinct connections created by computers in the respective schools.

<table>
<thead>
<tr>
<th>School Name</th>
<th>Number of Web Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day Snapshot</td>
</tr>
<tr>
<td>Mahatao NHS</td>
<td>8106</td>
</tr>
<tr>
<td>Sabtang NS of Fisheries</td>
<td>8874</td>
</tr>
<tr>
<td>Ivana NHS</td>
<td>603</td>
</tr>
<tr>
<td>Batanes GCHS</td>
<td>7756</td>
</tr>
<tr>
<td>Itbud IS</td>
<td>11101</td>
</tr>
<tr>
<td>Itbayat Agri NHS</td>
<td>11356</td>
</tr>
</tbody>
</table>

Table 3: Web Connections (September 2007)

From the above summary, we can see that there is reasonable usage of the network. It is noteworthy that Itbayat tops the usage summary. One reason for this is the remoteness of Itbayat. The island is 40 km north of the main island; the wireless network is the most efficient way of getting information to and from the island.

7 Conclusion

With the wireless network only more than a year old, it is still early to say its effectiveness is bridging the digital divide in the Batanes island. Further analysis of the logs are necessary to assess its impact on education. But indications are already there that wireless network is playing some role in the bridging the divide.

Finally, another realization from these deployments is how the locals from the school or the area are very much willing to help with the effort, especially when education is concerned. It seems clear that education and improving its current state are considered a worthy cause by most people, and support from other groups takes the cause even further. One surely knows after seeing the excitement of the students and teachers in being able to send their first email and browse the web from their school that the hard work of trekking up mountains with the wireless equipment, 10 kg battery and 80 W solar panel on your backs has paid off.

References


