Implementing a portable outdoor wireless network within a budget

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Abstract. This paper describes the implementation of an affordable portable outdoor wireless network for supporting PDAs. We describe our results and report on the tradeoffs, and difficulties discovered when dealing with areas that are heavily wooded, and have no existing network connectivity or power.

1 Introduction

An essential element for the success of many pervasive computing projects is the ability to provide seamless wireless communication among devices. While there are companies that provide wireless networking expertise and services, they often exceed the budget of both small public institutions (e.g. museums and galleries) and research groups. Furthermore, this cost is likely to rise when seeking to build a wireless network in an outdoor environment, where the equipment and overall difficulty of setting up and testing is more complicated. Factors such as lack of power sources, variable signal strength, and unexpected obstacles, such as trees and rivers, all have to be taken into account. There are several tradeoffs that must be considered in terms of equipment and architecture. This paper describes how we attempted to implement an affordable outdoor mobile wireless network for supporting PDAs in a very large densely wooded area. Also, we outline some of the difficulties that surfaced, and discuss some of the tradeoffs that need to be considered.

1.1 The Lilly-Arbor Project

The Lilly-Arbor project provides a range of environmental science education programs for the local community. It focuses on experimentation and evaluation of restored ecosystems and habitats. As part of this enterprise it has been developing different environmental restoration techniques for a number of sites. One of these sites is a half-mile stretch of land along the White River in Indianapolis, Indiana, where over 3,000 trees have to be measured biannually. Currently, this is done by hand, using paper records. Their aim was to use PDAs for data entry, and enhance the learning experience by providing real-time data analysis in the field. Our role was to develop a technological solution that implemented a portable wireless network that could be installed and removed in different locations on a daily basis. Our budget for the networking equipment was limited to approximately $1,000. This paper describes how we approached this challenge.

2 Related Work

Several UbiComp projects have been conducted that require outdoor wireless networks. For example, a multi-user game was created that allowed users to play an augmented reality version of Pacman on part of the campus at the National University of Singapore [1]. This setup used backpacks that contained powerful laptops, batteries, and external wireless cards, which allowed for long-range connections to the campus wireless network. A similar game was created in Sheffield in the UK where three runners moved through the city streets chasing online players across a virtual map of the city [2]. The real-world players used PDAs, which had a less powerful wireless signal than the laptops used in Human Pacman. The researchers accommodated for the weaker signal by adding an extended antenna and external battery. This arrangement allowed for an urban playing field that was roughly 400 meters by 800 meters, and was supported by seven wireless access points (WAPs). However, even with a significant amount of wireless saturation the authors reported difficulties in maintaining a constant network connection due to the "narrow and built up nature of the city streets." In another mixed-reality game, children used PDAs, sensors, tangibles, and RFID, to learn as much as they could about an invisible virtual creature known as the Snark [3]. This project was run successfully in a controlled lab setting but once the researchers tried to create a similar setup outdoors, several adjustments had to be made. Other than the obvious problems (such as the lack of an existing network or power) the researchers found that the natural foliage blocked a large amount of the radio signal, which required the use of more wireless access points (three outdoors vs. one in the lab). These projects have constructed wireless networks for particular situations, whereas ours seeks to provide a sustainable and portable solution allowing for easy setup in different locations.

3 Setup and Testing

The Lilly-Arbor researchers required a wireless network that could be taken to remote locations, quickly set up, used for at least eight hours, and be easily dissembled at the end of the day. These remote locations would have no access to existing networks or power sources, and involve terrains that make cabling difficult. This meant that we had to implement our network such that *all* point-to-point communications were done wirelessly, and batteries had to be used to power the wireless access points.

We initially bought 10 common off-the-shelf WAPs. The model chosen was the TEW-430APB from TRENDnet. The TEW-430APB WAPs reported a 300-meter wireless range, and supported the *Wireless Distribution System* (WDS) protocol, which allows access points to be chained together wirelessly, further reducing the amount of cabling necessary. Also, this particular model could be purchased cheaply at only $56. To address our power concerns we purchased 10 standard marine batteries that cost $10 each. These batteries were each connected to an access point using an AC inverter, which cost $17 each. The marine battery is smaller, lighter, and less expensive than a car battery and after testing we were confident that it would power one of our access points for well over eight hours. We created our field setup by mounting each WAP to a 10-foot pole with a small plastic tub at the base for the battery and AC inverter. Adding in a few other small pieces of equipment (extension cords, connectors, plastic poles, etc) our total cost for equipment was under $900.

Other than the wireless network equipment, our technological setup included a laptop PC acting as the server, and a number of PDAs used by the scientists in the field. The Lilly-Arbor scientists chose the IPAQ H5550 because it came equipped with internal wireless cards and could run continuously anywhere from six to eight hours.

To test the actual range of the IPAQ's internal wireless card, we set up one of our WAPs in an open field and connected it wirelessly with both a PDA and a laptop for comparison. We were discouraged to find that at approximately 20 meters the PDA lost its connection entirely, but the laptop kept its signal beyond 100 meters. The PDA's signal range was much smaller than expected, and meant that regardless of the broadcast range of our WAPs, we would need to place each one within 40 meters of each other to maintain a connection. When we then tested our setup in the wooded area, we found that we were further limited to only 30 meters due to the additional interference of the dense foliage. Conveniently, the width of the project site was approximately 30 meters, which allowed us to set up our WAP stations in a straight line down the middle of the woods. The weak signal from the PDAs meant that the 10 WAPs we purchased could provide a useable wireless signal to an area 330 meters long by 30 meters wide, which was approximately 38% of the total project site.

Next, we set up the WAPs to pass information between each other using the built-in WDS configuration. Initially we linked each node to its four nearest neighbors in order to add redundancy to the network (see Fig. 1), but this caused many packets to be broadcast repeatedly and reduced the speed of the network such that it was unusable. However, when we changed the WDS configuration so that each access point was linked only to its nearest neighbor (e.g., 2↔3, 3↔4, 4↔5, etc.) the network started to function normally. Finally, we attached the central server physically to one of the central nodes. This configuration was optimal for this range, but it is likely that an adjustment would have to be made for even larger areas because of some limitations with WDS.

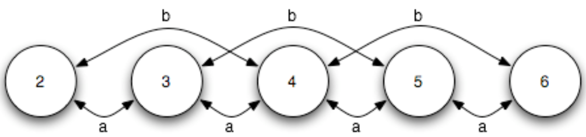

Fig. 1. Display of how the nodes in the wireless network were configured using the WDS protocol: (a) First layer of connectivity between nodes (b) the second, redundant, layer. The redundant layer had to be removed in order for the network to function.

4 Tradeoffs, and Difficulties

The tradeoffs we had to consider when assembling our network involved the signal strength of the PDAs, the battery life of the PDAs, and the number of WAPs necessary to cover the site. If an external card is used then the PDA gets a stronger signal, but the battery life is lowered, meaning that the devices would not last through the day. If an external card is not used, then more WAPs must be used to provide wireless coverage in the site, increasing the overall cost. We chose to use the internal wireless cards because we did not want scientists to have to deal with carrying extra batteries, or restarting the PDA application.

One of the difficulties we were confronted with was diagnosing connection issues in a heavily wooded area. In general, diagnosing wireless connection issues is difficult because there are a number of issues (hardware, software, natural obstructions, etc.) that keep information from flowing, and many of the tools provided to test these issues are not helpful. These problems are compounded when working in a wooded area. Discovering and repairing network issues required several people navigating long distances, back and forth, through thick foliage, causing the setup to take much longer than predicted. Regardless of the prep work done in the lab, the actual outdoor setup took much longer than expected.

In summary, when designing a portable network (i.e. one that can be set up and dismantled on a daily basis, in different locations) for large outdoor terrains, we recommend the following: (1) The number of WAPs necessary to make an outdoor area "wired" is mostly dictated by the signal strength of the devices you wish to support, so it is important to test the individual devices wireless strength before considering how many WAPs to use. (2) Consider how long you need your network to function. WAPs can be powered for a very long time using inexpensive batteries, but most PDAs and laptops have a shorter battery life. If the network only needs to function for a few hours, powerful external wireless cards can be used with fewer WAPs. (3) Regardless of the amount of prep done before hand, the chances are good that it will take longer to set up and configure the network than expected. This should be accounted for when considering how long the network can function on battery power. Finally (4) consider your terrain carefully. Laboratories, cities, fields, and wooded areas have different attributes (e.g., steel and glass vs. wood and leaves) that can affect signal quality, and will require slightly different layouts.

References

1. Cheok, A. et al. 2004. Human Pacman: a mobile, wide-area entertainment system based on physical, social, and ubiquitous computing. *Personal Ubiquitous Comput.* 8, 2 (May. 2004), 71-81.
2. Crabtree, A. et al. 2004. Orchestrating a mixed reality game 'on the ground'. In *Proceedings of* CHI '04. ACM Press, New York, NY, 391-398.
3. Harris, E. et al. 2004. From snark to park: lessons learnt moving pervasive experiences from indoors to outdoors. In *Proceedings of the Fifth Conference on Australasian User interface - Volume 28* (Dunedin, New Zealand). A. Cockburn, Ed. ACM International Conference Proceeding Series, vol. 53. Australian Computer Society, Darlinghurst, Australia, 39-48.