# Building the Wireless Campus

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## Abstract

This prototype is a continuation of a series of wireless prototypes which began in August 2001 and was reported on again in August 2002. This is the final year of this prototype. This continuation allowed Saint Francis University's Center of Excellence for Remote and Medically Under-Served Areas (CERMUSA) to refine the existing WLAN for the Saint Francis University (SFU) campus and attempted to show if computer modeling software was a legitimate tool for designing wireless campuses.

The prototype was divided into two distinct divisions. The first portion of the prototype consisted of verifying that the access points were located in optimal locations on the SFU campus. Previous wireless prototypes consisted of doing base wiring of the SFU campus. The second current portion of the prototype consisted of wiring the greenspaces of the campus, and testing "leaky wire" antenna technology as a viable option for indoor wiring applications.

For the 2003-2004 funding year, the testing of the greenspaces on the SFU campus was the main thrust of the research. Additionally, experiments were done with various wireless technologies.

## Background

Implementing wireless computer networks in buildings has its challenges, but setting up a wireless network outside, in green areas, presents its own set of problems to overcome. One has to not only consider artificial structures like buildings, but natural ones like hills, trees and landforms. Additionally, weather patterns, trees, and bushes can make a difference in signal propagation. CERMUSA has published the lessons learned and best practices for the set-up of a wireless network within campus buildings, the conclusions of which were, "Creating a wireless campus is a difficult task. Using computer modeling techniques provides the precision and flexibility for creating multi-building, multi-floor, and multi-channel wireless connectivity."

In May of 2003, CERMUSA commissioned GROK Technology, Inc. to do an outdoor survey of wireless networks at the campus of SFU. To summarize, expanding the SFU wireless network to the quads and outdoor areas of the campus was feasible, so CERMUSA set-out to find a cost-effective and sustainable way to "light up" the outdoor areas.

Variables to consider are the effectiveness of powered versus un-powered antennas, foliage, land forms, physical structures, and weather.

## Methods and Materials

### *Outdoor Coverage*

The placement of antennas outdoors presented several challenges. The first task was to specify and purchase the antenna equipment needed for the installation. GROK had identified viable options for the project, the previous year, during their site survey. The information gathered by GROK provided a basis to build on for the equipment list.

Three different types of antennas were used on the project, as shown in the following figures:

Figure 1
7 Decibels Isotropic (dBi) Omni-Directional Antenna

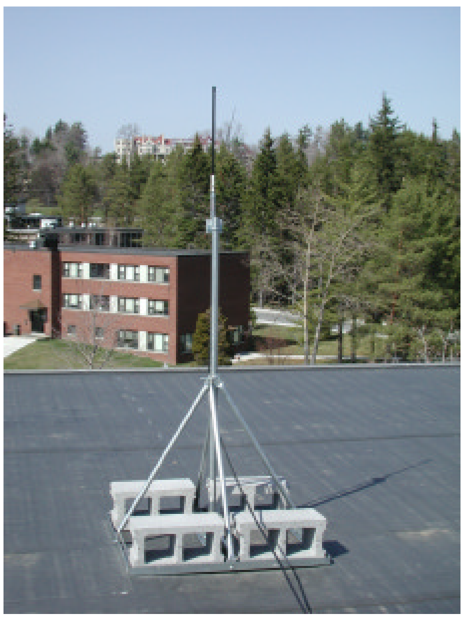


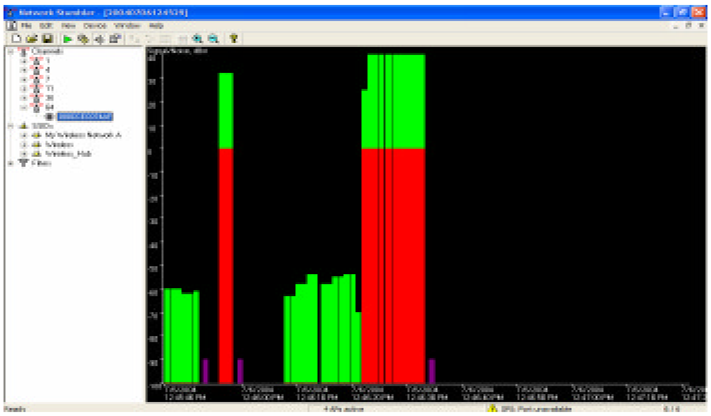
Figure 2
12 dBi Flat-Panel Amplified Antenna

Figure 3
16 dBi directional mast

Once the equipment arrived, the antennas were placed on the roofs of three buildings throughout the SFU campus in locations determined previously from the GROK site survey. To connect the antennas with the access points, which remained sheltered inside a wiring closet within their respective buildings, LMR-400 coaxial cable was utilized. Because signal is lost as it travels through a cable, it is ideal to keep the cable length between the antenna and the access point as short as possible. LMR-400 cable provides an acceptable 6.8 dB of signal loss per 100 feet (Flickenger 2003) while still priced at an affordable cost. Cable runs between 60 and 100 feet were used in the project. Additionally, a grounded lightning arrestor was placed inline with the cable between the access point and antenna. Should lightning strike one of the outdoor antennas, this arrestor will aid in preventing damage to the more expensive access point.

The antenna was connected to a Proxim Orinoco AP-2500 access point. A survey team then surveyed the area of intended coverage to verify that signal strength was adequate throughout the coverage area. To measure signal strength, a free software application called NetStumbler was used. This software measured several vital signal statistics, including signal strength, amount of noise, and signal-to-noise ratio as shown in Figure 4.

Figure 4
Screen Capture of NetStumbler



The survey team was outfitted with laptops nearly identical to those used by the SFU students, so that the results would not be significantly different from the results the students would experience.

Additionally, one computer on each survey team would perform a "continuous ping" test by establishing and constantly sending network traffic to a computer known to be connected to the campus's hard-wired network. This test verified that network connectivity was established and maintained throughout the testing period. If connectivity dropped because degraded signal strength, the survey team marked their location on a campus map.

***Leaky Cable***

The leaky cable portion of this prototype was undertaken when the SFU Wireless Committee discussed placing wireless access points in the dormitories of SFU. Because the dormitories had been hardwired shortly before the academic buildings on campus went wireless, the university's dormitories had not been converted to wireless. However, the students had been requesting wireless in the dormitories, and the SFU Wireless Committee searched for economical methods of placing wireless within the dormitories.

The SFU Wireless Committee researched Rubytron (http://www.rubytron.com) as a provider of "leaky" 2.4 GHz wireless antennas. These antennas work on the principle of "surface wave" technology. In brief, the idea is to send radio signal down the outside of a cable, rather than the traditional coaxial cable, where the internal metal core is surrounded by an insulator. As the radio signal travels down the antenna (cable), it radiates in all directions. Therefore, a leaky cable acts as a conductor to broadcast a radio signal instead of focusing it in one direction. According to the manufacturer's installation instructions, the radiating wire should have a "virtual tube" with a diameter of 4-inches, void of any metal objects existing in the entire length of the cable.

To research whether or not the leaky cable solution would be a viable method to place wireless coverage in the dorms, two campus dorms which are architecturally similar were selected to act as the test bed. Both dormitories were fairly simple two-story buildings without any angles present. Amici Hall would be outfitted with a leaky cable solution, while Giles Hall would be set up with traditional access points. Once the wireless was turned on in the dorms, surveys would be completed by residents to compare the results of the two methods.

Installation of the leaky cable took place in June of 2004. To prevent student damage and theft, the installation plan included placing the leaky cable above the ceiling tiles in the dormitory. This proved to be a challenging install. Approximately 150 feet of cable was run above the ceiling tile. Additionally, "collector" horn antennas were placed at the two ends of the cable. Unfortunately, the space between the ceiling tile and the actual tile was already crowded with existing cabling, rebar, and conduit, which prevented the 4-inch "virtual tube" from existing as shown in Figure 5.

Figure 5:
Leaky Cable Installation in Crowded Ceiling Space


A method similar to measuring the outdoor signal strength was used. NetStumbler was installed on a survey team's laptop. Once the Proxim Orinoco AP-2500 access point was connected to the cable, the survey team traversed throughout the dormitory measuring signal strength and network connectivity. Attention was paid to the rooms furthest from the physical location of the access point.

## Results of the Research

### *Outdoor Coverage*

After the testing phase had concluded, the results were aggregated into overhead campus maps of the reported signal coverage for each antenna as shown Figures 6 through 10.

Figure 6:
Coverage Pattern of Omni-Directional Antenna on Pasquerilla Library

Figure 7:
Coverage Pattern of Directional Antenna on Pasquerilla Library

Figure 8:
Coverage Pattern of Directional Antenna Facing the Pine Bowl on Schwab Hall

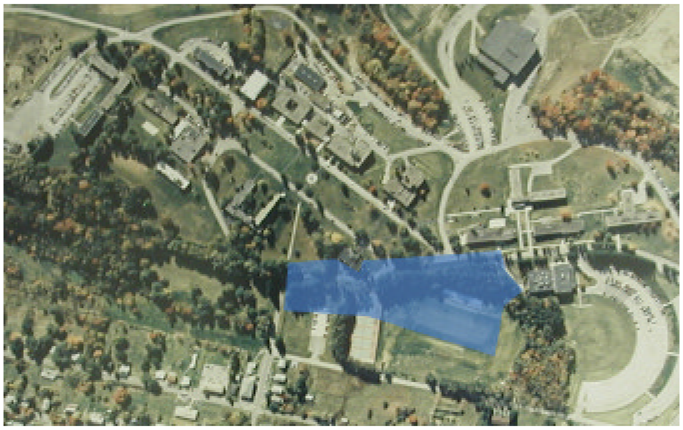


Figure 9:
Coverage Pattern of Directional Antenna Facing the Mall on Schwab Hall

Figure 10:
Coverage Pattern of Directional Antenna on Torvian Dining Hall

Additionally, a composite map was created that shows signal coverage for the entire SFU campus as shown in Figure 11.

Figure11:
Composite Coverage Area of all Antennas

In July of 2004, the SFU Wireless Committee met to evaluate the coverage maps. Coverage was deemed acceptable, however, it was noted that radio signal did not propagate to the two largest parking lots on campus. In the future, these areas may be covered. The SFU Wireless Committee decided to turn on the antennas and begin collecting data.

To collect the data, the access points were configured to direct the users to a brief survey (Figure 12) before being allowed to continue to connect to the Internet. The survey would simply ask the location of the user, when he or she connected to the access point. A list of predefined locations would be presented, with the option of an "other" field, if the location was not shown. This data would provide CERMUSA with usage statistics as well as, specifying whether the users were actually using their computers outdoors or if they were connecting from indoor locations using "bleed-over" signal.

Figure 12:
Outdoor Wireless Location Survey

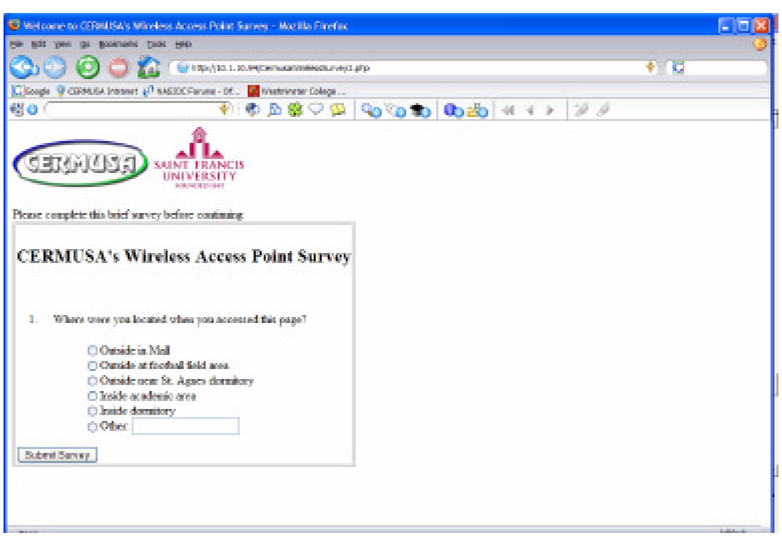
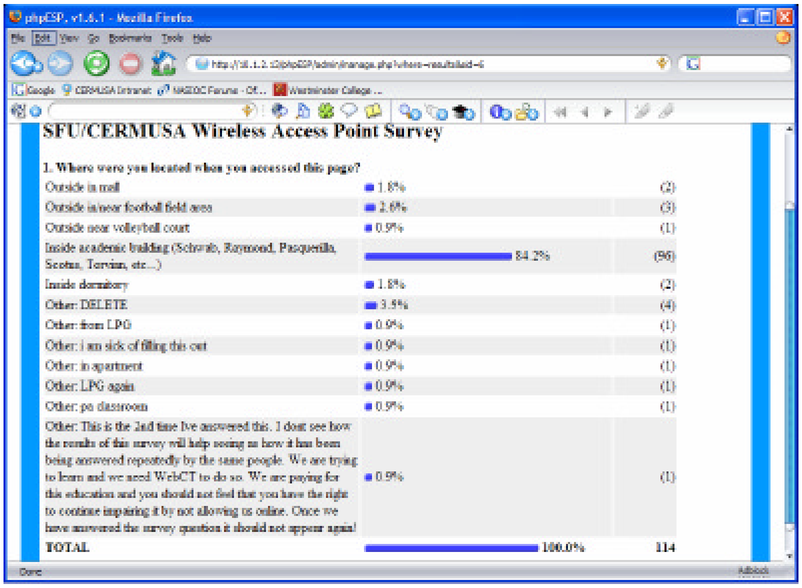


Figure 13:
The Results as of July 14th, 2004




***Leaky Cable***

The leaky cable in Amici Hall, when placed in the space above the ceiling tile and the actual ceiling, performed poorly. The signal dropped significantly the further the survey team traveled from the access point. The network connectivity dropped approximately 100 feet from the source access point. This poor performance was attributed to the fact that four-inch “virtual tube” did not exist down the entire length of the cable.

After viewing the results, the SFU Wireless Committee decided to remove the leaky cable from above the ceiling tile and install it below the tile. Since this installation method left the cable placed in a visible location to be easily tampered with, the installation would not be permanent. After the cable was installed and tested, it would be removed from the dormitory.

This test proved to be much more successful. The leaky cable propagated enough usable signal to cover the entire dormitory. Both the first and second floors of the dormitory received a strong signal. The coverage from the leaky cable as it was hung from the ceiling was adequate for Internet usage. However, during the school year, there would be 120 students in the dormitory. One access point for 120 potential users is taxing the aggregate Internet connection speed. Giles Hall, the dormitory that is the same as Amici in terms of floor layout and number of students, had two access points throughout the dorms tested. Findings were similar in terms of coverage, with the main difference being that only 60 potential students per access point, thus raising the aggregate Internet connection speed. Cost of the leaky cable kit came to $463.50 plus one access point at $540.15 totaling $1003.65. Cost for the two access points, at $540.15 per unit came to $1080.30.

## Conclusions/Discussions/Lessons Learned

Some conclusions that were drawn from this year's research:

- Powered antennas make a difference in signal propagation – When sending the signal through trees and over great distances, amplification of the wireless signal goes a long way to provide a decent signal-to-noise ratio (2:1 and higher) and a higher quality of service than with a non-amplified antenna. They also limit on the number of additional repeater antennas that add costs to implementing a wireless solution.

- Outdoor setups of wireless network need to take into account the factors that are different than indoor wireless networks – Landforms can block a signal and create valleys, as well as degrade the signal. Buildings can block wireless signals and introduce interference. Trees can block the 2.4 GHz RF with their leaves and trunks. Weather can disrupt a signal. All of these factors need to be taken into consideration when setting up an outdoor wireless network.

- Leaky cable shows promise, however is limited in certain arenas – While disappointed with the performance in the dormitory, leaky cable show promise in areas that are open and with regard to cost. Remember that an unobstructed 4-inch "tube" is necessary for the antenna to work. However, if a signal is needed in an area like a hallway or through a tunnel, leaky cable is a reasonable alternative. Considerations need to be taken with regards to the potential number of users that will be using the leaky cable and the associated access point.

- Consideration of the interaction and possible inference of indoor and outdoor wireless networks – If there is a chance that an indoor and an outdoor network will mesh; network administrators need to make sure that there is no harmful interference that can cause one or both networks to fail.

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## References

"CERMUSA Rural Health Annual Progress to the Navy," August 5, 2002 to March 31, 2004. Attachment Q, 802.11b Standard Wireless Campus/Bluetooth.

"WLAN Report: CERMUSA/St. Francis University," Grok Technology Inc. wireless report.

Flickenger, R. (2003). Building wireless community networks, 2nd edition. Sebastopol, CA: O'Reilly and Associates.

Rubytron Installation Instructions, Rubytron, Inc. 2003