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A Study of WiMAX Implementation at University Campuses

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Abstract

The technology of Worldwide Interoperability for Microwave Access (WiMAX) is based on the IEEE 802.16 standard which enables the delivery of last mile wireless broadband access within tens of kilometers. Under a single base station, the coverage is much wider than WLAN and can reach a transmission rate of 70Mbps. In this paper, we study the implementation of WiMAX for university campuses in the Taichung metropolitan area. Feng Chia University is such a university with multiple campuses providing e-services to the university communities. We have integrated WiMAX with existing Wi-Fi and MESH networks in a three-layer configuration. As a result, the system capacity and performance of this cross-campus wireless network have both increased. We have improved the access coverage and quality such that the overall usage of the wireless network at Feng Chia University is also increased.

Keywords: *WiMAX, MESH, Wi-Fi, IEEE 802.16*

1. Introduction

To improve the effective coverage and quality of Wi-Fi network access, we aim to become a Ubiquitous Network Society (UNS). With an environment that can provide any wireless network service at any time and any location, we will be able to perform innovative applications and build a technology society that can meet most people's individual needs.

Based on the IEEE 802.16 standard, WiMAX provides the wireless transmission of data in many ways. The implementation of IEEE 802.16 wireless networks can expand the wireless access coverage and improve the quality of service. It can provide enough bandwidth and a wireless alternative to cable and DSL for "last mile" broadband access. Considered one of the next generation technologies (4G), this ubiquitous wireless network of broadband access will allow more convenient and secure roaming services.

This paper describes the implementation of an IEEE 802.16-2004 network to connect Feng Chia University (FCU) campuses in the city of Taichung, Taiwan. We have also integrated WiMAX with existing Wi-Fi and MASH networks in a three-layer configuration. Therefore, the system capacity and performance of the FCU wireless network are expanded. By improving the access coverage and quality, our goal is to increase the overall usage of the wireless network. Our first-hand experiences with configuring WiMAX equipment and its performance measurement are reported.

2. Related Work

IEEE 802.16 [1][4] series have seven standards: 802.16, 802.16a, 802.16c, 802.16d, 802.16e, 802.16f and 802.16g. Among them, 802.16, 802.16a, and 802.16d do not provide mobility functions while 802.16e does. Currently, 802.16-2004 (Fixed WiMAX) and 802.16e-2005 (Mobile WiMAX) [8-11] are the two major standards used in the market. Based on these, many applications can be developed for the infra-structures of the backhaul portion of the network while fixed, portable, and mobile applications are for client sites. In addition to having more transmission bandwidth than 2G/3G systems, mobile WiMAX also offers more mobility than Wi-Fi. The IEEE 802.16 wireless network can be used as a platform for personal broadband mobile systems to provide triple play services for communication, data, and media.

Wi-Fi [2][3] is defined as any wireless local area network (WLAN) based on the IEEE 802.11n, 802.11a, 802.11b, and 802.11g standards. The term is owned by Wi-Fi Alliance (formerly known as WECA), which is an organization with the mission of certifying all 802.11-based products for interoperability.

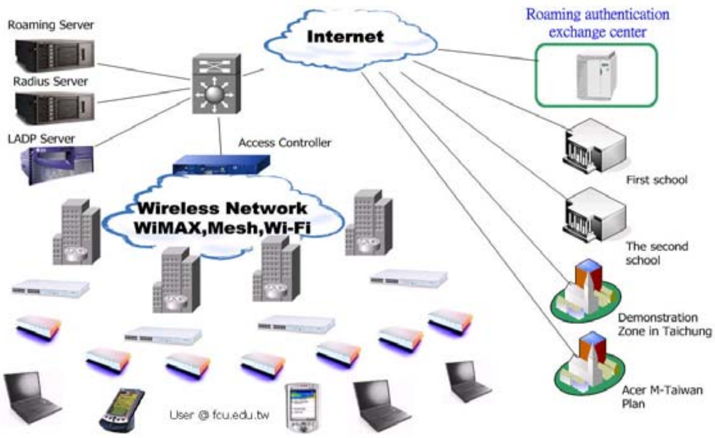

Figure 1. Architecture of the FCU campus wireless network

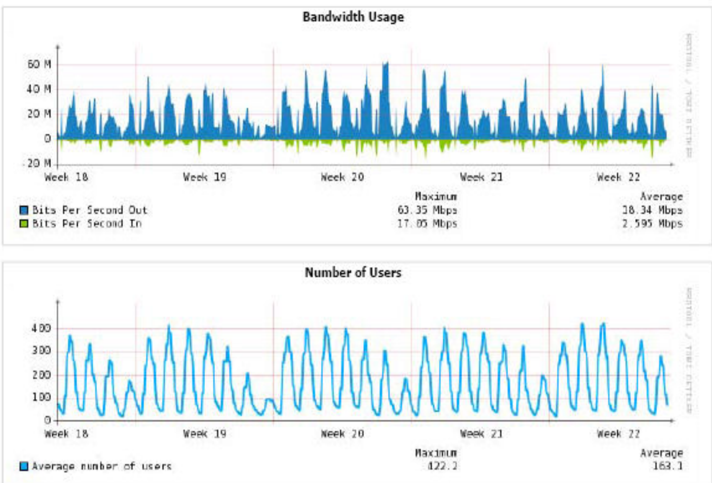

Figure 2. Bandwidth usage and number of network users in a month

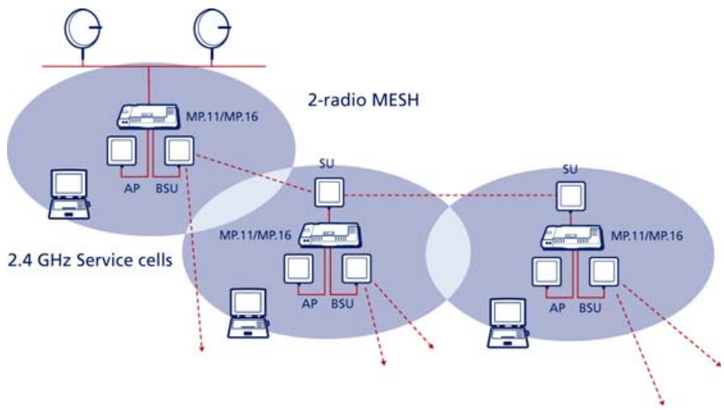

Figure 3. Integration of WiMAX, MESH, and Wi-Fi

Wireless Mesh Network (WMN) is a dynamically self-organized and self-configured wireless network. In this ad hoc network, nodes can establish and maintain mesh connectivity amongst themselves. WMNs offer low up-front costs and easy network maintenance since they can be deployed incrementally, one node at a time, based on the actual need. In addition, WMN provides more robustness and reliable services because each node can operate not only as a host, but also as a router to forward packets. It can extend the network coverage easily and increase usable bandwidth.

3. Implementation

Fig. 1 shows the architecture of the FCU campus wireless network with more than 400 access points. The average number of users logged in the wireless network at the same time is about 423 per day, and the bandwidth usage reaches 63.35Mbps, as shown in Fig. 2. In this project we implemented and integrated WiMAX with the existing MESH and Wi-Fi networks in a three-layer configuration as illustrated in Fig. 3.

Table 1. Experimental environment

Hardware	
Items	qty
Proxim Tsunami MP16 3500 Base Station	1
Proxim Tsunami MP16 3500 Subscriber Station	1
Antenna for WiMAX BS	1
Antenna for WiMAX SS	1
IBM T43 NoteBook	2
Software	
Windows XP	2
IxChariot	1

Currently the cross-campus wireless network covers the main campus (380 APs) and the Fuhsing campus (10 APs), which is located about 1.1 KM away. The university has 23,000 network users where 2,000 of them are faculty members and staff. The main campus has 22 buildings in an area of 50.7 acres, while the Fuhsing campus has seven dormitory buildings in 40.7 acres. Located 5 KM away from the main campus, the Central Taiwan Science Park campus (37 APs are planned in 7 acres) and some of the off-campus dormitory areas will be included in the later phases. Based on this configuration, we perform the experiments on the network traffic. The facilities used in the experimental environment are listed in Table 1.

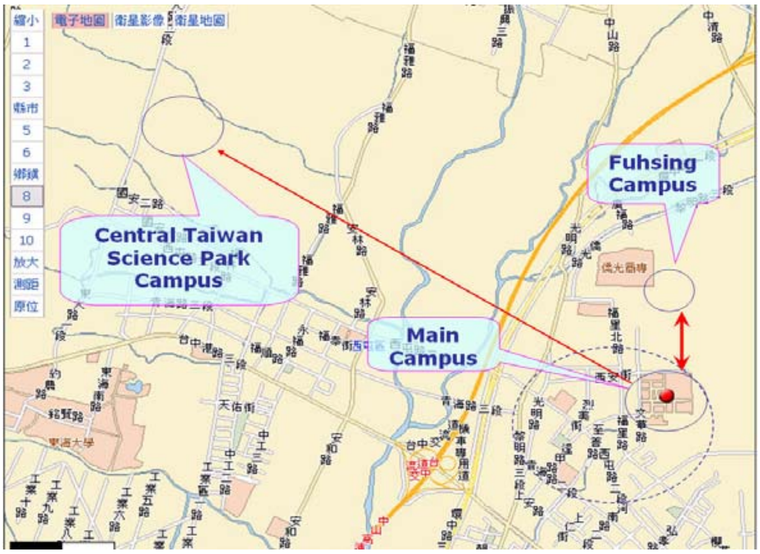

Figure 4. WiMAX coverage map

Fig. 4 depicts the coverage of the FCU cross-campus WiMAX architecture where the main campus and Fuhsing campus are equipped with a Proxim WiMAX Base Station (BS) and a Subscriber Station (SS), respectively [6]. We followed the IEEE 802.16d standard with time division duplex (TDD). TDD has a strong advantage when the asymmetry of the uplink and downlink data speed is variable. As the data volume of the uplink fluctuates, the bandwidth can be dynamically allocated. Our uplink and downlink frequency is between 3400 and 3600 MHz. We used Quadrature Amplitude Modulation (16QAM-1/2) for digital modulation. From Table 2, we should be able to achieve a burst data rate of 5.6 Mbps [6][7].

Table 2. List of 3.5MHz radio performance

Modulation & FEC	Rx Sensitivity (10^{-6})	Minimum C/I	Spectral Efficiency	Burst Data Rate, Tg/Tb = 1/16
BPSK- 1/2	-95 dBm	4.5 dB	0.5 bps/Hz	1.4 Mbps
QPSK- 1/2	-92 dBm	6.6 dB	1 bps/Hz	2.8 Mbps
QPSK- 3/4	-90 dBm	8.9 dB	1.5 bps/Hz	4.2 Mbps
16QAM- 1/2	-87 dBm	11.9 dB	2 bps/Hz	5.6 Mbps
16QAM- 3/4	-84 dBm	15.2 dB	3 bps/Hz	8.5 Mbps
64QAM- 2/3	-80 dBm	19.3 dB	4 bps/Hz	11.3 Mbps
64QAM- 3/4	-78 dBm	21.3 dB	4.5 bps/Hz	12.7 Mbps

To ensure the best positioning of antennas for base stations and subscriber stations, we used Global Positioning System (GPS) to measure the coordinates and orientations. Table 3 lists the location of the actual installations at the main campus and Fuhsing campus. The Central Taiwan Science Park campus will join the cross-campus wireless network in the next phase.

Table 3. Locations of the installed WiMAX facilities

Location	Longitude	Latitude
Main campus	120° 38′ 48.0″	24° 10′ 43.0″
Fuhsing campus	120° 38′ 17.0″	24° 11′ 13.0″

IxChariot [5] was used to test network traffic. It can run tests for the network application layer and predict device and system performance under various load conditions. We ran many tests to measure the network capacity and performance under different applications and parameters. In addition to load tests, we also checked the throughput of the network, time delay, packet loss, and response time to evaluate the overall performance. The results are discussed in the next section.

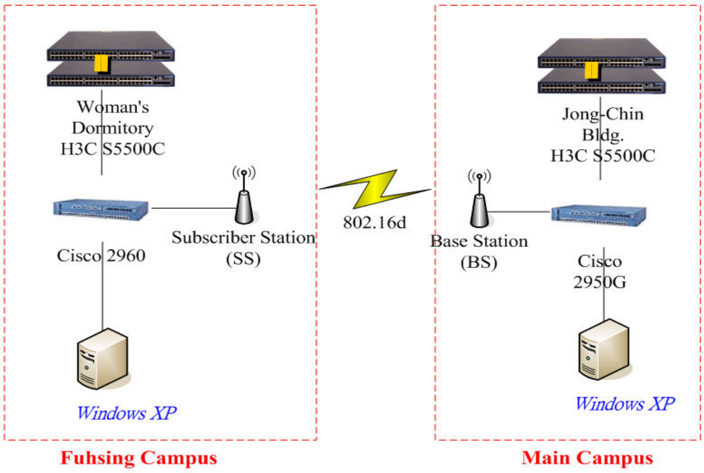

Figure 5. Configuration of the cross-campus WiMAX network

4. Results

Fig. 5 shows the configuration of the cross-campus WiMAX network connecting the main campus and Fuhsing campus. Using IxChariot, the agent software at both sites can perform load/stress testing. To find the bandwidth of the maximum load, we set the file size to 1GBytes and selected 200 test samples. Using eight hours as a testing period, we found the quality of the network data transmission to be very stable with an average bandwidth of 5.6Mbps as expected before testing. Fig. 6 shows the result of the load/stress tests for our cross-campus WiMAX network. The variances of throughput values are very small.

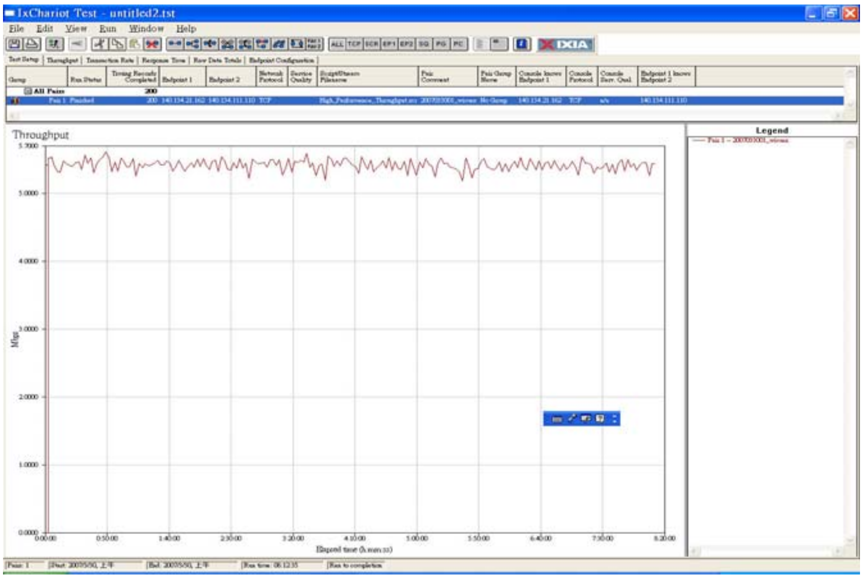

Figure 6. Test result of the cross-campus WiMAX network

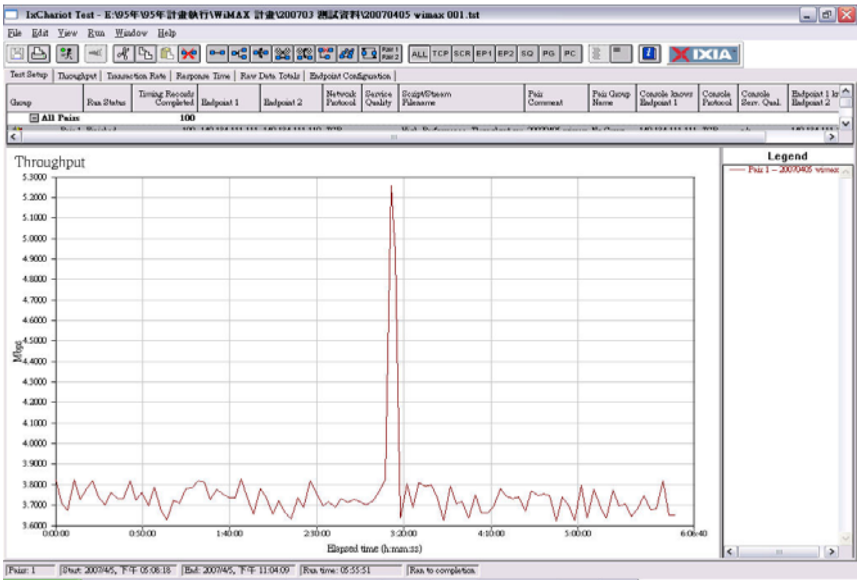

Figure 7. The result of an ill-tuned experiment

During the experiment, we tested different types of antennas, adjusted the location of equipment, and tuned the system parameters accordingly. We found that the most important factor that can affect the quality of reception is the selection of the antenna position. For example, Fig. 7 shows the result of an ill-tuned experiment where the average throughput is only 3.7Mbps with large variances.

To resolve this problem, we varied the height, angle, and orientation of the antenna while following these guidelines:

1. Adjusted the differences in height above sea level.
2. Avoided blockage between two stations to prevent signal path obstruction by large objects or used the NLOS (Non Light of Sight) method to improve the quality of signal reception.
3. Experimented with 120-degree ~ 30-degree antennas. Currently, we are using the 60-degree antenna in the Point-to-Multipoint transmission mode, which will incur a lower cost to expand the access coverage for off-campus dormitory areas in the future.
4. Tested the influence of output power on the transmission distance and the interference by noise.
5. Avoided the high voltage transformer.
6. Made the coverage plan based on radiation patterns.

5. Conclusion

The WiMAX network aims to provide broadband wireless last-mile access in a metropolitan area with easy deployment, high speed data transmission, and a large frequency spectrum and spanning area. Our implementation of the cross-campus WiMAX network expands the coverage of wireless access for a metropolitan university where the network deployment costs are high. The experience of using the IEEE 802.16d technologies to connect two campuses' wireless networks and integrate existing MESH and Wi-Fi networks in a three-layer configuration provides a reference for those who are interested in the research and deployment of WiMAX.

The quality, reliability, and robustness of the wireless access are very important to the success of the WiMAX implementation. These are especially critical concerns for deploying WiMAX regionally in Taiwan due to its subtropical climate. With heavy rains and typhoons, we need to ensure that the radio frequency antenna and WiMAX equipment can work properly and maintain the quality of service of the network. In addition to examining the effects of severe weather conditions, we also plan to study the following issues in the near future: channel allocation, co-channel interference, antenna gain, horizontal and vertical orientation of antenna, and control of output power.

6. Acknowledgements

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