Study of Temple University WiMAX performance

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***Abstract*— Wireless metropolitan area networks (WMANs) based on IEEE 802.16 standard are widely deployed to provide users with wireless network connectivity, anytime, anyplace. In particular IEEE 802.16 standard has been developed to provide fixed broadband applications at lower costs for installation as compared with traditional wired infrastructures. Fixed WiMAX has used to support fixed and nomadic applications. WiMAX technology is deployed in general in large area public venues like airport, university, communities and offices.**

In this paper we present active measurement results from Temple University WiMAX-based network (TU-WiMAX), with primary focus on link performance. Since the deployment of TU-WiMAX, no paper has been published concerning its performance. We measure three links performance, namely receive signal strength indicator (RSSI), carrier to interference plus noise ratio (CINR), and bandwidth on different locations at Temple University Main campus. After depicting these measurement values, we analyze and provide estimation of the actual system rate, and we present an approach to predict the future state of link quality.

***Keywords*- RSSI; CINR; bandwidth; WiMAX**

I. INTRODUCTION

Wireless Internet access is an essential requirement for today's tech-savvy users, including students, professors, researchers, and business users. However, users often have to make the choice between fixed high-speed local accesses. There is a strong desire to bridge this gap and offer high-speed internet access, with performance comparable to wired broadband. One promising technology is based on the IEEE 802.16 family of standards, commonly referred to as WiMAX (Worldwide Interoperability for Microwave Access). While WiMAX is commonly viewed as a metropolitan-area technology (WMAN), it can offer a service range of up to 50 km and transmit data rate up to 100 Mbps under ideal conditions. In the typical operation mode the WiMAX system consists of two parts: a WiMAX base station and a WiMAX receiver.

The purpose of our study is to investigate the link performance of Temple University WiMAX-based networks, and to assess their potential impact on Temple University and city of Philadelphia surveillance for law enforcement. To the best of our knowledge, this is one of the first detailed studies of link performance of TU-WiMAX network.

The rest of the paper is organized as follows. Section 2 provides background on WiMAX. Experimental methodology is discussed in Section

3. Section 4 presents the measurement results and analysis. Prediction mechanism is discussed in section 5 and Conclusion is given in 6.

II. BACKGROUNG

Jperf is a network tool measuring maximum TCP and UDP bandwidth, delay, jitter, latency and datagram loss. Kannon is a platform that provides solution for WiMAX links monitoring including Receive Signal strength indicator, carrier to inference plus noise ratio, frequency, and transmission power.

Our experiment is limited only for the measurement of CINR, RSSI, and bandwidth. Typically RSSI is a measure of dBm, which is ten times the logarithm of the ratio of the power (P) at the receiving end and the reference power [2], CINR is a measure of dB and bandwidth in Mbps. The document explains methods to depict the values of CINR and RSSI but it does not explain the method to estimate the bandwidth due to unstable internet connection. Thus, we provide a convenient and accurate method to predict the CINR which is considered to be link quality.

III. EXPERIMENTAL METHODOLOGY

TU-WiMAX Base Station antenna is positioned on the most visible building (Wachman Hall) of Temple University. We conducted both on campus and out off campus measurement. The measurement equipment consisted of one IEEE 801.16-2004 Base Station, two laptops (one running windows 7 and other running vista), Jperf tool to measure the bandwidth, Kannon tool to measure RSSI and CINR, and Alvarion USB dongle to receive signal from base station. On campus measurements are collected inside different Temple University buildings including Wachman Hall, Alter Hall, Tutleman Center, and Tech Center. We conducted also mobile experiment nearby these buildings. Out off campus measurements are collected by driving around Temple University shown in Fig.1 and Fig. 2

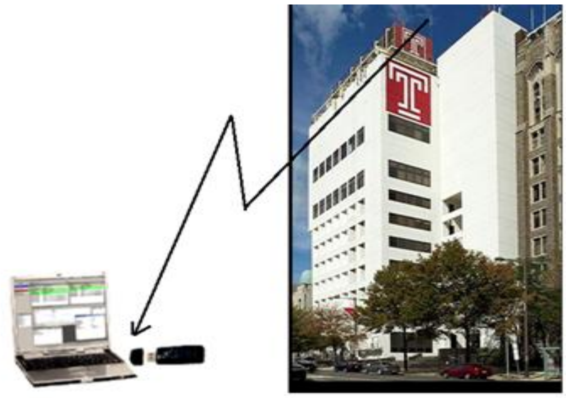

Figure 1: WiMAX System Setup

IV. MEASUREMENT RESULTS AND ANLALYSIS

When we took each measurement, we recorded the values in an excel spreadsheet. Afterwards we created graphs for each location. Each graph shows the values of RSSI, CINR, and Bandwidth in function of time usually in second. These graphs shown in Fig. 2, Fig. 3, fig. 5, and Fig.5 are the results of the experiments conducted on campus.

In Alter Hall only a few feet from the base station, RSSI range between -60 and -70 decibels and CNIR vary between 20 and 25 decibels as shown on Fig. 3 and Fig 4. Fig 2 shows clearly that the average bandwidth of TU-WiMAX is 800 Kbits per second on campus. The data rate varies on different location on campus, but is closely equal to the above rate. Fig 5 shows that the signal quality is better when the signal strength increases.

A signal map is shown in Fig. 6 where signal level distribution is depicted. Temple University base station is directional antenna facing south from Wachman Hall. The antenna radiates signal up to 3.7 km in main lobe and up to 2.57 km in the side lobes. As expected, excellent signal level is seen at areas close to the base station. It is also observed that some areas though close to base station experience shadowing leading to low signal level. This can be attributed to the building in the neighborhood of the base station. For example, on the eastern side of the base station signal level ranges between -60 and – 50 decibels; however, due many temple university buildings signal strength drops between -70 to -80 dBm on 12th street between Montgomery and Norris. So obstructions

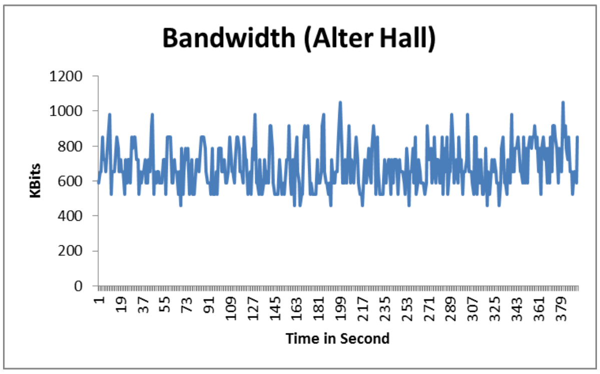

Figure 2: Bandwidth measurement inside Alter Hall

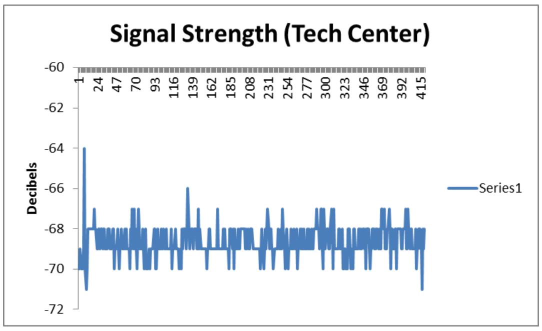

Figure 3: RSSI measurement inside Tech Center

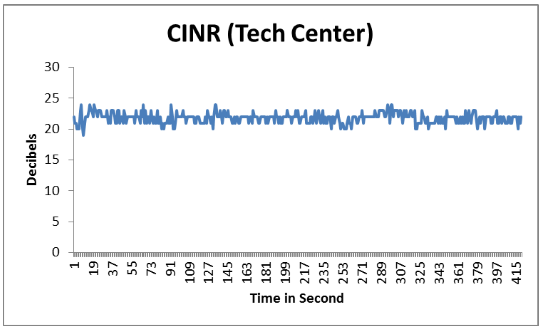

Figure 4: CINR measurement inside Tech Center

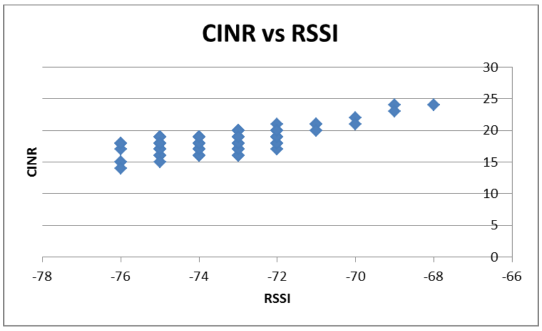

Figure 5: CINR versus RSSI

like trees and buildings between the base station and receiver have some impact on the signal propagation which can cause path loss. Another factor that affects the level of signal strength is the propagation path distance between transmitter and receiver. TU-WiMAX base station propagates signal from Temple campus to center city around Market Street. Signal level at Market Street becomes erratic and weaker (ranging between -90 and -80 dBm) due the distance between the base station and the receiver.

Link quality map is shown on Fig. 6. The significance of this data is to demonstrate the impact of interference dynamics when analyzing the performance of the network. It is observed that signal quality is quite good for distance with 2.7 m from the BS. One thing that should be noted from these results is that the received signal strength indicator (RSSI) alone is not enough to represent the network performance.

It is observed that CINR between 10 and 20 decibels is obtained for RSSI between -60 and -70 dBm and the same signal quality is obtained for low signal strength ranging between -90 and -100 dBm. The explanation is that RSSI does not directly take the interference situation into account. Therefore, RSSI may be very good but the interference could also be very high to produce a low effective link quality (CINR). It is known that CINR ultimately determines the achievable performance of network.

Table 1 and Table 2 shown below are the data from multiple experiments distance versus RSSI and distance versus CINR. Just as predicted, distance and RSSI show a high correlation such that the RSSI value decreases with increase in distance. However, the relationship between CINR and distance is not the same as signal quality and distance. As the table shown, CINR does not necessary depend on distance like RSSI which indicates a low correlation between link quality and distance. For example we obtained the same value

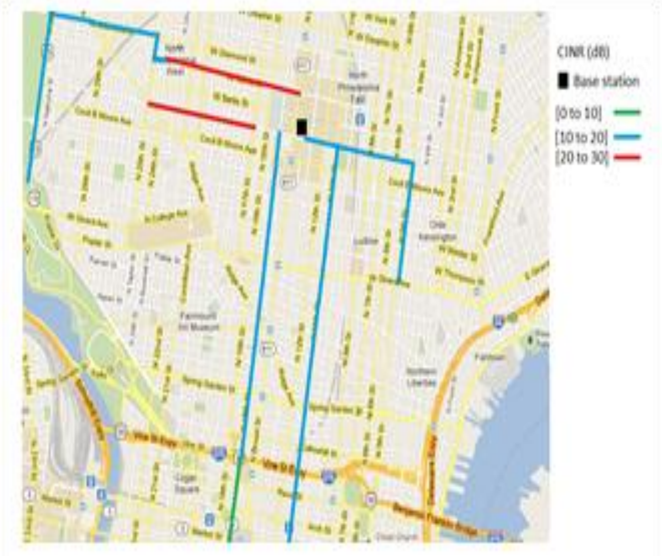

Figure 6: Map of depicted CINR around Temple University

of CINR (15 dB) at two different locations 0.96 km and 2.89 km from the base station following the main lobe.

Distance(km)	RSSI(dbm)	CINR (dB)
0.96	-55	15
1.29	-65	14
2.09	-75	16
2.89	-85	15

Table 1: Correlation CINR and RSSI in function of distance following main lobe of antenna

Distance(km)	RSSI(dbm)	CINR (dB)
1.3	-45	25
1.6	-65	25
2.09	-75	16
2.73	-95	16

Table 2: Correlation CINR and RSSI in function of distance following side lobes of antenna**.**

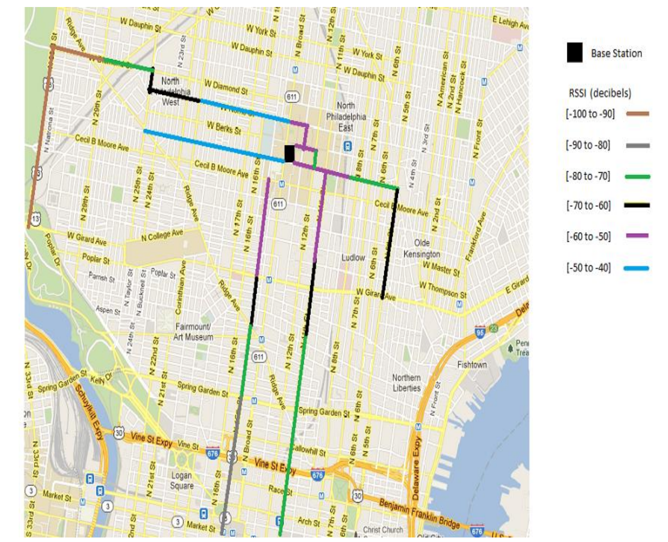

Figure 7: Map of depicted RSSI around Temple University

V. PREDICTION OF LINK QUALITY

The main purpose of this section is to predict the link quality according to the past and the present status of the signal. We focus on the Carrier to interference plus Noise Ratio (CINR) measurements to predict the future state of a link. We have chosen to use the CINR value as a measure of link quality because the CINR not only takes into account the signal strength, but also the amount of noise and interference in the signal. Carrier-to-interference-ratio (CIR), carrier-to-interference-plus-noise-ratio (CINR), signal-to-interference-ratio (SIR), signal-to-noise-ratio (SNR), and signal-to-interference-plus-noise-ratio (SINR) are the most common ways of measuring the channel quality during (or just after) the demodulation of the received signal.

The Signal to Noise Ratio (SNR) is generally defined as

$$SNR = 10 * \log \left(\frac{P\ signal}{P\ noise}\right) \qquad (1)$$

where P signal is the power level of the signal and P noise is the power level of noise. The signal power is influenced by several parameters of the communication system [1]. At the sender, it depends on the transmission power of the sending device and the antenna gain. Both CINR and SNR provide information on how strong the desired signal is compared to the interferer (or noise, or interference plus noise).

V.1 Prediction Technique

Autocorrelation is the cross-correlation of a signal with itself. It can be exploited for predictions: an autocorrelated time series is predictable, probabilistically, because future values depend on current and past values. Autocorrelation refers to the correlation of a time series with its own past and future values. The definition of the autocorrelation between times *s* and *t* is

$$R(s, t) = \frac{E[(X_t - U_t)(X_s - U_s)]}{V_t * V_s} \qquad (2)$$

Where R is correlation coefficient and E is the expected value. Xi, Ui, and Vi are respectively the random process, mean value and variance at time i. R ranges between -1 and 1. When R is 1 then the quality of the signal at time t and s is 100 percent the same which indicates perfect correlation between both signals; however, signal quality get more and more different over the time when R is getting smaller until it reaches -1. In this case, the similarity between signal at time t and s is called anti- correlation.

As an example, the autocorrelation cofficient of Carrier to interference plus Noise ratio is shown on Fig. 8. The correlation coefficient is 0.9 at t equal 1 and decreases until time equal 17 seconds and reaches the minimum correaltion of 0.2. As an explanation of this graph at t equal one both signals are 90 percent of similarity, but as time goes on there is a huge different between both signals. For example at time equals 17 second there is only 20 percent of similarity between them.

V.2 Prediction via Autocorrelation Function.

In this section, we present our prediction mechanism which implements link quality prediction based on pattern observed on the autocorrelation function. Use of autocorrelation function has the advantage of providing a method to predict the near future state of link quality. Figure 9 shows the prediction of CINR in short term. The graph in blue is the current evolution of CINR for seventeen seconds. The dotted read graph is the estimation of the current values of CINR base of the autocorrelation function. Based on our estimation of the current values of the Carrier to interference plus noise ratio we predict its value, shown in color gray on figure 9.

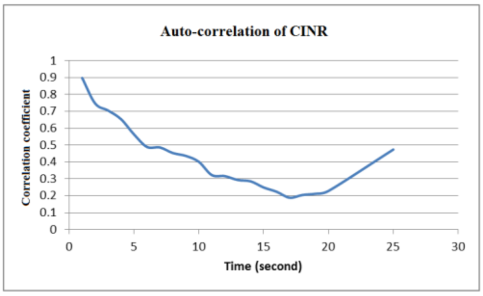

Figure 8: Auto-correlation of CINR

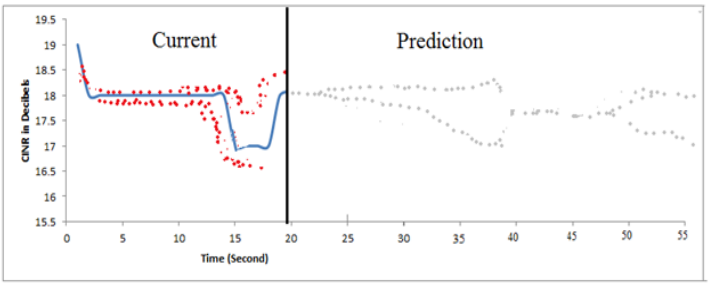

Figure 9: prediction of CINR

VI. CONCLUSION

This paper presented an empirical measurement and analysis of the RSSI, CINR and bandwidth of Temple University WiMAX based networks. Experimental results were conducted in a number of settings, both indoors and outdoors of main campus. At various locations link quality and signal quality were measured in urban areas of Temple University and near Center city of Philadelphia. Also we proposed an accurate prediction mechanism for TU-WiMAX link quality. The prediction mechanism is based on autocorrelation model of smoothed past and current measurements of the Carrier to interference plus Noise Ratio. Our method can predict at short ranges (up to 20 seconds).

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