XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6-11, 2009, Lisbon, Portugal

AVAILABLE MEASUREMENTS IN CURRENT WiMAX NETWORKS AND POSITIONING OPPORTUNITIES

Mussa Bshara and *Leo Van Biesen*

Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium
Tel: +32 (0)2 629.29.46, Fax: +32 (0)2 629.28.50
Email: {mbshara,lvbiesen}@vub.ac.be

Abstract – In this paper, we consider the practical issues related to positioning in WiMAX networks depending on the available measurements. The network under study is the Clearwire network deployed in Brussels capitol city. The focus lies on making the available terminal-based measurements, study the possibility of using these measurements in positioning and provide a comparison between these measurements depending on the accuracy achieved and the difficulty to obtain them.

Keywords: Received Signal Strength, SCORE, WiMAX.

1 Introduction

Positioning in wireless networks depending on the network resources has gained a lot of attention lately, especially after some of the most interesting positioning application areas have emerged in wireless communications. The most important are the *Federal Communications Commission* (FCC) and *the European Recommendation E112*, both of which require that wireless providers should be able to locate within tens of meters users of emergency calls. There are several types of measurements can be made on a wireless network to obtain localization. Some of these measurements are hard to obtain like the time of arrival (TOA) which needs synchronization, and some are easy to obtained like the received signal strength (RSS) or RSS-based measurements and Cell-ID. Adding new hardware to the base stations to obtain accurate localization (for example using array antennas or adding localization measurement unit (LMU) to each base station (BS)) is possible, but this option suffers from the high roll-out cost. The measurements can be made in the network itself (network side), in the user terminal (terminal side) or in both. From now on we will refer to these measurements as network measurements regardless where these measurements have been conducted, and the considered measurements in this study are the terminal side measurements.

In this paper, we consider the problem of localization in WiMAX networks depending on the available terminal-based measurements. Measurements like timing adjust (TA) are not considered because they are not supported (yet) by the deployed network. However, mobile WiMAX is an emerging technology which expected to be widely adopted in the up-coming years, and this kind of measurements will be available. The focus now on RSS and RSS-based measurements in addition to Cell-ID and angle of arrival (AOA) measurements [2].

2 Network structure and technical information

The network in the area under study consists of six sites as is shown in figure 1; the sites from number 1 until 4 (the yellow ones) have been received in the “measurement area” (shown as blue roads), i.e. the data which has been measured in this area is generated by those 4 sites. The site number 5 (the green one) has been used to conduct RSS and received signal strength index (RSSI) measurements to develop path loss models dedicated for localization purposes. The signals which has been originated from site number 6 (the red one), could only be received in a few points in the measurement area, so they have been neglected and this site was not used.

Every site contains a number of base stations, but only the contributing ones were considered. A contributing BS means a considerable number of measurements were originated from this BS. The number of base stations and the considered ones for each site are shown in table 1, and the base stations technical specifications are summarized in table 2. Note that the used bandwidth in the current Pre-WiMAX is 7 MHz [1].

The measurement area reflects the typical environment of Brussels (except the center where high building could be found including high glass ones). The buildings are 3 to 7 floors height, some houses are also could be

Table 1: The available BS numbers and the considered ones

Site No.	Number of available BSs	Considered BSs
1	4	BS1, BS2
2	4	BS3, BS4,BS5
3	3	BS6,BS7
4	4	BS8
5	3	BS9
6	3	—

Table 2: Base stations technical specifications

BS	Az.(°	Chan. No.	TX power (w)	Open. angle Ver. (°)	Open. angle Hor. (°)	Gain (dBi)
1	155	12	2	7	60	17.3
2	245	7	2	7	60	17.3
3	0	6	2	7	90	15.2
4	90	14	2	7	90	15.2
5	270	12	2	7	90	15.2
6	0	7	2	7	60	14.3
7	270	13	2	7	60	14.3
8	180	13	2	7	90	15.2
9	240	5	2	7	60	17.3

found beside the buildings. The area is not at the same level but it varies between relatively high and low land. Trees could be found almost everywhere. The *Woluwe* park is a low land plenty of trees and water, and this might explains why the site4 (BS8) could be received in the measurement area. The average distance between the sites is about 1000 m (between 900 and 1200 m), this distance depends on the nature of the area (low land, high land, number of buildings, high or low buildings, the green areas . . . etc) and the inhabitants density, but the value of 1000 m is considered to be the average distance between the sites in Brussels.

3 Measurement campaigns

In this section, we describe all the different measurement campaigns and measurement setups which have been used to conduct measurements on the pre-WiMAX network deployed in Brussels. The measured quantities are: the received signal strength (RSS), the received signal strength index (RSSI), the SCORE , the base station identifier (BSID) or the Cell-ID and the angle of arrival (AOA).

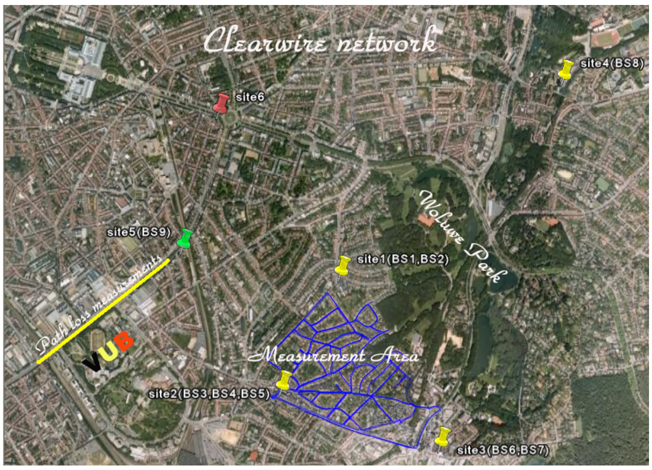


Figure 1: The network structure in the area under study

3.0.1 Received Signal Strength (RSS) measurements

The RSS measurements have been conducted using the "Anritsu MT8222A BTS" [3], which is a powerful base station analyzer supports more than one wireless standard including WiMAX. It offers a full analysis of all the received signal parameters including the RSS values measured in dBm. To study the possibility of using RSS values in localization, RSS measurements have been collected along with the exact location of the measurement points. The exact location of the measurement points were provided by the analyzer's built-in high accuracy GPS receiver. The analyzer was guided by a portable computer armed with suitable programs. The two small size antennas mentioned in the connection diagram (the WiMAX Omni-directional antenna and the GPS antenna) were easily mounted on a top of a vehicle using their magnetic bases. The measurement setup is shown in figure 2.The collected data was saved on the hard disk of the computer for later processing.

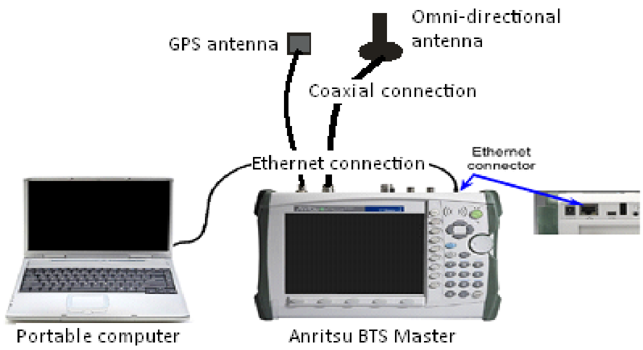


Figure 2: The "RSS" measurement setup using Anritsu spectrum analyzer

3.0.2 Received Signal Strength Index (RSSI measurements)

The RSSI measurements have been conducted using a special modem dedicated for measurements offered by Clearwire. This modem can measure RSSI values using a special software developed for this purpose (a software model has to be uploaded to the modem). The connection diagram is shown in figure 3, and the modem is shown in figure 4.

3.0.3 SCORE measurements

The SCORE values are used by the standard WiMAX modems to evaluate the connection quality between the

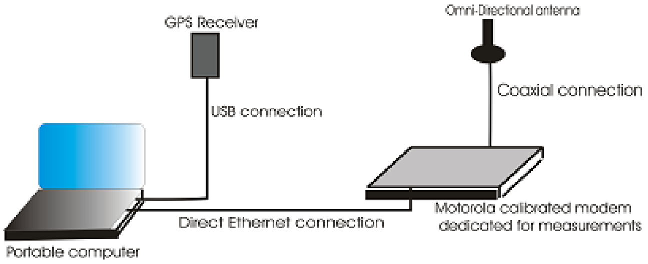


Figure 3: The "RSSI" measurement setup using Motorola modem

Figure 4: The used modem to measure RSSI, with the used Omni-directional antenna

subscriber station (SS) and the available BSs. The advantage of using the SCORE values is the possibility to obtain them for all the available BSs simultaneously and without adding any extra software or hardware. But the disadvantage lies in their low accuracy comparing to RSS values. A standard WiMAX modem was used to conduct SCORE measurements after replacing its directional antenna with an Omi-directional antenna as shown in figure 5; and the measurement setup is shown in figure 6. The measurement's exact location was obtained by using a GPS receiver which has been connected to the computer using the blue tooth port. The acquisition programs are written in MATLAB® and the obtained values were saved for later processing.

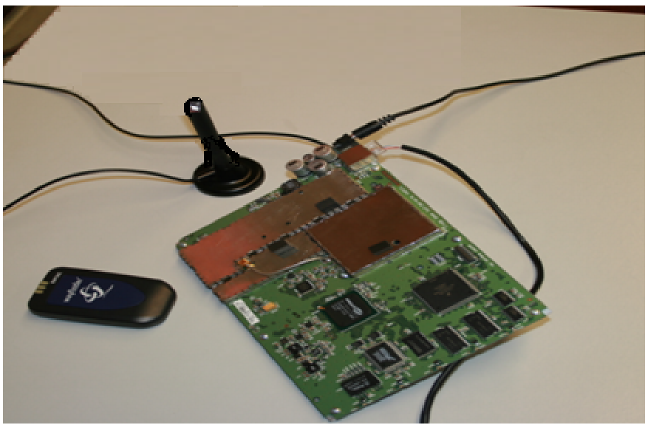


Figure 5: The used standard modem to measure SCORE values. The Omni-directional antenna and the GPS receiver are also shown

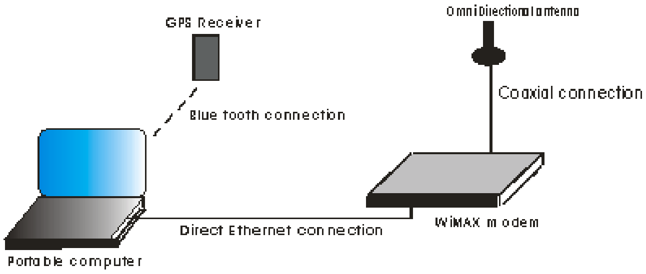


Figure 6: The SCORE measurement setup

3.0.4 Base Station Identifier BSID measurements:

This concept is the same as Cell-ID in GSM networks. The position of a terminal can be determined depending on the serving base station coordinates. This value can be obtained -by the terminal- by obtaining the serving base station MAC address which is broadcasted over the control channel. The same setup used to measure the SCORE values can be used to measure the BSID for all the available base stations in the area under study.

The BSID values were collected simultaneously with the SCORE and RSSI values.

3.0.5 Base Station Identifier BSID measurements

This concept is the same as Cell-ID in GSM networks. The position of a terminal can be determined depending on the serving base station coordinates. This value can be obtained -by the terminal- by obtaining the serving base station MAC address which is broadcasted over the control channel. The same setup used to measure the SCORE values can be used to measure the BSID for all the available base stations in the area under study.

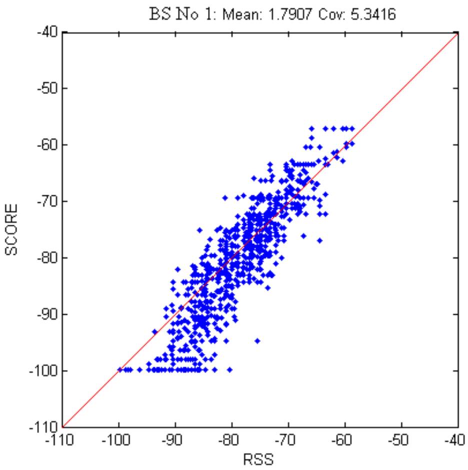
The BSID values were collected simultaneously with the SCORE and RSSI values.

3.0.6 Angle of Arrival (AOA) measurements:

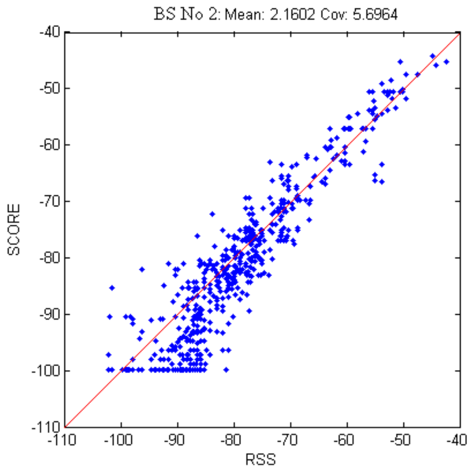
WiMAX uses directional antennas which allow the determination of the azimuth of a terminal seen by a certain base station. The current antennas used in Pre-WiMAX network in Brussels provide this information as sectors (60 , 90 and 120 degrees). WiMAX networks started to use advanced antenna arrays where *beamforming* allows rotating narrow beams. The narrow antenna patterns will increase the accuracy of the measured terminal azimuth.

4 Measurements evaluation from positioning point of view

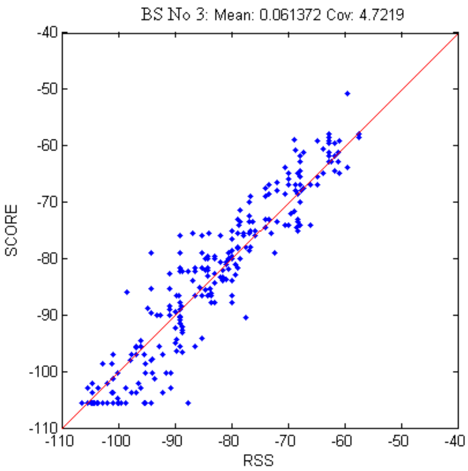
It is known that the received power depends on the distance between the transmitter and the receiver. *Okumura-Hata* model depicts this relation for the frequency range between 150 and 1500 MHz (OH model is based on measurements made in and around Tokyo in



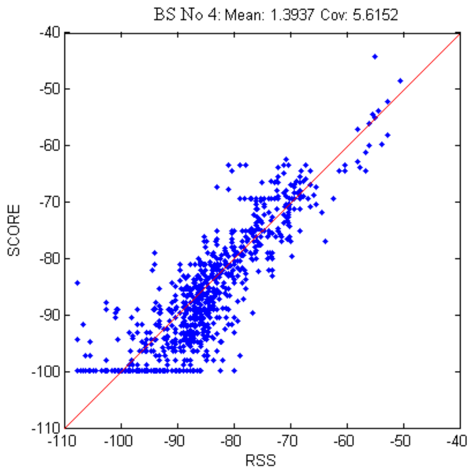
(a) Antenna 1



(b) Antenna 2

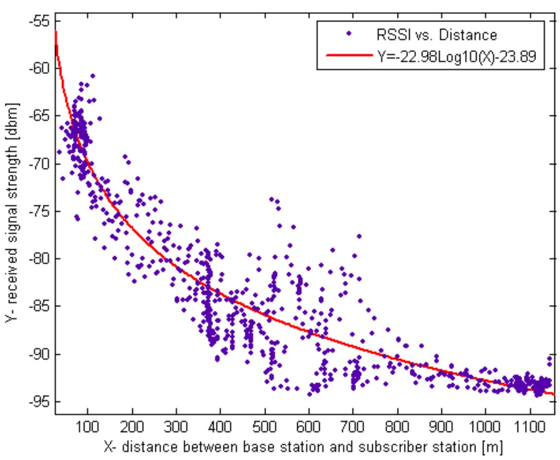


(c) Antenna 3

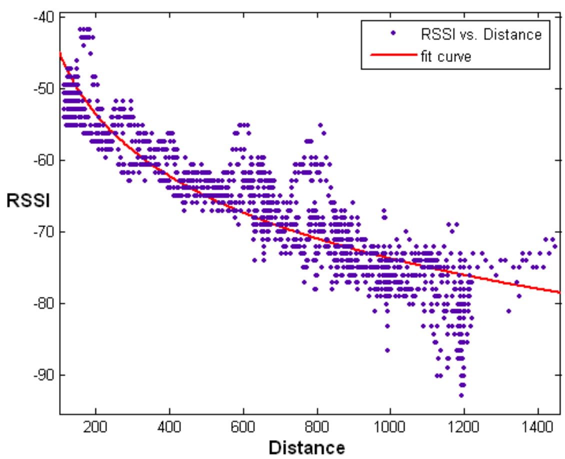


(d) Antenna 4

Figure 7: The correlation between the measured SCORE and RSS values



(a) RSS Vs Distance



(b) RSSI Vs Distance

Figure 8: The relation between the received power and the distance to the serving BS. Note the multipath high components near the high glass building (distance 600-700 m)

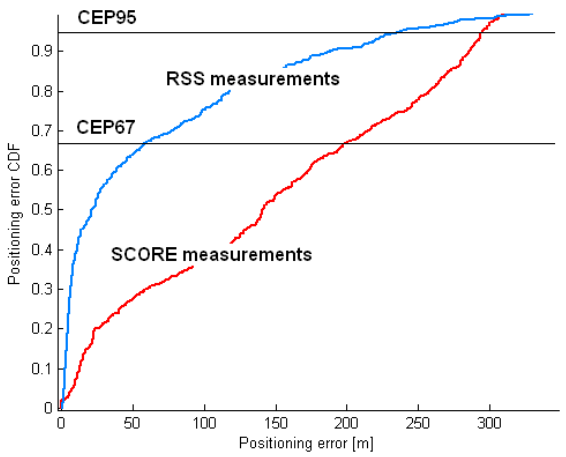


Figure 9: The positioning error CDF, using RSS and SCORE measurements

1968) [8, 6]. This relation has been exploited in localization by estimating the target's range to known BSs depending on RSS measurements and a path loss model for the considered environment. It is very important to have an accurate path loss model to obtain accurate range estimations. Figure 8 shows two path loss models; one developed using RSS measurements and the second one is obtained from RSSI measurements. It is clear that in both cases the received power depends on the distance and can be used to estimate the distance to the serving BS. But the RSS measurements (collected by Anritsu analyzer) are more accurate and there is a better matching between the measurements and the obtained model (the r-squared value is 0.8958 and the root mean square error (RMSE) is 3.061; and for the RSSI model the r-squared value is 0.8061 and the (RMSE) is 4.385). Indeed, the two types of measurements can be used for localization with reasonable positioning accuracy [5, 4]. But using Anritsu analyzer in applications is not possible (high price, heavy, measures one frequency (channel) at a time), and also the used measurement modem is capable of measuring only one channel, so it can't be used in applications too. The current standard modems need -at least- software upgrading in order to be able to measure RSSI values and for all the channels simultaneously. Until then, the only available option is to use the SCORE values, we know that the SCORE values are related to RSS, but how much they are related (correlated)?. in order to answer this question a large number of measurements were collected in the measurement are shown in figure 1, and the relation between the measured SCORE and RSS values is studied by computing the average error and the covariance between the two quantities. Figure 7 shows good correlation between SCORE and RSS values which means that using SCORE values instead of RSS values is possible, but lower positioning accuracy is expected as shown in figure 9. Figure 9 depicts the positioning error cumulative distribution function (CDF) in rwo cases: the case of using RSS measurements to position a user and the case of using SCORE measurements to position the same user (the same trajectory has been used)[7][9].

Using the AOA in WiMAX networks is possible in the same way as in GSM networks. In addition WiMAX networks started to use advanced antenna arrays. Also using BSID is expected to provide better accuracy than the Cell-ID in GSM networks, because the used cells in WiMAX networks are much smaller than in GSM networks.

5 Conclusion

The available measurements using the current WiMAX networks provide enough information to obtain localization with sufficient accuracy for most of location based services (LBS). However, the practical implementation of a localization system have to depend on the current modems that can provide BSID information, AOA as a rough estimation (sectors) and SCORE values. The provided example showed acceptable performance when using the SCORE values taking into consideration that the provided localization is for static user and no motion model information has been used. Using the motion model information will increase the localization accuracy. Using BSID and AOA information is expected to provide better (or the same in worst case) accuracy than in GSM networks (smaller sectors).

References

[1] Bipt belgian institute for postal services and telecommunications website.

[2] Jeffrey G. Andrews, Arunabha Ghosh, and Rias Muhamed. *Fundamentals Of WiMAX: Understanding Broadband Wireless Networking*. Prentice Hall, Upper Saddle River, NJ, USA, 2007.

[3] Anritsu. *Anritsu Bts Master MT8222A Application Note*, 2006.

[4] S. Gezici, Z. Tian, B. Giannakis, H. Kobayashi, and A. Molisch. Localization via ultra-wideband radios. 22:70–84, 2005.

[5] Fredrik Gustafsson and Fredrik Gunnarsson. Possibilities and fundamental limitations of positioning using wireless communication networks measurements. 22:41–53, 2005.

[6] M. Hata. Empirical formula for propagation loss in land mobile radio services. 29(3):317–325, August 1980.

[7] Mahdy Nabaee, Ali Pooyafard, and Ali Olfat. Enhanced object tracking with received signal strength using Kalman filter in sensor networks. *Internatioal Symposium on Telecommunications*, pages 318–323, 2008.

[8] Y. Okumura, E. Ohmori, T. Kawano, and K. Fukuda. Field strength and its variability in VHF and UHF land-mobile radio service. *Rev. Elec. Commun. Lab.*, 16:9–10, 1968.

[9] Junichi Shirahama and Tomoaki Ohtsuki. RSS-based localization in environments with different path loss exponent for each link. *Vehicular Technology Conference*, pages 1509–1513, 2008.