Chapter 1
Analysis of Propagation Models, Delay, and Throughput for WiMAX in Urban Environments

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ABSTRACT
This chapter presents a theoretical and experimental analysis of the electromagnetic signal propagation between a base station and a subscriber station in an urban setting using the IEEE 802.16d standard and test bed results, which are then compared to Ergog’s (1998) modified version of the Hata-Okumura (1980) mathematical propagation model. The experimental results of the measurements are similar to the model using the type terrain Category B (Suburban). Additionally, under experimental conditions, equipment with technology IEEE 802.16d and IEEE 802.16e were used to analyze delay and throughput while data, voice, and video was transmitted. The tests show that delay is acceptable for Fixed WiMAX, although it is barely adequate for Mobile WiMAX. As far as throughput is concerned, the average rate is adequate to support applications that include data, voice, and video.

INTRODUCTION
The demand for connectivity and bandwidth have increased, meaning that present physical connections and fixed workstations no longer satisfy the needs of a new generation of users whose online interactions require ever-growing resources. With the rise of wireless technologies, different technologies have been developed to provide connectivity solutions. At a local level, WiFi technology described in the 802.11 standard is preferred because of its characteristics of...
mobility, bandwidth, and low cost compared to similar technologies. Because WiFi only provides connectivity in a very localized area, WiMAX technology was created to serve larger areas requiring connectivity.

WiMAX is the name by which the new IEEE 802.16 standard is known. It is presented as an alternative and/or extension to other wide band technologies such as ADSL (Asymmetric Digital Subscriber Line), Cable Modem, 2.5 and 3G. It was created to provide voice services and broadband wireless data and enables rapid deployment of telecommunications networks in areas where there is no an adequate physical infrastructure (Etemad & Lai, 2011).

There are currently three different WiMAX systems:

- Fixed (IEEE 802.16-2004).
- Mobile (IEEE 802.16e-2005).
- Mesh (IEEE 802.16-Mesh).

Fixed WiMAX systems have a coverage area of 3.5-7 km. This standard determines the fixed line connections between a base station and one or more subscriber stations, and works through point-to-multipoint links (Zhang & Chen, 2007).

Mobile WiMAX is a broadband wireless access technology which allows the connection of mobile subscriber stations that are found in a wider area coverage than that of the base station (Jau-Yang & Yu-Chen, 2012), which can handle mobile telephone services via IP service or high speed mobile services.

Furthermore, in the Mesh WiMAX mode, the base station provides connections to one or more subscriber stations, although they are not directly connected to the base station. In this scheme, the network base or subscribers are called nodes. The connection between the nodes is measured by the number of hops and the way in which any two nodes maintain a connection. A subscriber node maintains the connection with its parent node at a distance of one hop, both sending and receiving information. This subscriber node can, in turn, become a parent node for other nodes, thus extending the network range (Algamali, Jianxin, & Alhamidi, 2009).

The different WiMAX systems allow network designers to choose the best solution to satisfy the needs of each customer. Some common scenarios using WiMAX networks include:

- Residential Market.
- SOHO Networks.
- Wireless backhaul islands.
- Telecommunications Services on SME (Small and Medium Enterprises).
- Personal Mobile Access.
- Private Networks.

Although WiMAX systems allow connectivity over larger areas, link reliability depends on the characteristics of the devices and the type of area in which they are used. This chapter discusses the versions of fixed WiMAX and mobile WiMAX in an urban setting. Table 1 lists the key features of both IEEE 802.16d and IEEE 802.16e standards. It highlights a data rate of 75 Mbps and a coverage range up to 50 km maximum for a fixed WiMAX system and an 8 km maximum range for a mobile WiMAX system (Rangel Licea, 2009).

Additionally, this paper describes the propagation models applicable to fixed WiMAX for urban environments. It also describes the tests conducted under experimental conditions for both IEEE 802.16d and IEEE 802.16e standards. Furthermore, this chapter presents information about the characteristics of the radios used in the tests performed, detailing the configuration used in each one of them.

### IEEE 802.16

The demand for greater bandwidth for both conventional and wireless networks has increased dramatically over the past few years. In the area of