CHANNEL MODELING IN A WIRELESS NETWORK

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Abstract

The demand for wireless communications systems is ever increasing in all the human- life activities. This technology provides connectivity also where wiring is impossible or costly. Wireless technology can range from WLANs and cellular networks to headphones and microphones connections. It includes infrared (IR) devices, such as remote controls, cordless keyboards, and mice, all of which have a transmitter and a receiver. The high diffusion rate of this technology provoked some confusion in the user, as the industry developed many different wireless systems and services, which often were not able to interact with each other. The purpose of this study and research was to understand the concept of channel modeling and ray tracing. During the project different mechanisms and their impact was observed on a signal and their effect was calculated. An area with predefined specifications was modeled and the path of the signal from the transmitter to receiver was examined. Many scenarios were taken under consideration. The phenomenon like knife-edge diffraction, simple and complex shadowing and ray models were implemented and the result for every individual phenomenon was observed. The reasons for the loss of field strength and increase in path loss were studied, through changing different parameters like heights of the transmitter and receiver while moving along streets. All these observations were performed in MATLAB.

Table of Contents

List of Figures

List of Acronyms and Abbreviations

AMC	Adaptive Modulation and Coding
BER	Bit Error Rate
BWA	Broadband Wireless Access
CDMA	Code Division Multiple Access
DSL	Digital Subscriber Line
FDD	Frequency Division Duplexing
FWA	Fixed Wireless Access
IEEE	Institute of Electrical and Electronics Engineers
IPTV	Internet Protocol Television
LAN	Local Area Network
LOS	Line of Sight
LMDS	Local Multipoint Distribution Service
MAN	Metropolitan Area Network
MMDS	Multichannel Multipoint Distribution System
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiplexing Access
QAM	Quadrature Amplitude Modulation
SDMA	Space Division Multiple Access

TDD	Time Division Duplexing
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access

Chapter 1

Introduction

1.1 Introduction

The advancement in the wireless radio channels is ever increasing and the availability of swift communication is an additional feature of these wireless systems. In order to correctly predict and estimate the different features of a signal, the channel of the signal is examined and modeled according to the applied approximations and depending on the locality in which this model is being propagated. The channel calculations assist and facilitate the cellular networks to improve the quality of the service they provide. Another aspect of this modeling is that every region has to be modeled separately as there are varieties of obstacles in the surroundings which result in different paths for the signal to reach the receiver. When there are different paths for the signal, phenomenon like time delay and delay spread come into play. Ultimately channel modeling is the base of any computation related to wireless systems.

1.2 Motivation

Since the beginning of our degree, the Final Project was the most talked about event of the entire 4 years. It was supposed to be the culmination of our learning, the highlight of the program; the chance to demonstrate our knowledge, problem solving skills, and ability to perform under the pressure of deadlines. In short, we were supposed to show that we had evolved into engineers.

Our earliest motivation was just excitement at the prospect of being given the responsibility of doing a big project. Slowly, as we studied more and more technical courses, learnt more, this excitement got channeled into genuine desire, and motivation towards certain fields, in particular that of Wireless Communications. It started from the introductory course in this field, Signals and Systems. From the very beginning, we were intrigued with the entire science behind wireless signal transmission. News reports and magazine articles had been hailing it as the future of communication. To be able to study, and work, on an up and coming technology was a desire that was immediately instilled in all three of us, and unconsciously, at that stage, we had already made up our minds to pursue a project relating to Wireless Communications.

As our final year and the inevitable project loomed ever closer, we started consulting teachers as regards to our project advisor. We were immediately pointed in the direction of Mr. Muhammad Rizwan, who was lauded by senior students and teachers alike as a learned man, and a dedicated instructor. To our delight, we discovered that Mr. Rizwan too, was interested in Wireless Communication, and had even done his Masters' thesis on the very subject. Therefore, we approached him, and discussed with him the possibility of doing our Final Project under his tutelage. He readily accepted, and from that day one he became our guide and mentor.

After several discussions over possible project proposals, we finally expressed our desire to work on a project pertaining to WiMAX and its implementation. Out of all the new technologies in the field of wireless communication, WiMAX had been the one that had captured our attention the most. With greater emphasis on mobility, and range of service, it was easily one of the most important out of all the forthcoming technologies, and we were eager to get the chance to work on it. Our advisor concurred, and subsequently helped us bring a viable proposal into fruition

1.3 Previous Work

The wireless radio channel proves to be a severe challenge as a medium for reliable high-speed communication. It is not only susceptible to noise, interference, and other channel impediments, but these impediments change over time randomly and in an unpredictable ways due to user movement. Ray tracing and modeling of a site to find out the strengths and losses of any signal transmitted has been put into practice for the many previous years, which has been essential with the ever increasing need of wireless technology. As far as ray tracing and channel modeling is concerned, there have been many researches and papers, that have been published, that deal with these two terminologies and their respective features and calculations. With the emergence of softwares that helped in modeling and designing 3-D designs of outdoor and indoor environments, these tasks have become more simplistic. Geometrical theory of diffraction and uniform theory of diffraction has been a popular approach that has been used to represent and simulate a broadband channel using ray tracing technique. In order to drop off the run time of the computer, the number of rays that were to be examined were reduced as that was a very undesirable feature to confront. The propagation prediction and channel modeling were

examined for an LMDS system. The LMDS system operates across the 26 and 29 GHz band. At some regions this frequency may vary to 31-31.3 GHz. This approach was used to exemplify wireless channel in narrow band personal communication systems and through that parameters like RMS delay spread, mean excess delay, coherence delay were also computed while taking mechanisms like reflection, diffraction and scattering into consideration.

In some researches the shooting and bouncing method was implemented while the image theory was the basic theme of some papers. It was clear from the conclusive results of both the techniques mentioned above that the later was far more accurate and precise than the former. In order to speed up the process some algorithms were created and through those algorithms the runtime was reduced. Another popular method of reducing the complexity was to reduce the facets in the path of reflection while ignoring the facets and the sources that proved to be invisible to the intersecting points [1].Another work that was performed relating to the path loss and fading calculation was to investigate a certain area on a deployed frequency of 3.5GHz and at this frequency the median path loss fading and coverage was computed. The results were then compared with the result with the relatively newer band of 700MHz for the broadband wireless access.(BWA)[2].Previous projects involved the measurements for the 3.5GHz frequency band in a rural macro cell environment[3]. Similarly the calculations for the same frequency were performed but in a different environment like in an urban one which yielded significantly different results from those of the rural ones. Another aspect that different researchers and authors changed regularly was the range for which all the calculation was performed. While further advancement was being done in this field some authors concentrated on the presence of nulls predicted by the two ray model by deploying WiMAX in a seaport [4]. Authors did put their efforts into measuring and modeling the radio path loss and penetration loss in and around homes and trees at 5.85 GHz frequency for a range of 30m to 210m [5]. And a paper was presented that showed the propagation model for a frequency band 5.725-5.825 GHz but calculations were performed at a frequency of 5.8GHz for residential areas [6].Another noticeable work was performed by computing the downlink performance of WiMAX broadband from high altitude platform and terrestrial deployment on a 3.5GHz band [7]. But ultimately the main objective of all the procedures and techniques was to calculate and predict the amount of signal energy lost through mechanisms like path loss, Line of Sight (LOS), single and multiple reflections, diffraction and scattering. Another calculation to be made is the signal strength

needed to successfully receive a signal as a function of the distance between the transmitter and receiver.

1.4 Aim of the Project

The aim of this project is the introduction to wireless channel models, by providing a selection of the most popular ones. The types of fading typical of the wireless environment are also presented, together with the relevant propagation models. This project is currently carrying out outdoor measurement campaigns, in order to define channel models derived from the measures collected. We simulate a microcellular type signal propagation environment usually deployed in our part of the world and the basic aim of the project is to calculate the path loss and the required signal strength with respect to the heights of the receiver and transmitter as a function of the distance between them. The frequency of the operation can vary to some extent while the reflecting and diffracting objects are also specified with respect to their position. And for that an urban area with uniformity will be modeled in MATLAB to calculate the various parameters of interest like path loss through the phenomenon of the three basic mechanisms namely reflection, diffraction and scattering. Yet another basic aim of this project is to further do the calculations of Line of sight between the transmitter and the receiver. The three above mentioned mechanisms are the basics of calculation of any parameters related to signal strength and will be further classified into more detailed yet simple constraints. For example a knife-edge model for diffraction or a four ray model for reflection. In order to make the environment realistic the location of the houses and other construction is taken and so are the positions of the receiver and transmitter in the DD block of Defense Phase IV Lahore. The results obtained helped to understand the propagation behavior at different frequencies.

Chapter 2

WiMAX

2.1 Introduction

WiMAX is an abbreviation of Worldwide Interoperability for Microwave Access and it is a phenomenon that is intended for wireless "metropolitan area networks (MAN)".This technology was introduced by the WiMAX Forum in June 2001. This emerging technology is based on the IEEE 802.16 standard which is also called Broadband Wireless Access. The core 802.16 specifications is a standard for broadband wireless access systems operating at radio frequencies between 10 GHz and 66 GHz. Data rates of around 40 Mbps will be available for fixed users and 15 Mbps for mobile users, with a range of several kilometers. Many laptop and PDA manufacturers plan to incorporate WiMAX once it becomes available to satisfy demand for constant internet access and email exchange from any location. WiMAX will compete with wireless LANs, 3G cellular services, and possibly wired line services like cable and DSL. The ability of WiMAX to challenge or supplant these systems will depend on its relative performance and cost, which remains to be seen. It will also serve as a backhaul for access points and base stations. In case of the distance WiMAX can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3 - 10 miles (5 - 15 km) for mobile stations. In contrast, the Wi-Fi based on IEEE standard 802.11 which is the wireless local area network is limited in most cases to only 100 - 300 feet (30 - 100m).

2.1.1 802.16 Standard

The 802.16 standards are sometimes referred as "WiMAX", "mobile WiMAX", "802.16d" and "802.16e."Their formal names are as follow:

2.1.1.1 Fixed WiMAX

Fixed WiMAX is also known as 802.16d, which refers to the working party that has developed that standard. It is sometimes referred to as "fixed WiMAX," since it has no support for mobility.

2.1.1.2 Mobile WiMAX

Mobile WiMAX, often abbreviated to 802.16e, is an amendment to 802.16-2004 described above. It introduced support for mobility, among other things and is therefore also known as "mobile WiMAX" [10].

This standard is used as a replacement for the IEEE 802.11 which is the Wi-Fi Technology, and it contributes as a threat to the cellular telephony and it is said that this advancement will replace the previously installed wired networks.

The evolution of this technology began in the mid 90's when various groups started to promote the fixed wireless access solution. Their combined goal was to provide the capacity and reliability of wired line but all this with the flexibility and ease of deployment of the wireless. It can provide a versatile system for corporate and institutional backhaul and multiple networks. The two approaches that are usually focused are the following.

LMDS (Local Multipoint Distribution Service) commonly operates on microwave frequencies across the 26 GHz and 29 GHz bands. In the United States, frequencies from 31.0 through 31.3 GHz are also considered LMDS frequencies. LMDS was conceived as a broadband, fixed wireless, point-to-multipoint technology for utilization in the last mile. The last mile is the final leg of delivering connectivity from the communication provider to a customer. Throughput capacity and reliable distance of the link depends on common radio link constraints and the modulation method used either phase-shift keying or amplitude modulation. In general deployment links of up to 5 miles (8 km) from the base station are possible, but distance is typically limited to about 1.5 miles (2.4 km) due to rain fade attenuation constraints. It uses the conventional QAM modulation with upper layers to provide high speed service. MMDS

(Multichannel Multipoint Distribution System) is a technology that operates usually around the frequencies of 2GHz band under the Line of Sight conditions.

2.2 WiMAX and 3G Technology

The two systems are based on two different technologies. WiMAX is based on OFDM, and 3G is based on CDMA. Here we may compare the performance of the two. [8]

1. Spectrum Allocation

WiMAX can use licensed and unlicensed (2.5, 3.5, 5.8 GHz) bands, whereas the 3G technology is bound to only use a licensed band.

2. Multipath Environment

Since the data rate of OFDMA is slow in each subcarrier, OFDM is better at overcoming ISI (Inter symbol Interference) than CDMA.

3. Under Frequency-Selective Fading

Since the parallel nature of OFDMA allows errors in subcarriers to be corrected, OFDMA is more resistant to frequency-selective fading.

4. Frequency Offset and Phase Noise

Although OFDMA uses guard bands to avoid frequency offset, it is still more sensitive to frequency offset that causes phase noise.

5. Impulse Noise Rejection

An impulse noise may not cause an increase in the error rate in OFDMA because its symbols are of a longer duration than CDMA symbols. CDMA symbols may be lost because of the impulse noise and the systems could increase the coded BER (Bit Error Ratio).

6. Applying AMC with OFDM

Using AMC (Adaptive Modulation and Coding) not only achieves higher throughput for OFDMA systems but it also, if applied at the sub-channel level known as SDMA (Space Division Multiple Access), allows the optimization of sub-channel selection based on geographical location.

7. Frequency Reuse Scheme

OFDMA needs a frequency reuse of 3, which means the throughput per cell for a specific bandwidth must be divided by 3; CDMA employs interference averaging, which allows it to maintain a frequency reuse of 1.

8. Code Limitation

Since CDMA employs interference average; most 3G clients will be limited to 5 of maximum 15 codes. Each user needs at least one code for voice or data; this could have an impact on the number of users supported by each system. In OFDMA, there is a high number of sub-carriers to be assigned to the users.

9. Duplexing

WiMAX can take advantage of multiple duplexing modes, including TDD dynamic asymmetry. 3G is an FDD system.

10. Voice

Currently, CDMA can better handle mobile voice calls. It supports multiple voices coding schemes, seamless handoffs, and roaming. OFDMA has to use new techniques to make the voice quality better [8].

The data rates and latency comparison of the WiMAX and 3G is given in the table below

Technology	Peak Data Rate		RAN Access Latency	Idle to Active Transition Time
	Downlink	Uplink		
WiMAX	40 Mbps	10 Mbps	40 ms	100 ms
HSPA	14 Mbps	2Mbps	50-250 ms	600 ms
HSUPA	14 Mbps	5.8 Mbps	50-250 ms	600 ms

Table 2.1 Data Rates of WiMAX and 3G Technology

2.3 WiMAX versus Wi-Fi

1. It works same as Wi-Fi does, being more improved and efficient and it routes data to Wi-Fi. Wi-Fi devices can take advantage of a WiMAX connection.

2. WiMAX technology provides higher speed connection up to 70 Mbps over the area of 30 miles.

3. There is no need for line of sight connection between subscriber terminals and the base station in WiMAX technology and it can support hundreds if not thousands of subscribers from a single base station.

4. WiMAX supports advanced security features to protect information as it travels across the airwaves. It supports AES (Advanced Encryption Standard), a state-of-the-art security technology that encrypts data as it passes between the client and the base station. While in Wi-Fi there is no such feature like security.

WiMAX won't replace Wi-Fi, but rather will fill in between hotspots and extend the internet access on the move. As it covers even the spots that Wi-Fi misses. The coverage comparison between the Wi-Fi and WiMAX is shown in Fig.2.1

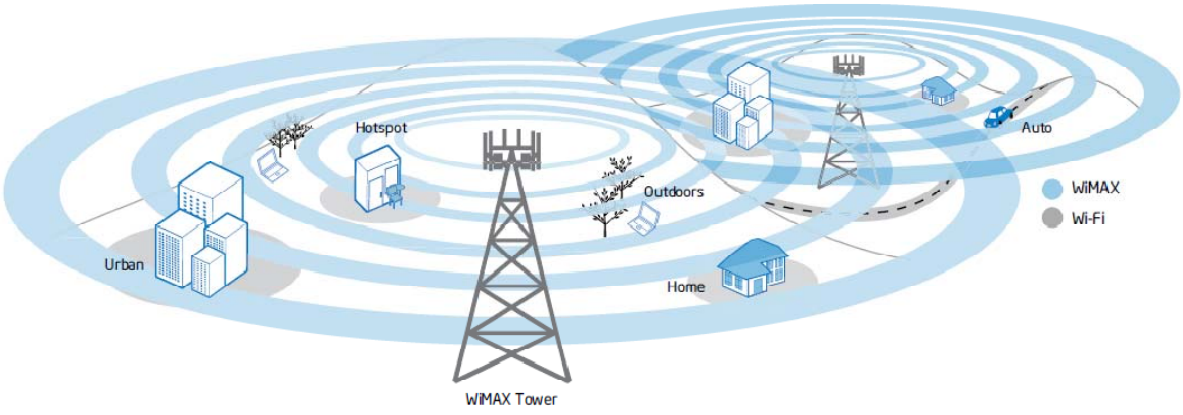

Fig 2.1 WiMAX blankets large areas with broadband internet [9]

It will allow connecting to the Internet, miles from the nearest Wi-Fi hotspot. Soon, Mobile WiMAX will blanket large areas metropolitan, suburban, or rural delivering mobile broadband Internet access at speeds similar to existing broadband.

2.4 Uses

The bandwidth and range of WiMAX make it suitable for the following potential applications:

- Connecting Wi-Fi hotspots to the Internet.
- Providing a wireless alternative to cable and DSL for last mile broadband access.
- Providing data, telecommunications and IPTV services (triple play).
- Providing a source of Internet connectivity as part of a business continuity plan. That is, if a business has both a fixed and a wireless Internet connection, especially from unrelated providers, it is less likely to be affected by the same service outage [10].

2.5 Limitations

There is no denying of the fact that WiMAX will prove to be an evolution in the wireless technology but still it has its limitations which are being reduced with the passage of time. As stated previously WiMAX provides coverage theoretically up to 30 miles, but that distance actually drops in urban markets to four to six miles, which is a cause of concern. Secondly current costs to install base stations and related infrastructure can be more than $25,000.Although this cost is declining; it is still expensive compared to Wi-Fi and DSL. Current cellular technologies exist at a 3G bandwidth capability. However, many top-tier wireless providers have failed to sign up with this so far. WiMAX needs a method of delivery in the market place. WiMAX was not initially designed for mobile phone use. Due to automobile speed mobility, price points and form factors will not be appropriate for current WiMAX products. In addition, the antennas being developed are too small and require too much energy to be efficient for such things as laptops and personal organizers further limiting market share. Mobile towers would need to be built that beam signals at much higher power, but these signals could provide additional interference with other devices.

WiMAX is a very interesting new development in the area of wireless broadband access. It is expected to be deployed by different kinds of network operators (wireless Internet service providers, cellular operators, DSL (Digital Subscriber Line) operators), using different business models. WiMAX signals the arrival of wireless data technological advancement as it provides features like mobility, high power efficiency and high speed. Unhampered by the short range data orientation of the wireless local area network these technologies hold the promise of taking the high speed wireless from the interiors to the exteriors like the roaming feature while travelling. The flexibility of the WiMAX technology gives it a significant advantage as it provides its services to both fixed and nomadic users all over the world. Moreover it operates on both licensed and unlicensed frequency bands, providing both consistent and variable delay services while operating in any environment. Although a great number of debates continue to swirl around the WiMAX standards and its comparison to incumbent cellular standards, the current trend suggests that WiMAX is an ideal platform for the delivery of voice, data and video over wireless. With WiMAX, Wi-Fi-like data rates are easily supported, but the issue of interference is lessened. WiMAX can be used for wireless networking in much the same way as the more common Wi-Fi protocol. WiMAX is a second-generation protocol that allows for more efficient bandwidth use, interference avoidance, and is intended to allow higher data rates over longer distances.