CHAPTER 1

INTRODUCTION

1.1 WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS (WIMAX)

Nowadays people are enjoying wireless internet access for telephony, radio and television services when they are in fixed or mobile conditions. The rapid growth of wireless internet causes a demand for high-speed access to the World Wide Web. To serve the demand for access to the internet “any where any time” and ensure quality of service, the IEEE 802.16 working group brought out a new broadband wireless access technology called “WIMAX” meaning Worldwide Interoperability for Microwave Access. Technologies that promise to deliver higher data rates are attracting more and more vendors and operators towards them. Many researchers do believe that WIMAX can move the wireless data transmission concept into a new dimension.

WiMAX Forum is a non-profit corporation that was formed in April 2001 by equipment and component suppliers to help to promote and certify the compatibility and interoperability of Broadband Wireless Access (BWA) equipment. The WiMAX Forum is an amalgamation of wireless and computer industry companies that have endorsed it and is aggressively marketing the WiMAX standard. The principal purpose of the organization is to promote and certify compatibility and interoperability of
devices based on various 802.16 specifications and to develop such devices for the global marketplace.

The Forum believes that the adoption of industry standards will be a key factor in any successful deployment of WiMAX technology. For example, one of the most significant problems with WiFi initial deployment was lack of early industry standards. In the early days of WiFi deployment, the marketplace was saturated with equipment well before industry standards were adopted. As a result, equipment often lacked interoperability and was expensive. One of the purposes of the WiMAX Forum is to create a single interoperable standard from the IEEE and ETSI BWA standards.

Today broadband users are restricted to Digital Subscriber Line (DSL) technology, which provides broadband over twisted-pair wires and cable modem technology which delivers over coaxial cable. Both of these wire line infrastructures are highly expensive and time-consuming to be deployed compared to the wireless technology. Another way of getting broadband access is through satellite service but it is costly and there is a half second delay between data transmission and reception. Wireless technology has also clear advantage in rural areas and developing countries which lack wire infrastructures for broadband services. Worldwide interoperability for microwave access is a broadband wireless technology which brings broadband experience to a Wireless context.

The group's initial focus was the development of a LOS-based point-to-multipoint wireless broadband system for operation in the 10GHz–66GHz millimetre wave band. The resulting standard with the original 802.16 standard, which was completed in December 2001 was based on a Single-Carrier Physical (PHY) layer with a burst time division multiplexed MAC layer. The IEEE 802.16 group subsequently produced 802.16a, an amendment to the standard, to include NLOS applications in the
2GHz–11GHz band, using an Orthogonal Frequency Division Multiplexing (OFDM)-based physical layer. Additions to the MAC layer, such as support for Orthogonal Frequency Division Multiple Access (OFDMA), were also included. Further revisions resulted in a new standard in 2004, called IEEE 802.16-2004, which replaced all prior versions and formed the basis for the first WIMAX solution. These early WIMAX solutions based on IEEE 802.16-2004 targeted the fixed applications. In December 2005, the IEEE group completed and approved IEEE 802.16e-2005, an amendment to the IEEE 802.16-2004 standard that added mobility support. The IEEE 802.16e-2005 forms the basis for the WiMAX solution for mobile applications and is often referred to as mobile WiMAX, but my research work is focused on fixed WIMAX.

<table>
<thead>
<tr>
<th>BOARD OF DIRECTORS</th>
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<tbody>
<tr>
<td>SPWG</td>
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<tr>
<td>AWG</td>
</tr>
<tr>
<td>NWG</td>
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<tr>
<td>TWG</td>
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<td>CWG</td>
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<td>RWG</td>
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<tr>
<td>MWG</td>
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Figure 1.1 WiMAX forum working groups
Network Working Group (NWG) is developing the higher-level networking specifications for WiMAX systems beyond what is defined in the IEEE 802.16 standard that simply addresses the air interface specifications. The combined effort of IEEE 802.16 and the WiMAX Forum help define the end-to-end system solution for a Mobile WiMAX network. The Figure 1.1 illustrates WiMAX Forum working groups.

### 1.2 WIMAX NETWORK REFERENCE MODEL

WiMAX Forum industry participants have identified a WiMAX Network Reference Model that is a logical representation of the network architecture. The NRM identifies functional blocks and reference points over which interoperability is achieved between functional blocks. The architecture with the objective of providing united support of functionality is needed in a range of network deployment models and usage scenarios.

![Network reference model](image-url)

*Figure 1.2 Network reference model*
Figure 1.2 illustrates the Network Reference Model, consisting of the following reasonable blocks: MS, ASN, and CSN and clearly identified reference points for interconnection of the logical entities. The figure depicts the key normative reference points R1-R5. Each of the blocks, MS, ASN and CSN represents a grouping of functional entities. Each of these functions may be realized in a single physical device or may be distributed over multiple physical devices. The grouping and distribution of functions into physical devices within a functional block (such as ASN) is an implementation choice.

The aim of the Network Reference Model is to allow multiple implementation options for a given functional block, and yet achieve interoperability among different realizations of functional blocks. Interoperability is based on the definition of communication protocols and data plane treatment between functional blocks to achieve an overall end-to-end function.

The ASN represents a boundary for functional interoperability with WiMAX customers, WiMAX connectivity service functions and aggregation of functions personified by different vendors. Mapping of functional blocks to logical blocks within ASNs as depicted in the NRM may be performed in different ways. Connectivity Service Network (CSN) is defined as a set of network functions that provide IP connectivity services to the WiMAX subscriber(s). A CSN may comprise network elements such as routers, AAA proxy/servers, user databases and Interworking gateway devices. A CSN may be deployed as part of a Greenfield WiMAX Network Service Provider (NSP) or as part of an incumbent WiMAX NSP.

The WIMAX architecture also allows both IP and Ethernet services, in a standard mobile IP compliant network. The flexibility and interoperability supported by the WiMAX network provides operators with a multi-vendor low cost implementation of a WiMAX network even with a
mixed deployment of distributed and centralized ASN’s in the network. The following Figure 1.3 shows WiMAX Network IP Based Architecture.

Figure 1.3 WiMAX network IP based architecture

The end-to-end architecture includes the support for:

i. Voice, multimedia services and other mandated regulatory services such as emergency services and lawful interception,

ii. Access to a variety of independent Application Service Provider (ASP) networks in an agnostic manner,

iii. Mobile telephony communications using VoIP,

iv. Support interfacing with various interworking and media gateways permitting delivery of incumbent/legacy services
translated over IP (for example, SMS over IP, MMS, WAP) to WiMAX access networks and

v. Support delivery of IP Broadcast and Multicast services over WiMAX access networks.

Interworking and Roaming are another key power of the End-to-End Network Architecture with prop up for a number of deployment scenarios. In particular, there will be support of

i. Loosely-coupled interworking with existing wireless networks or existing wired networks,

ii. Global roaming across WiMAX operator networks, including support for credential reuse, consistent use of AAA for accounting and billing, and consolidated/common billing and settlement,

iii. A diversity of user authentication credential formats such as username/password, digital certificates, Subscriber Identify Module (SIM), Universal SIM (USIM), and Removable User Identify Module (RUIM).

The IEEE 802.16 WiMAX standard allows data transmission using multiple broadband frequency ranges. The original 802.16a standard specified transmissions are in the range 10 - 66 GHz, but 802.16d is allowed in the case of lower frequencies in the range 2 to 11 GHz. The lower frequencies used in the later specifications mean that the signals suffer less from attenuation and therefore they provide improved range and better coverage within buildings. This brings many benefits to those using these data links within buildings and means that external antennas are not required. Different bands are available for WiMAX applications in different parts of the world. The frequencies
commonly used are 3.5 and 5.8 GHz for 802.16d and 2.3, 2.5 and 3.5 GHz for 802.16e but the use depends upon the countries. The Table 1.1, gives frequency band details of different region.

**Table 1.1 WiMAX frequency bands**

<table>
<thead>
<tr>
<th>Region</th>
<th>Frequency Bands(GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia Pacific (inc China, India, Australia, etc)</td>
<td>2.3, 2.5, 3.3, 3.5, 5.8</td>
</tr>
<tr>
<td>Russia</td>
<td>2.5, 3.5, 5.8</td>
</tr>
<tr>
<td>Middle East and Africa</td>
<td>2.5, 5.8</td>
</tr>
<tr>
<td>Canada</td>
<td>2.3, 2.5, 3.5, 5.8</td>
</tr>
<tr>
<td>USA</td>
<td>2.3, 2.5, 5.8</td>
</tr>
<tr>
<td>Central and South America</td>
<td>2.5, 3.5, 5.8</td>
</tr>
<tr>
<td>Europe</td>
<td>2.5, 3.5, 5.8</td>
</tr>
</tbody>
</table>
1.3 WIMAX DUPLEX MODES

The WiMAX, 802.16 standard offers two forms of duplex transmission to separate the uplink and downlink messages. Both WiMAX TDD (time division duplex) and WiMAX FDD (frequency division duplex) are available. In order for radio communications systems to be able to communicate in both directions it is necessary to have what is termed a duplex scheme. A duplex scheme provides a way of organizing the transmitter and receiver so that they can transmit and receive. There are several methods that can be adopted. For applications including wireless and cellular telecommunications, where it is required that the transmitter and receiver are able to operate simultaneously, two schemes are in use. The process known as FDD or frequency division duplex uses two channels, one for transmit and the other for receiver. The other scheme known as TDD, time division duplex uses one frequency, but allocates different time slots for transmission and reception.

It is often necessary to distinguish between the link from the mobile to the base station, and the link from the base station to the mobile. There are obviously two links:

- **Downlink link:** This is the link from the base station to the mobile or user equipment. The words may be abbreviated to DL or D/L.

- **Uplink link:** This is the link from the mobile or user equipment to the base station. The words uplink may be abbreviated to UL or U/L.

One of the key elements of any radio communications system is the way in which radio communications are maintained in both directions. Terms
including simplex, duplex, frequency division duplex, FDD, and time division duplex, TDD, are all methods that can be used.

For WiMAX systems it is necessary that it is possible to talk or send data in both directions simultaneously, and this places a number of constraints on the schemes that may be used to control the transmission flow. As it is such a key element of the system, it is necessary to settle on the scheme that will be used from the outset. As a result the duplex scheme to be used forms a very basic part of the overall specification for the cellular (or any radio communications system) that is to be used. The different schemes for controlling the transmission range from simplex through half duplex to full duplex. Furthermore, schemes such as TDD and FDD need to be defined for the system depending upon its application and the traffic it is likely to carry.

FDD, uses the idea that the transmission and reception of signals are achieved simultaneously using two different frequencies. Using FDD it is possible to transmit and receive signals simultaneously as the receiver is not tuned to the same frequency as the transmitter. For the FDD scheme to operate satisfactorily, it is necessary that the frequency, i.e. channel separation between the transmission and reception frequencies must be sufficient to enable the receiver not to be unduly affected by the transmitter signal. This is known as the guard band.

Receiver blocking is an important issue with FDD schemes, and often highly selective filters may be required. For cellular systems using FDD, filters are required within the base station and also the handset to ensure sufficient isolation of the transmitter signal without desensitising the receiver. While cost is not such a significant driver for the base stations, placing a filter into the handsets is more of an issue. The use of an FDD system does enable true simultaneous transmission and reception of signals. However two
channels are required and this may not always use the available spectrum efficiently. The spectrum used for FDD systems is allocated by the regulatory authorities. As there is a frequency separation between the uplink and downlink directions, it is not normally possible to reallocate spectrum to change the balance between the capacity of the uplink and downlink directions if there are changing capacity requirements for each direction.

The other system uses only a single frequency, and it shares the channel between transmission and reception, spacing them apart by multiplexing the two signals on a time basis. Time Division Duplex, TDD, is used with data transmissions, transmitting a short burst of data in each direction. As the transmission periods are relatively short, no time delay is noticed on voice transmissions resulting from the time delays introduced by using TDD.

FDD transmissions require a guard band between the transmitter and the receiver frequencies; TDD schemes require a guard time or guard interval between transmission and reception. This must be sufficient to allow the signals travelling from the remote transmitter to arrive before a transmission is started and the receiver inhibited. Although this delay is relatively short, when changing between transmission and reception many times a second, even a small guard time can reduce the efficiency of the system as a percentage of the time must be used for the guard interval.

The guard interval required for TDD will comprise two main elements:

- A time allowance for the propagation delay for any transmissions from the remote transmitter to arrive at the receiver. This will depend upon the distances involved, but it
takes 3.3 microseconds to travel a kilometer, and 5.4 microseconds to travel 1 mile.

- A time allowance for the transmitter receiver to change from receive to transmit. Switching speeds can vary considerably between equipments but can take a few microseconds.

TDD is not normally suitable for use over long distances as the guard time increases and the channel efficiency falls. Also transmit receive switching must be fast. Using a TDD system it is possible to change the capacity in either direction relatively easily by changing the number of time slots allocated to each direction. Often this is dynamically configurable so it can be altered to match the demand.

A further aspect to be noted with TDD transmissions is the aspect of latency. As data may not be able to be routed immediately onto a transmission as a result of the time multiplexing between transmit and receive, there will be a small delay between the data being generated and it being actually transmitted. Typically this may be a few milliseconds dependent upon the frame times, but in some applications it may be of interest, although for normal digitised speak, there would be no noticeable delay.

It is possible to use both FDD and TDD for WiMAX. However FDD transmissions require the use of two channels, one for the uplink and one for the downlink. These need to be separated sufficiently to enable the receiver to operate without being desensitised by the transmitter which needs to operate simultaneously. This not only requires there to be a separate frequency separation between uplink and downlink, but it is normally also necessary to incorporate additional filtering to remove the transmitter frequency from the receive band. Any paired spectrum allocated, is normally
split such that there is equal bandwidth available in both directions. This is not ideal where the traffic may be asymmetric and the balance may be variable.

Using WiMAX TDD it is possible to accommodate the asymmetry in the traffic balance. By altering the number of frames for traffic in each direction it is possible to make far more efficient use of the available spectrum. The balance of frames for each direction, and hence the capacity can be altered dynamically, enabling the system to respond to the actual traffic travelling in each direction. Therefore TDD can handle both symmetric and asymmetric broadband traffic and therefore TDD has higher spectral efficiency than FDD for these applications.

With both types of WiMAX duplex scheme being available for use, it is necessary to choose the correct form of duplex scheme for the particular type of deployment. To achieve the optimum form, it is necessary to undertake a WiMAX TDD FDD comparison to ascertain the optimum version subject to any regulatory constraints. It is useful to note that the first release of fixed WiMAX support both TDD and FDD duplex modes, although Mobile WiMAX only includes TDD mode.

### 1.4 FUNDAMENTALS OF OFDM

The propagation paths are in most situations hostile and unpredictable, and susceptible to even a small change in the environment. Signal processing techniques are therefore playing an extremely important role to overcome these problems. One of the most profound achievements of signal processing on the physical layer might be Orthogonal Frequency Division Multiplexing (OFDM), which will be the major research subject. OFDM has proved to be a superior solution against multipath propagation, and is adopted in many contemporary communication protocols. Despite its
numerous merits, the performance of OFDM is far less satisfactory in a high mobility communication scenario, where the so-called Doppler effect plays a significant role.

OFDM is an advanced form of Frequency Division Multiplexing (FDM) where the frequencies multiplexed are orthogonal to each other, and their spectra overlap with the neighbouring carriers. In a standard FDM system the sub carriers do not overlap which represents the amplitude frequency response of such systems. OFDM is built on the principle of overlapping orthogonal sub carriers. The peak of one sub carrier coincides with the nulls of the other sub carriers due to the orthogonality. Thus there is no interference from other sub carriers at the peak of a desired sub carrier even though the sub carrier spectrums overlap. The Figure 1.4, gives the comparison representation of FDM and OFDM.
OFDM is well known for effectively combating the frequency selective fading which arise due to multi path reflections of the wireless channel. The Inverse Fast Fourier Transform (IFFT) replaces the bank of modulators needed in a conventional multi carrier system. It can be considered that the input data symbols to the IFFT modulates the sub carriers, each of which has a pulse period which is the product of the sampling period of the system times the number of sub carriers in the system. In other words, each data symbol modulates one sub carrier. During the OFDM system design, parameters are chosen in a way such that the sub carrier bandwidth is smaller than the coherence bandwidth of the channel so that each sub carrier experiences at flat fading. This together with the use of cyclic prefixed Guard Interval (GI) helps in using a one tap equalizer at the receiver.

The one tap equalizer can be realized if there is no ISI. ISI between consecutive OFDM symbols is avoided by the use of GI, which is discarded at the receiver to reject the ISI. Using Cyclic Prefix (CP) in the GI is a very effective technique to preserve the orthogonality among sub carriers. The CP is an extension of the last part of the time domain signal. The length of CP is designed to be larger than the maximum delay of the channel. After the OFDM symbol with the CP passes through a time dispersive channel, the interference from the previous symbol is limited to be within the CP. The contaminated CP is rejected at the receiver. The continuity of the signal waveforms in time domain inside the GI in the form of CP ensures that the remaining portion contains full cycles of the sub carriers. This prevents orthogonality loss among the sub carriers and between consecutive OFDM symbols. The long symbol duration which brings in several benefits is limited by the Doppler condition of the channel. When the number of sub carriers is made large, the system bandwidth is sampled at a higher rate in the frequency domain, which in turn makes the sub carrier bandwidth smaller. This leads to a higher pulse duration. To maintain orthogonality among the sub carriers
OFDM systems must have a static channel during the pulse period, i.e. the coherence time of the channel must be much larger than the pulse period of the OFDM symbol.

The IEEE 802.16-2004 standard specified OFDM as the transmission method for NLOS connections. The OFDM signal is made up of many orthogonal carriers, and each individual carrier is digitally modulated with a relatively slow symbol rate. This method has advantages in multipath propagation because, in comparison with single carrier method at the same transmission rate, more time is needed to transmit a symbol. The BPSK, QPSK, 16QAM and 64QAM modulation modes are used, and the modulation is adapted to the specific transmission requirements. Transmission rate of up to 75 Mbps is possible. In the normal OFDM mode, 200 carriers are available for data transmission, and both TDD and FDD methods are used. WIMAX has selected to specify OFDM with 256 FFT for the 802.16d physical layer profile and not OFDMA with 2048 FFT. With 802.16e, WIMAX makes enhancements to the physical layer by employing Scalable OFDMA (SOFDMA).

1.5 FADING

In wireless communications, fading is deviation of the attenuation affecting a signal over certain propagation media. The fading may vary with time, geographical position or radio frequency, and is often modeled as a random process. A fading channel is a communication channel comprising fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading.
The presence of reflectors in the environment surrounding, a transmitter and receiver, creates multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Each signal copy will experience differences in attenuation, delay and phase shift while travelling from the source to the receiver. This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. Strong destructive interference is frequently referred to as a deep fade and may result in temporary failure of communication due to a severe drop in the channel signal-to-noise ratio.

Fading channel models are often used to model the effects of electromagnetic transmission of information over the air in cellular networks and broadcast communication. The Figure 1.6, gives the detailed classification of fading channels. Mathematically, fading is usually modeled as a time-varying random change in the amplitude and phase of the transmitted signal.

Reflection, diffraction, and scattering have a great impact on the signal power, and they constitute the main reasons for signal attenuation (fading). The interaction between the waves derived by reflection, diffraction and scattering cause multipath fading at a specific location.

Fading can be categorized into two main types: large-scale fading and small-scale fading. Large-scale fading is due to motion in a large area, and can be characterized by the distance between transmitter and receiver. Small-scale fading is due to small changes in position (as small as half wavelength) or to changes in the environment (surrounding objects, people crossing the line of sight between transmitter and receiver, opening or closing of doors, etc.). Figure 1.5 illustrates the wireless channel fading types.
1.6 PROPAGATION MODELS

A radio propagation model is an empirical mathematical formulation for the characterization of radio wave propagation as a function of frequency, distance and other conditions. A single model is usually developed to predict the behavior of propagation for all similar links under similar constraints. Created with the goal of formalizing the way radio waves are propagated from one place to another, such models typically predict the path loss along a link or the effective coverage area of a transmitter.

As the path loss encountered along any radio link serves as the dominant factor for characterization of propagation for the link, radio
propagation models typically focus on realization of the path loss with the auxiliary task of predicting the area of coverage for a transmitter or modeling the distribution of signals over different regions. Because each individual telecommunication link has to encounter different terrain, path, obstructions, atmospheric conditions and other phenomena. As a result, different models exist for different types of radio links under different conditions. The models rely on computing the median path loss for a link under a certain probability so that the considered conditions will occur.

Radio propagation models are empirical in nature, which means, they are developed based on large collections of data collected for the specific scenario. For any model, the collection of data has to be sufficiently large to provide enough likeliness to all kind of situations that can happen in that specific scenario. Like all empirical models, radio propagation models do not point out the exact behavior of a link, rather, they predict the most likely behavior the link may exhibit under the specified conditions. The Figure 1.6, shows the channel propagation models.

![Figure 1.6 Channel propagation models](image)

**Figure 1.6 Channel propagation models**
In respect of the performance of the developed communication system, an accurate description of the wireless channel is required to address its propagation environment. The radio architecture of a communication system plays a very significant role in the modeling of a channel. The wireless channel is characterized by: Path loss, Multipath delay Spread, Fading characteristics, Doppler spread, Cochannel and adjacent channel interference. All the model parameters are random in nature, and only a statistical characterization of them is possible, i.e. in terms of the mean and variance value. They are dependent upon terrain, tree density, antenna height and beamwidth, wind speed. The path loss models are classified in to three types as follows.

### 1.6.1 Empirical Models

It is impossible to explain a situation by a mathematical model. In that case, we use some data can be used to predict the behaviour approximately. By definition, an empirical model is based on data used to predict, not explain a system and it is based on observations and measurements alone. It can be split into two subcategories, time dispersive and non-time dispersive. The time dispersive model provides information about time dispersive characteristics of the channel like delay spread of the channel during multipath. The Stanford University Interim (SUI) model is the perfect example of this type. COST 231 Hata model, Hata and ITU-R model are an example of non-time dispersive empirical model.

### 1.6.2 Deterministic Models

Nowadays, the visualization capabilities of computer increases quickly. The modern systems of predicting radio signal coverage are Site Specific propagation model and Graphical Information System database. SISP model can be associated with indoor or outdoor propagation
environment as a deterministic type. Wireless system designers are able to design actual presentation of buildings and terrain features by using the building databases. The ray tracing technique is used as a three-dimensional representation of building and can be associated with software, that requires reflection, diffraction and scattering models, in case of outdoor environment prediction. Architectural drawing provides a SISP representation for indoor propagation models. Wireless systems have been developing by the use of computerized design tools that ensure more deterministic comparing statistical.

1.6.3 Stochastic Models

This is used to model the environment as a series of random variables. Least information is required to draw this model but its, accuracy is questionable. Prediction of propagation at 3.5GHz frequency band is mostly done by the use of both empirical and stochastic approaches.

For investigation, SUI channel model has been preferred. SUI channel models are an extension of the earlier work by AT&T Wireless and Erceg et al. In this model a set of six channels was selected to address three different terrain types that are typical of the continental US. This model can be used for simulations, design, and development and testing of technologies suitable for fixed broadband wireless applications.

1.7 INDIAN SCENARIO

India is a huge market for broadband wireless services and offers immediate and enormous potential for growth. WiMAX is the only 4G broadband technology compatible with the 2.3 GHz BWA spectrum in India that today enjoys widespread global deployment along with a mature ecosystem of vendors, devices and applications. It offers Indian consumers
both fixed and mobile high speed access to all internet services. WiMAX already powers a wide array of terminal devices today, from notebooks, dongles, CPEs, handhelds, and home/business VoIP gateways to the latest Smartphones, personal hotspots, and machine to machine devices. WiMAX has commercial networks in 149 countries today. Mobile WiMAX subscriptions are projected to growing to 130 million subscribers by 2014.

In India, BSNL has been looking forward to extensive WiMax deployment to provide wireless broadband solution to a larger section of population. In 2004 itself BSNL deployed 802.16d-2004 standard based WiMAX system at 10 locations - 6 being in urban metros and 4 locations being in rural areas of Haryana on pilot basis. Spectrum of 20 MHZ had been allocated to BSNL in July 2008, facilitating FDD Mode 2540 and 2640 MHZ with 10 MHz in each band in Gujarat, Maharashtra and Andhra Pradesh, and over the rest of India 20 Mhz with TDD Mode with a carrier frequency of 2645 Mhz.

| Table 1.2 CSN and ASN for WiMAX Network in India |
|-----------------|-----------------|-----------------|
| **Circle**      | **Station**     | **ASN or CSN+ASN** |
| Chennai         | Chennai         | ASN             |
| Jharkhand       | Ranchi          | ASN             |
| Orissa          | Bhuvneshwar     | ASN             |
| Punjab          | Chandigarh      | ASN             |
| MP              | Bhopal          | ASN             |
| UP              | Agra            | ASN             |
| Maharashtra     | Pune            | CSN +ASN        |
| AP              | Hyderabad       | CSN +ASN        |
| Rajasthan       | Jaipur          | CSN +ASN        |
| Bihar           | Patna           | CSN +ASN        |
India's Bharat Sanchar Nigam Ltd (BSNL) had launched the country's first urban WiMAX network, in Ernakulam, a district of Kerala in Southern India. The network comprises 25 base stations. It has plans to expand the network to 900 base stations throughout Kerala. The first phase, with 450 towers, will cover all major cities, district headquarters and prominent towns. Fifty-nine towers will be set up in Ernakulam and Idukki districts during the second phase, extending the coverage to panchayat areas. The Table 1.2, gives the details of CSN and ASN for WiMAX Network in India.

1.8 OBJECTIVES AND THESIS ORGANIZATION

The main objectives of the present research are:

The objective of the research is to analyze the physical layer performance of WiMAX communication system using fading channels. The wireless channel is characterized by: Path Loss, Multipath Delay Spread, Fading Characteristics, Doppler Spread, Cochannel and Adjacent Channel Interference. All the model parameters are random in nature, and only a statistical characterization of them is possible. They are dependent upon terrain, tree density, antenna height, beamwidth and wind speed. In practice, most simulation studies use empirical models like Hata Model, COST 231 Extension to Hata Model, COST 231-Walfish-Ikegami Model, Erceg Model, Stanford University Interim (SUI) Channel Models and ITU Path Loss Models that have been developed, being based on measurements taken in various real environments. The SUI channel model has been considered for incisive analysis. Hari (2000), the author, proposed a six interim channel model for G2 MMDS fixed broadband wireless communication application. The channel model is heavily dependent upon the radio architecture. Daniel S. Baum (2001) has proposed the simulation of the SUI models that will go a
long way in the implementation of these models into a software channel simulator.

This model can be used for simulations, design, and development and testing of technologies suitable for fixed broadband wireless applications. The simulation is performed for Fixed WiMAX, and the performance measures are taken for the bit error rate (BER) versus the ratio of bit energy to noise power spectral density (Eb/No). The investigation involves several modulation techniques for fixed WiMAX based OFDM system including BPSK, QPSK, 16QAM and 64QAM with different cyclic prefix and FEC which are tested for SUI channels conditions with different channel bandwidth.

The rest of the thesis is organised as follows.

Chapter 2: Presents the literatures available in the field of Fixed WiMAX communication system.

Chapter 3: Presents the comparative Study of SUI Channels in Fixed WiMAX communication system using Different Cyclic Prefix.

Chapter 4: Presents the Forwarded Error correction(FEC) and Bandwidth Efficiency Analysis of Fixed WiMAX communication system.

Chapter 5: The conclusions derived from this research work and works for the future research are provided.