

Performance and Capacity Evaluation for Mobile WiMAX IEEE 802.16m Standard

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Abstract The next generation of mobile WiMAX is IEEE 802.16m which amends the IEEE 802.16e specification to provide an advanced air interface for operation in licensed bands. It is a recommended candidate for 4G. For the next generation mobile networks, it is important to consider increasing peak, sustained data rates, spectral efficiencies, system capacity, cell coverage, and providing QoS. In this paper the capacity estimation for both downlink and uplink direction in IEEE 802.16m, is presented. Moreover, bandwidth and minimum demand for different distribution modeling and different classes of services, VoIP, Video Conference, Streaming Media, Web browsing, Multiplayer interactive gaming, and Media Content downloading at channel bandwidth of 20MHz. Matlab simulation programs are also considered.

Keywords: WiMAX, broadband wireless, adaptive modulation

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1. Introduction

One of the newest technologies, that satisfy the ongoing demand for faster data rates with longer transmission ranges and that are thus suitable for new applications is mobile WiMAX. Mobile WiMAX will compete with cellular, Wi-Fi, and last-mile Internet access technologies such as DSL and cable.

The next generation of mobile WiMAX is IEEE 802.16m amends the IEEE 802.16e specification to provide an advanced air interface for operation in licensed bands. It is a recommended candidate for 4G. Unlike other wireless standards, WiMAX allows data transport over multiple broad frequency ranges. This lets the technology avoids using frequencies that would interfere with other wireless applications.

IEEE 802.16 is a set of telecommunications technology standards aimed at providing wireless access over long distances in a variety of ways- from point-to-point links to full mobile cellular type access. It covers a metropolitan area of several kilometers and is also called Wireless MAN. Theoretically, a WiMAX base station can provide broadband wireless access in range up to 35 miles (56 kms) for fixed stations and 3 to 10 miles (5 to 15 kms) for mobile stations with a maximum data rate of up to 70 Mbps as shown in [1]. Compared to Wi-Fi with 54 Mbps for the currently adopted IEEE 802.11g version, to several hundred meters, CDMA2000 with 2 Mbps for a few kms, or 3G cellular's maximum data rate is about 3 Mbps [2].

2. Features of IEEE 802.16m

The system profile for the next generation of mobile WiMAX is expected to be based on IEEE 802.16m, which is targeted for completion in 2010 and certification/deployment in 2011/2012.

The following are some of the key enhancements expected in 802.16m:

- Higher spectrum efficiency through more advanced and higher-order MIMO solutions, including multiuser MIMO as well as lower MAC and PHY overhead
- Higher peak and user data rates using wider-band carriers (including 20 MHz) and multicarrier aggregation
- Enhanced coverage in high interference environments with improved preamble and control channel
- Lower latency through faster MAC/signaling
- Support for higher mobility through a faster feedback mechanism and link adaptation
- Flexible spectrum deployments (both FDD and TDD support in contiguous and noncontiguous bands)
- Optimizations for improved inter-working and coexistence with other access technologies such as 3G systems, Wi-Fi, and Bluetooth.
- Support for integrated multi-hop relay and femto-cells
- Improved power saving operation.

All features and enhancements in 802.16m/ WiMAX release 2 are required to be backward compatible with previous releases.

2.1. Physical Layer of IEEE 802.16m

This section contains an overview of some Physical Layer enhancements that are currently being considered for inclusion in future systems.

2.1.1. Flexibility Enhancements to Support Heterogeneous Users in IEEE 802.16m

Because the goal of future wireless systems is to achieve the needs of different users, efficient and flexible designs are needed. For some users (such as streaming low-rate applications) link reliability may be more important than high data rates, whereas others may be interested in achieving the maximum data rate even if a retransmission takes place [3]. For these reasons, the frame format, the subcarrier mapping schemes and the pilot structure are being modified for 802.16m with respect to 802.16e. The general structure of WiMAX frame consists of a downlink (DL) and an uplink (UL) part separated in time by an OFDMA symbol and is of variable size [4,5,6]. The (downlink or uplink) frame begins by control information that all users employ to synchronize and to determine if and when they should receive or transmit in the given frame. Control information is followed for data transmission by the base station (in the downlink subframe) or the mobile stations (in the uplink subframe). For each mobile station, transmission or reception happens in blocks that are constructed from basic units called slots. Each slot can be thought of as a two-dimensional block, one dimension being the time, the other dimension being the frequency. In general, a slot extends over one subchannel in the frequency direction and over 1 to 3 OFDMA symbols in the time direction, depending on the permutation scheme. The subchannels are groups of OFDMA subcarriers. The number of subcarriers per subchannel and the distribution of the subcarriers that make up a subchannel in the OFDMA symbol are determined based on the permutation scheme. As explained in more detail below, the subcarriers of a given subchannel are not always consecutive in frequency. Downlink and uplink subframes can be divided into different zones where different permutation schemes are used [1,7].

In the Partial Usage of Subchannels (PUSC) zone that is mandatory, the priority is to improve diversity and to spread out the effect of inter-cell interference. Each slot extends over 2 OFDMA symbols, and a subchannel consists of 24 data subcarriers that are distributed over the entire signal bandwidth (OFDMA symbol). When PUSC is used, the available subchannels are distributed among base stations so that adjacent base stations would not use the same subchannels. When the inter-cell interference is not significant, as in the case of mobile stations located closely to a base station, it may be advantageous to employ Full Usage of Subchannels (FUSC). The goal of the FUSC permutation scheme is similar to PUSC, i.e., to improve diversity and to spread out the effect of inter-cell interference. However, as the name suggests, in the FUSC zone all subchannels are used by a base station. For this reason, the design of the pilot pattern for the FUSC zone is slightly more efficient compared to PUSC. A subchannel in

the FUSC permutation zone consists of 48 data subcarriers and the slot only comprises one OFDMA symbol.

Several antenna techniques are supported by IEEE 802.16m including single- and multiuser Multiple-Input Multiple-Output (MIMO) in both spatial multiplexing and beam forming, as well as transmit diversity schemes such as Open-loop and Closed-loop transmit diversities. For single-user MIMO (SU-MIMO), only one user is scheduled in one Resource Unit (RU) and only one FEC block exists at the input of the MIMO encoder, meanwhile for multi-user MIMO (MUMIMO), multiple users can be scheduled in one RU, and multiple FEC blocks exist at the input of the MIMO encoder. Current Mobile WiMAX profiles include support for up to 2 transmit antennas even though the IEEE 802.16e standard does not restrict the number of antennas, and allows up to 4 spatial streams. The current aim for Next Generation WiMAX systems is to support at least up to 8 transmit antennas at the base station, 4 streams and Space-Time Coding.

2.1.2. Interoperability and Coexistence

In order for the standard to be able to support either legacy base and mobile stations or other technologies (e.g. LTE), the concept of the time zone, (an integer number greater than 0) for consecutive subframes, is introduced.

The 802.16m Network Reference Model permits interoperability of IEEE 802.16m Layer 1 and Layer 2 with legacy 802.16 standards [8,9]. The motivation for ensuring interoperability comes from the fact that WiMAX networks have already been deployed, and it is more realistic to require interoperability instead of an update of the entire network. Another advantage is that each 802.16 standard provides specific functionalities in a WiMAX network. The goal in 802.16m is to enable coexistence of all these functionalities in a network without the need to create a new standard that contains all of them. The frame structure is summarized in Figure 1. The legacy standard can transmit during the legacy zones (also called LZones), whereas 802.16m capable stations can transmit during the new zones. The Uplink (UL) portion shall start with the legacy UL zone, because legacy base stations, mobile stations or relays expect IEEE 802.16e UL control information to be sent in this region. When no stations using a legacy 802.16 standard are present, the corresponding zone is removed. The zones are multiplexed using TDM in the downlink, whereas both TDM and FDM can be used in the uplink. The Access Service Network can be connected with other network infrastructures (e.g. 802.11, 3GPP etc.) or to the Connectivity Service Network in order to provide Internet to the client.

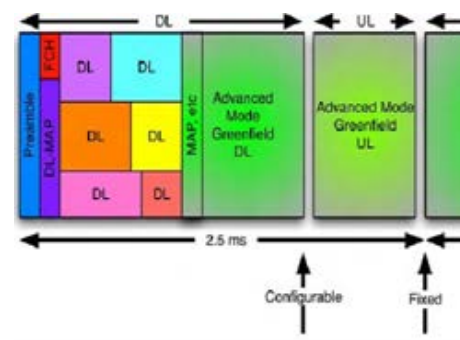


Figure 1. IEEE 802.16m frame structure with TDM Downlink and FDM Uplink [8,10]

2.1.3. Basic Functionality of Mac Layer in WiMAX IEEE 802.16m

In WiMAX technology, second network layer plays some critical roles in the specification such as packeting and fragmentation, channel allocation, scheduling, QoS, security provision and finally mobility management [11,12]. In WiMAX networks the power saving implementation incorporates service differentiation on power classes. MAC addresses play the role of identification of individual stations. IEEE 802.16m introduces two different types of addresses in the MAC sublayer. 1) The IEEE 802 MAC address that has the generic 48-bit format and 2) two MAC logical addresses that are assigned to the mobile station by management messages from the base station.

3. Mathematical Analysis for IEEE 802.16m

In this section an algorithm to estimate the capacity for Mobile WiMAX in both downlink and uplink directions based on traffic modeling will be introduced. Some basic assumptions for modulation and applications distribution adopted from references will be explained in details. For QoS support, two parameters (CR and OSR) are introduced that have a significant roll in system resource allocations and scheduling modeling. A step by step PHY and MAC overheads and bandwidth estimations are also considered. Finally, a Matlab simulation for the proposed algorithm is presented and its results are illustrated.

3.1. Contention Ratio (CR)

CR is a measure of the simultaneity of users requesting bit rate from the Base Stations. In simplest terms it means that, the absolute peak demand on shared resources rarely occurs. According to the algorithm, there are two contention ratios defined for the non-guaranteed partition of the bandwidth. Typical values for contention ratios can be about 30 for residential users (less priority) up to 10 for business users (higher priority and throughput). For example, if a Residential Class and a Business Class Subscribers have contracted a downlink BE service of the rates 512 kbps and 1Mbps respectively, $512/30=17$ kbps and $1000/10=100$ kbps are the actual data-rates that must be considered in the system total capacity calculations [13].

3.2. Over Subscription Ratio (OSR)

Table 1. Modulation Distribution Assumption

Modulation Type	Coding Rate	Weight	K
BPSK	1/2	5%	1
QPSK	1/2	2.5%	2
	3/4	2.5%	2
16-QAM	1/2	5%	4
	3/4	5%	4
64-QAM	2/3	40%	6
	3/4	40%	6

OSR is the ratio of the total subscriber's demand over the reference capacity of the base station when taking into account the adaptive modulation. The reference capacity of the base station corresponds to the available bit rate of the lowest modulation scheme served with that BS. According to Table 1 the lowest modulation level is BPSK1/2. The assumption belongs to the DL direction in an urban environment and the value k refers to the number of bits per symbol in each modulation type.

The reference capacity for the system reported here can be expressed as:

$$C_{ref} = \frac{FFT_{used}}{2T_s} \quad (1)$$

Where, the values for FFT_{used} (the number of used data subcarriers) and T_s (the total symbol duration ms) depend on the channel bandwidth and the Cyclic Prefix factor respectively.

The total subscriber's demand capacity refers to the repartition of the subscribers based on their type of service. For example residential class occupies 58% of the users under cover of the base station while the business class users are confined to 42%. In this case the total capacity for OSR calculation would be:

$$C_{tot} = N \times (58\% \times 512 + 42\% \times 1000) \quad (2)$$

$$OSR = C_{tot} / C_{ref}$$

Where, N refers to the number of users that are connected to the base station. As mentioned before OSR is a measure of QoS in cell planning.

3.3. Application Distribution

There are several applications that are defined based on IEEE-802.16e-2005 standard. The WiMAX Forum has broken these applications into five major classes that are:

1. Multiplayer interactive gaming,
2. VoIP and Video Conference,
3. Streaming Media,
4. Web browsing and instant messaging,
5. Media Content Downloading [14].

Table 2. Application Distribution Assumption [13]

Application	Date-rate (kbps)	Weight
Multiplayer interactive gaming	50	25.0%
VoIP and Video Conference	32	10.0%
Streaming Media	64	12.5%
Web browsing and instant messaging	Nominal	32.5%
Media Content Downloading	BE	20.0%

According to the WiMAX Forum publications for the Mobile Profile applications the first application class (Interactive Gaming) needs a minimum reserved data rate of 50 kbps for each user. The second class belongs to the CBR (Constant Bit Rate) service type with the average reserved data rate of 32 kbps for each user. The Streaming Media application group can be classified into VBR (Variable Bit Rate) services with reserved data rate of 64 kbps [12,13]. The last two application classes can be considered as BE (Best Effort) service type. The web browsing application group can be assigned the nominal data-rate of the user and the FTP class is supported with the remaining capacity assigned to each Subscriber that is available after satisfying other guaranteed service types.

Table 2 summarizes this model which is the final distribution that will be taken in to consideration in our capacity calculation algorithm. In this algorithm, the traffic demand is categorized into 2 subscriber classes (residential, and business) classes.

3.4. Bandwidth Estimation

We can obtain channel's raw bandwidth according to [10,13] as:

$$BW_{raw} = \frac{FFT_{used} \times \sum (\%P \times K \times OCR)}{T_s} \quad (3)$$

Where, %P is the percentage (weight), k is the number of bits per symbol and OCR is the overall coding rate, respectively, for each modulation type as can be found in Table 1. The FFT_{used} and T_s and based on the modulation distribution assumption in Table 1.

DL: UL Ratio: is DL and UL sub-frames ratios are separated with an 11.4 μ s transmission gap. The DL: UL ratio is used to calculate the available data rate (Raw BW) in each direction also used to calculate the duration of DL subframe (TDL) and UL duration (TUL) as:

$$\begin{aligned} T_{DL} &= DL / (DL + UL) \times T_f \\ T_{UL} &= UL / (UL + DL) \times T_f \end{aligned} \quad (4)$$

Where the WiMAX profile supports DL: UL ratios ranging from 3:1 to 1:1 to accommodate different traffic profiles, and T_f is the frame duration, $T_f = \{2.5, 4, 5, 8, 10, 12.5, 20 \text{ ms}\}$ [12].

UL/DL Traffic Ratio: the traffic ratio is used to obtain the UL traffic demand based on the DL demand, while the total bandwidth is shared between DL and UL and the system parameters of the DL direction are available so in order to find data rate in downlink direction (raw bandwidth BW1) based on the system parameters should be multiplied with DL / (DL+UL) and with UL / (UL+DL) for UL. Calculate raw bandwidth (BW1) based on the system parameters as:

$$BW1 = (DL / (DL + UL)) \times BW \quad (5)$$

To find out how many complete symbols (N_{S-DL}) can be embedded in the downlink subframe (T_{DL}).

$$N_{S-DL} = \left\lceil (T_{DL} - T_g) / T_s \right\rceil \quad (6)$$

Where $T_{DL} = DL / (DL + UL) \times T_f$ and $T_f = 2.5 \text{ ms}$ and $T_g = 11.4 \mu\text{s}$ (the guard time) are fixed values in Mobile WiMAX applications. The available BW can be calculated as:

$$BW2 = [N_{S-DL} \times T_s / T_{DL}] \times BW1 \quad (7)$$

The first symbol in the DL subframe is dedicated to preamble which does not carry any data to the subscribers and is used for synchronization purposes. This extra symbol from is removed the useful DL bandwidth, therefore:

$$BW3.1 = (N_{S-DL} - 1) \times BW2 \quad (8)$$

MAU: Minimum Allocation Unit refers to the smallest two-dimensional quantum of frequency and time that can

be allocated for sending data across the channel. The MAU can be calculated in bytes as:

$$MAU = [(N_C \times OCR) / N_{Sub-CH}] \quad (9)$$

Where, N_C the coded block size in bytes and OCR is the coding rate of the most robust in use modulation scheme, here 64-QAM as the worst case and N_{Sub-CH} is the number of sub-channels based on the system's channel bandwidth using PUSC permutation. MAU concept can be used in packet mismatch errors as well. In general, *Packing* and *Fragmentation* methods are used to fit the size of packets to be sent to the available MAU. In the analysis presented here, a 50% mismatch error is considered by adding MAU/2 bytes overhead to each of the data burst.

DL-MAP: The downlink map begins with eight Bytes of header information followed by a number of information elements (DL-MAP IE). There is one information element for each active connection using the downlink frame and the map must terminate with an IE marking the end of the map. Each DLMAP_ IE is at least four Bytes long to include a specific MAC connection (CID). Multiple downlink map IE may point to the same burst, so that a burst can be shared between one or more subscriber stations. Furthermore, we assume each subscriber station connecting to the sector imposes a 4 byte IE in the Map message. So,

$$\text{The DL MAP overhead} = 8 + N \times 4 + 4 + MAU/2 \text{ bytes} \quad (10)$$

Where, N represents the number of active subscribers and considering mismatch error.

UL-MAP: Practically speaking, an uplink map is essential for subscriber stations to coordinate their uplink access. The uplink map begins with 11 bytes of header information. The same as DL-MAP, each active connection represents an IE in the map message, but this time each with a length of 6 bytes. So,

$$\text{The UL MAP overhead} = 11 + N \times 6 + 6 + MAN/2 \text{ bytes} \quad (11)$$

MAC-PDU: there are some additional information bits in a MAC protocol data unit rather than the data payload. The 6 bytes long Generic Header and 4 bytes CRC checksum are always present in the PDU, while there may be some additional optional sub headers. Examples of sub-headers are packing and fragmentation that each is 3bytes long. The overall overhead imposed by MAC-PDUs in the downlink subframe can be expressed as:

$$\text{MAC - PDU}_{overhead DL} = N_{PDU} \times (6 + 4 + 3) \text{ bytes} \quad (12)$$

Data Burst: each burst is consisted of one or more MAC-PDUs that are collected under the same burst profile to be transmitted over the downlink subframe. As PDUs placed in the burst can have variable lengths, the overall size of each burst is variable too.

Uplink-Ranging: Mobile WiMAX supports Initial and periodical ranging processes as an uplink physical layer procedure that allows the BS and the MS to perform time and power synchronization with respect to each other's various radio-link parameters during the initial network entry and periodically. According to the standard the periodical ranging must be done at least every 2 seconds. So the overall overhead symbols presented with the ranging interval for the UL over a 5ms TDD frame can be estimated as:

$$N_{Ranging} = (T_f / 2000) \times (4 / N_{S-UL}) \quad (13)$$

Where, N_{S-UL} is the total number of symbols in the uplink subframe as can be obtained from (6) while the UL value is considered.

Uplink-Contention: In the uplink, the MS requests resources by either using a standalone bandwidth request MAC-PDU (BRH) or piggybacking bandwidth requests. The BRHs are sent within the contention intervals that are periodically assigned in the UL subframe. This interval starts with a one-symbol preamble followed by one or more symbols configured for the resource allocation request. The size of the allocation should be sufficient to send one BRH for each requesting MS while Each BRH is 6+4=10 Bytes (Header + CRC). The worst case would be to assume that each connecting MS is sending a BRH in each periodical polling interval. Assuming a 100ms period between each polling interval, the overall overhead symbols of contention interval for the uplink over a 5ms frame can be estimated as:

$$N_{contention} = (T_f / 100) \times \frac{(N \times 10 / MAU) + 1}{N_{S-UL}} \quad (14)$$

The piggybacking bandwidth request refers to the subscribers that have already allocated uplink access by contention or polling process to inform the base station that they require another allocation to send pending data. To do so the subscriber adds 2 bytes Grant Management (GM) Sub-header in its MAC-PDU. In this case the overall overhead bytes imposed by PDUs would be:

$$MAC - PDU_{overheadUL} = N_{PDU} \times (6 + 4 + 3 + 2) \text{ Bytes} \quad (15)$$

3.5. Maximum User Per Sector Determination

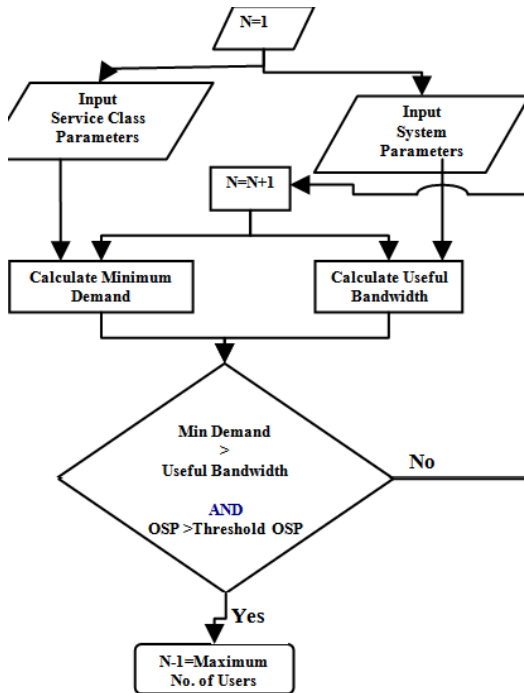


Figure 2. Maximum Number of Users per Sector Calculation Algorithm

In the work reported here, the maximum amount for users that can be simultaneously supported by a sector with respect to the previously obtained information is

calculated. Figure 2 illustrates a flow chart for this methodology.

4. Computer Simulation

The above algorithm can be implemented in both DL and UL directions, separately. It works as follows; first we start with one single user trying to connect to the sector. In the second step, based on the two types of input (service class and system parameters), the Minimum Demand data-rate and the available bandwidth are to be calculated. The traffic demand is calculated for residential and business class subscribers and the Total Traffic Demand for DL and UL is obtained according to Table 2. The overhead removal procedures described in section 3-4 are then applied to estimate the useful bandwidth. The traffic demand and useful bandwidth are compared to check if the load in both DL and UL can be served. If there is enough bandwidth available, the number of subscribers is increased by one and the channel availability process is being rechecked by comparing the additional data-rate required by the added user. Whenever the minimum demanded data-rate exceeds the amount of available bandwidth in each direction, the algorithm stops and introduces the maximum number of subscribers that can be simultaneously served by the particular sector.

An additional feature to provide QoS control in network planning projects is the OSR parameters, discussed in Section-3.2. This parameter can be calculated using (eq.-2) and implemented in the above procedure each time the number of users is increased. This is continued until it reaches the threshold value in the input.

In this part of work, three different case-studies for each Business Class Subscribers, Residential Class Subscribers and both are considered based on different system parameters and traffic services. Results for each case based on IEEE 802.16m standard are illustrated in Table 3 and Table 4, and Figure 3, Figure 4, and Figure 5. The input values are chosen according to the practical situations. The case-studies are arranged in an order to arrive at an optimized conclusion. Matlab programming code procedure is designed to perform the above mentioned procedure and the results are explained as follows.

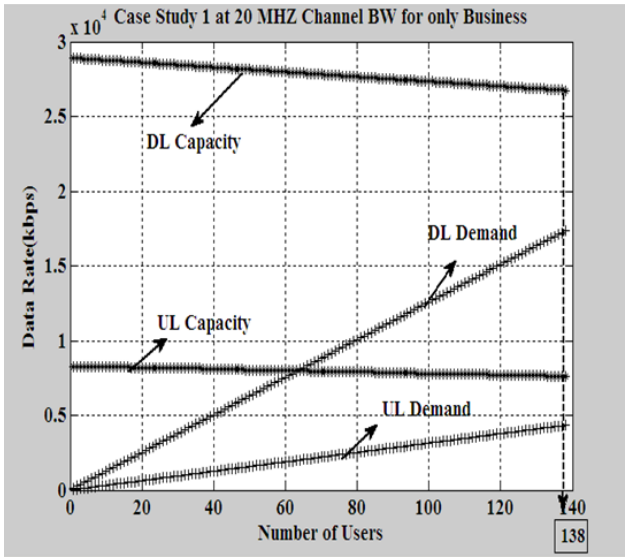
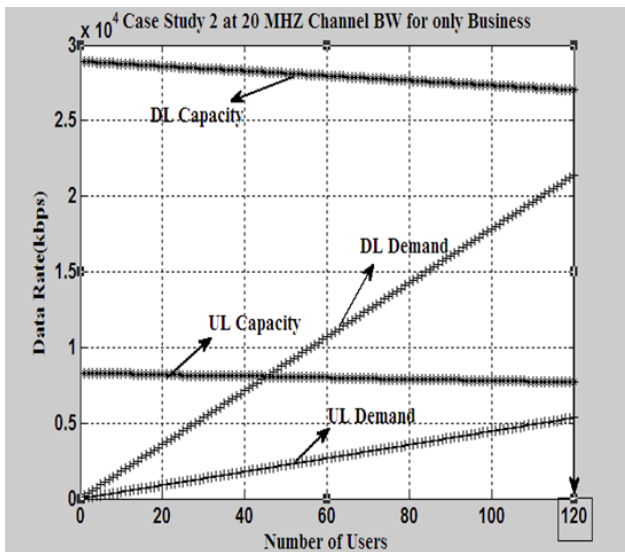
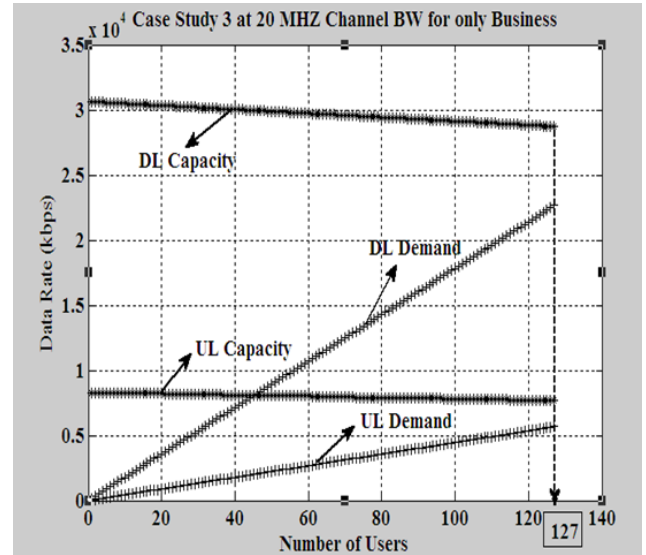
Table 3. Parameters for Case Studies

Parameters	Case Study 1	Case Study 2	Case Study 3
Channel bandwidth (MHz)	20	20	20
Subframe ratio (DL/UL)	3/1	3/1	7/2
Cyclic prefix rate	8	8	16
DL/UL traffic ratio	4	4	4
PDUs per data burst	2	2	2
Connections per PDU	2	2	2
Over Subscription Ratio (OSR) [Threshold]	50	65	65
DATA-RATE for Business Class Subscribers (kbps)	2000	3000	3000
DATA-RATE for Residential Class Subscribers (kbps)	512	1000	1000

The above parameters are fixed for all experiments.

Table 4. Parameters Specific for Each Class of Subscribers

Class of Subscribers	Parameters	Value
Only Business Class Subscribers	Percentage of Business Class Subscribers	100%
	Contention Ratio for Business Class Subscribers	10
Business and Residents Class Subscribers	Percentage of Business Class Subscribers	40%
	Percentage of Residential Class Subscribers	60%
	Contention Ratio for Business Class Subscribers	10
	Contention Ratio for Residential Class Subscribers	30
Only Residents Class Subscribers	Percentage of Residential Class Subscribers	100%
	Contention Ratio for Residential Class Subscribers	30

**Figure 3. (a)** Case-Study-1 for WiMAX IEEE 802.16m only Business Class Subscribers**Figure 3. (b)** Case-Study-2 for WiMAX IEEE 802.16m only Business Class Subscribers**Figure 3. (c)** Case-Study-3 for WiMAX IEEE 802.16m only Business Class Subscribers

It can be seen from Figure 4 for Case-Study-1, the sector with the specified parameters can support 138 mixed traffic users (based on the values listed on Tables 1 and 2). As the number of users reaches 138, the peak data-rate in DL reaches 26719.7kbps instead of 28905.5kbps. In the same time, the minimum demand data rate is 17357.6kbps with the available bandwidth in the DL. When three sector antennas are used, the above values will be multiplied by three, that is, the cell can support up to $138 \times 3 = 414$ users. Moreover, using MIMO can increase the system capacity by a factor equal to the minimum number of antennas in both sides of the link. for example for 4×4 MIMO system the capacity will be 115622 kbps which is increased by factor of 4, similarly for 4×2 MIMO, the capacity will be 57811 kbps is increased by factor of 2.

In Case-Study-2, the system parameters are kept the same as Case-Study-1. Only the Service class parameters are changed. The subscribers in both residential and business service classes are assigned higher data-rate values, since Case-Study-2 is offering more data-rate per user, and it suffers more over subscription ratio.

It is seen from the results of Case-Study-3 that a greater increase in DL peak data rate as compared to Case-Study-2. Introduce a greater peak data-rate in the downlink 30613.5 kbps instead of 28905.5 kbps in Case-Study2. Note that the DL: UL Ratio assignment must be done in an efficient way to provide both directions with the required capacity. The system based on the new parameters in Case-Study-3 can support 127 subscribers that are 7 more user compared with Case-Study-2. In other words, in Case-Study-3 the system capacity and demand are matched in an optimized way, as both DL and UL entire capacities are efficiently filled with each direction's traffic demand. When three sector antennas are used, the above values will be multiplied by three, that is, the cell can support up to 414, 360, and 381 simultaneous users for Case-Study-1, Case-Study-2, and Case-Study-3 respectively. Moreover, in 4×4 MIMO system the capacity will be 122.454 Mbps which is increased by factor of 4.

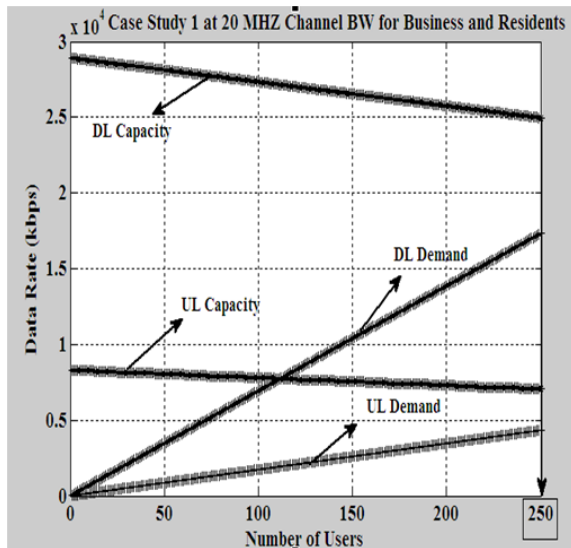


Figure 4. (a) Case-Study-1 for WiMAX IEEE 802.16m Business and Residents Class Subscribers

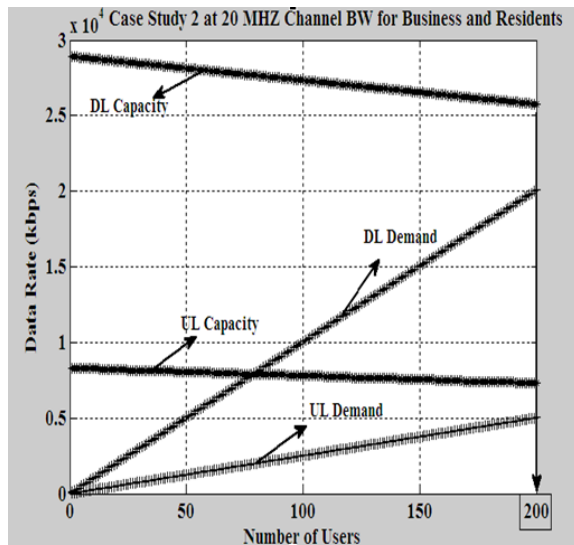


Figure 4. (b) Case-Study-2 for WiMAX IEEE 802.16m Business and Residents Class Subscribers

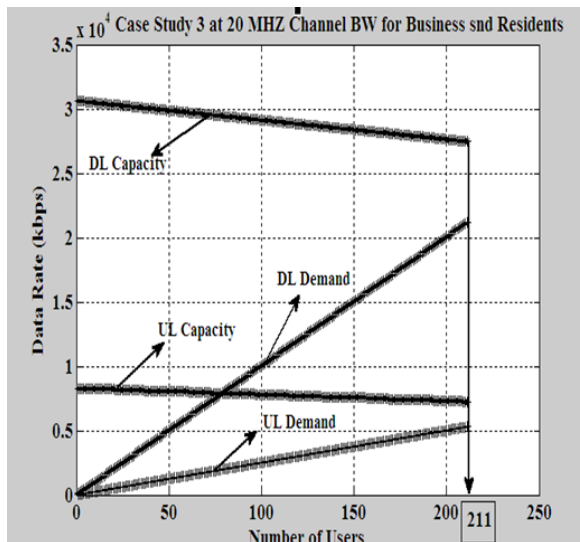


Figure 4. (c) Case-Study-3 for WiMAX IEEE 802.16m Business and Residents Class Subscribers

From Figure 4, for business and residents users, it can be seen that, the sector with the specified parameters can

support 250, 200, and 211 simultaneous users for each Case-Study-1, Case-Study-2, and Case-Study-3 respectively. When three sector antennas are used, the above values will be multiplied by three, that is, the cell can support up to 750, 600, and 633 simultaneous users for Case-Study-1, Case-Study-2, and Case-Study-3 respectively.

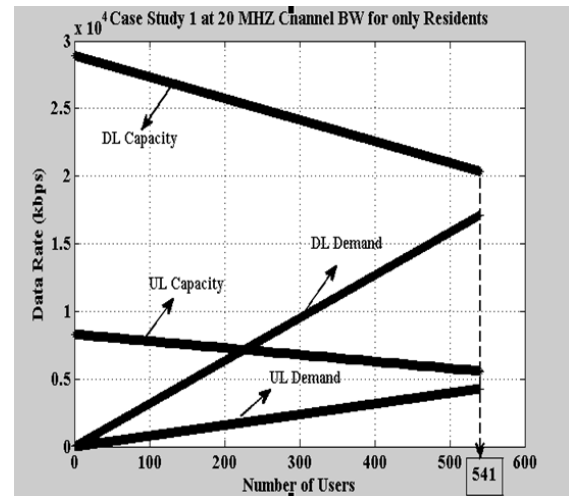


Figure 5. (a) Case-Study-1 for WiMAX IEEE 802.16m for Only Residents Class Subscribers

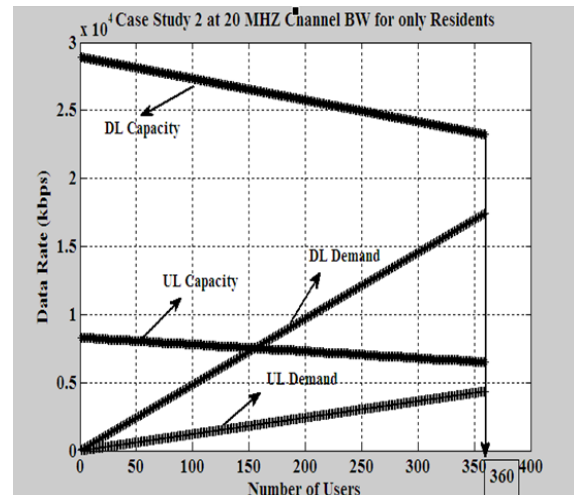


Figure 5. (b) Case-Study-2 for WiMAX IEEE 802.16m for Only Residents Class Subscribers

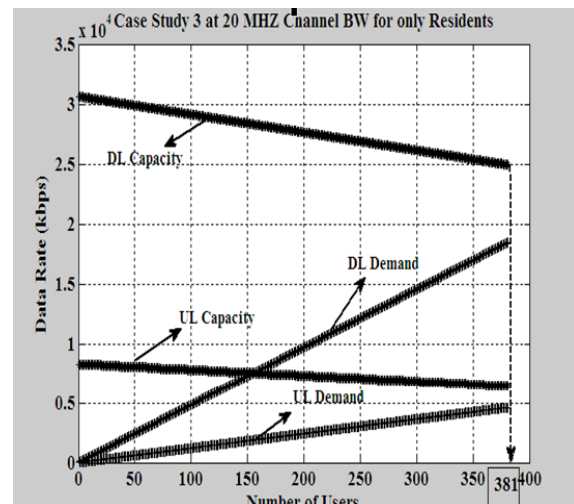


Figure 5. (c) Case-Study-3 for WiMAX IEEE 802.16m for Only Residents Class Subscribers

In Figure 5, for resident users only, it can be seen that, the sector with the specified parameters can support 541, 360, and 381 simultaneous users for each Case-Study-1, Case-Study-2, and Case-Study-3 respectively. When three sector antennas are used, the above values will be multiplied by three, that is, the cell can support up to 1623, 1080, and 1143 simultaneous users for Case-Study-1, Case-Study-2, and Case-Study-3 respectively. Moreover, in 4×4 MIMO system the capacity will be 122.454 Mbps which is increased by factor of 4. If three sectors per cell are used, these values are increased will be by factor of three, then the peak available data rate will be increased to 367.362 Mbps.

5. Conclusions

In this paper the IEEE 802.16m WiMAX standards are analyzed and the system capacity is examined in three different case studies. It is noticed that due to dynamic allocation of different modulations and coding rates the channel capacity varies depending on link conditions. This becomes a real challenge when attempting to predict the overall capacity of a WiMAX base station in advance. The WiMAX TDD frame structure placed overhead along data, therefore, overhead removal method is used to estimate exact available data rate. The bandwidth and minimum demand for different distribution modeling and different classes of services, VoIP, Video Conference, Streaming Media, Web browsing, Multiplayer interactive gaming, and Media Content downloading at channel bandwidth of 20MHz are calculated as well as system capacity for UL and DL using Matlab programming. It has been found that the results are encouraging so that IEEE 802.16m may be recommended as a good candidate for 4th generation mobile system.

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