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Simulation of Four Layered WiMAX/OFDM/OFDMA PHY for NLOS application.

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ABSTRACT

The first specification of Metropolitan Area Wireless Network was approved under the IEEE 802.16 standard with product certification name of WiMAX. The IEEE 802.16-2004 standard has been developing to add NLOS applications support to the basic standard. This standard serves will fix and nomadic users in the frequency range of 2 – 11 GHz. In order to add mobility to wireless access, the WiMAX, IEEE 802.15e-2005 specifications should be utilize with the frequencies below 6 GHz. There are multiple physical-layer choices, within IEEE 802-16 standard are available. To grant interoperability the WiMAX Forum defines a limited number of system profiles and certification profiles. In this work, two different system profiles are plane to define: one based on IEEE 802.16-2004, OFDM PHY, called the fixed system profile; the other one based on IEEE 802.16e-2005 scalable OFDMA PHY, called the mobility system profile. The Mobile WiMAX standard will be develop to the best wireless broadband standard for portable devices which are enabling a new era of high throughput and high delivered bandwidth together with exceptional spectral efficiency when compared to other 3G+ mobile wireless technologies. In this simulation work, location distance based data rate in 4- layer design have to be used and enhance the number of supported subscribers.

Keywords: WiMAX, OFDM PHY, IEEE 802.16-2004, TDMA

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INTRODUCTION

It is well known that the NP-hard problem has mainly exhibit due to the planning of wireless radio network problem [1-3]. Meta-heuristic is one of the prominent technique is used for solving this type of problem in traditional cellular networks. In the planning of wireless network, RF optimization is the key factor. Maximizing coverage, minimizing operational and capital costs is the main objective for provide a network solution. A numerous methods have described by corresponding related decision variables along with the radio-electrical and physical antenna parameters such as power values, candidate locations, activation statuses, service, transmission frequency and solving capacity and coverage planning problems have been enhanced and given to the design of UMTS [4-9] and GSM [10-16]. In spite of this, with emergence of standard WiMAX, this provided new challenges and technologies implementation such as, adaptive modulation and coding schemes (AMC), OFDMA, spatial multiplexing and space-time coding, flexible network deployment and flexible subchannelization. Nowadays, the main research attention is devoted to scheduling optimization and radio resource allocation problems disregarding the significant of RF optimization and network dimensioning. Since October 2010, the WiMAX forum obtained over 592 WiMAX for both fixed and mobile netwroks installed in over 148 countries with covering over 621 million subscibers. In 2011, cited coverage of WiMAX Forum over 823 million people and expected over 1 billion subscribers by the end of year 2011.

Network dimensioning activity is proposed to estimate and evaluate the main infrastructure requirements needed to offer capacity, coverage and quality of service. This could be estimate the operational and capital costs for designing a broadband WiMAX network with peculiar characteristics. From the literature survey, especially in WCDMA network dimensioning [17-20], required the sole purpose of dimensioning which gives a quick count of sites in response with some computational approach, which gives a basis for the further step of network planning. Thus, network dimensioning activity has revealed a great impact in the case of WiMAX network investment business. Numerous papers have been published in 3G network dimensioning techniques [21-23]. Even though, their work is constrained with two studies [24, 25] which are referred the network dimensioning of WiMAX technology. Similar approach have been used to incorporating two stages for both capacity and coverage analysis to find the required number of base sectors and stations satisfying the business model.

High speed broadband wireless networks is a most thrust area in the whole world due to the enhancement of new innovative technologies in the field of wireless networks. At present, one of the most significant wireless access technologies is IEEE 802.16e standard which is represent as WiMAX. The most prominent implementation of WiMAX standards is IEEE 802.16e. Thus, in the present work mainly concentrated on IEEE 802.16 standard.

PHYSICAL LAYER OF WIMAX

OFDM

The WiMAX physical layer is based on Orthogonal Frequency Division Multiplexing. OFDM is the transmission scheme of choice to enable high-speed data communications in broadband systems.

OFDM belongs to a family of transmission schemes called multicarrier modulation, which is based on the idea of dividing a given high-bit-rate data stream into several parallel lower bit-rate streams and modulating each stream on separate subcarriers. This technique helps us with minimizing the Intersymbol Interference (ISI). The number of substreams is chosen to ensure that each subchannel has a bandwidth less than the coherence bandwidth of the channel, so the subchannels experience relatively flat fading.

In order to keep each OFDM symbol independent of the others after going through a wireless channel, it is necessary to introduce a guard time, Tg, between OFDM symbols. This way, after receiving a series of OFDM symbols with duration Ts, as long as the guard time is larger than the delay spread of the channel, each OFDM symbol will interfere only with itself.

In order to completely eliminate the ISI and benefit a ISI-free channel Cyclic Prefix technique is used.

Figure 1 represents the concept of CP. The ratio of cyclic prefix to useful symbol time is indicated by G and can undertake values of 1/4 , 1/8 , 1/16 or 1/32.

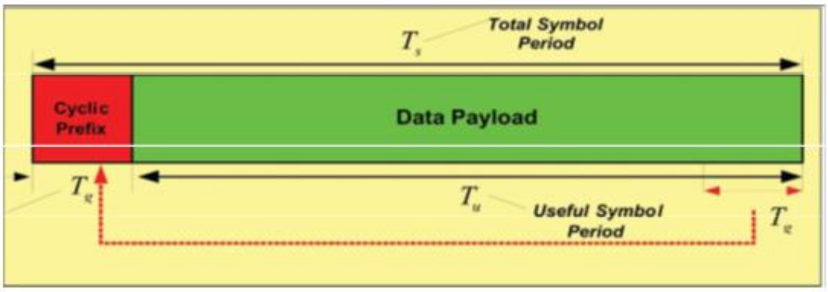

Fig 1. OFDM Symbol Structure with Cyclic Prefix

OFDMA

The total capacity available with a base station is shared among multiple users on a demand basis, using a burst TDM scheme. When using the OFDMA-PHY mode, multiplexing is additionally done in the frequency dimension, by allocating different subsets of OFDM subcarriers to different users. This is done based on subchannelization method.

Subchannelization is the method that differentiates OFDMA with OFDM. The available subcarriers within the total bandwidth can be divided into several groups of subcarriers called subchannels. Subchannels can be assigned to the users on a logical procedure based on user demands and channel conditions. OFDMA is essentially a hybrid of FDMA and TDMA: Users are dynamically assigned subcarriers (FDMA) in different time slots (TDMA).There are 4 different types of subcarriers in an OFDMA symbol. Data subcarriers and Pilot subcarriers (used for estimation and synchronization purposes). These two first types are considered Active subcarriers. DC subcarriers together with Guard subcarriers (used for guard bands) are commonly denominated as Null subcarriers. Figure 2 illustrates the OFDMA symbol's subcarrier structure.

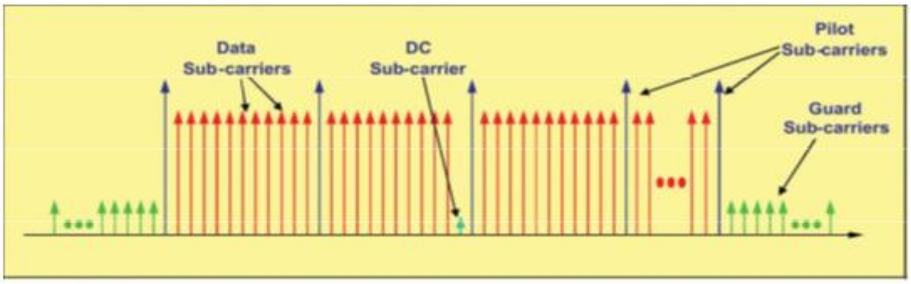

Fig 2. Frequency domain representation of OFDMA symbol

Figure 3 reveals a graphical comparison between OFDM and OFDMA considering 4 different users sharing same bandwidth in both techniques in the uplink.

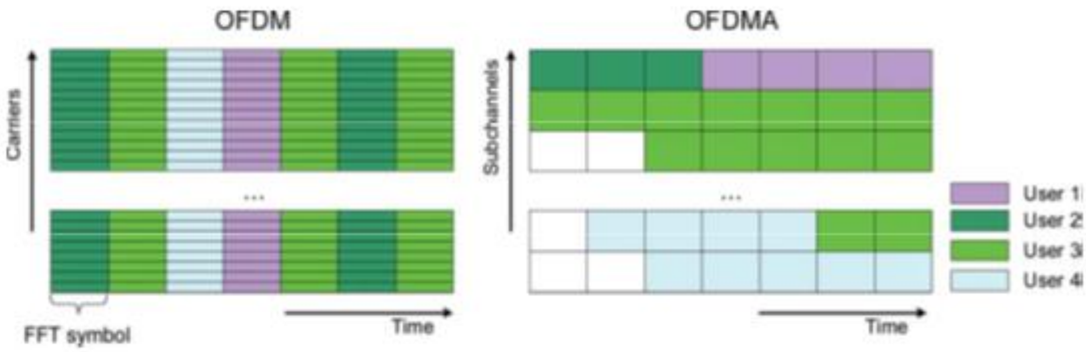

Fig 3. OFDM and OFDMA channel allocation in uplink

SOFDMA

The mobile WiMAX - IEEE 802.16e-2005, is based on Scalable Orthogonal Frequency Division Multiple Access. The available bandwidth for WiMAX can vary based on the local frequency usage over the globe and the scalability is developed to support these worldwide variations. Therefore SOFDMA refers to the capability of choosing the number of subcarriers according to the available bandwidth. The channel bandwidth can vary from 1.25 MHz to 20 MHz and thus, a number of 128 to 2048 subcarriers can be assigned to each bandwidth correspondingly.

Table 1 summarizes the OFDM symbol parameters for Fixed WiMAX (IEEE 802.16-2004) and the equivalent OFDMA symbol parameters used in Mobile WiMAX (IEEE 802.16e-2005) in downlink direction. The diverse values for parameters in OFDMA refer to the scalability concept.

Table 1: OFDM symbol parameters for Fixed WiMAX and the equivalent OFDMA symbol parameters used in Mobile WiMAX in downlink.

PARAMETER	FIXED WIMAX OFDM-PHY	MOBILE WIMAX SCALABLE OFDMA-PHY
Subcarrier frequency spacing(khz)	15.625	10.94
Useful symbol time(us)	64	91.4
OFDM symbol duration(us)	72	102.9
Cyclic prefix	1/32	1/16
Number of OFDM symbols in 5 ms frame	69	48

As can be observed in Table 1, the subcarrier distribution for Mobile profile is derived with respect to PUSC permutation mode that is the mandatory resource grouping method in IEEE 802-16e standard. In this permutation mode, the DL usable sub-carriers (pilot and data) are grouped in clusters where each cluster contains 14 contiguous sub-carriers per symbol.

THROUGHPUT AND COVERAGE

Throughput And Data-Rate

The channel efficiency concept refers to gain as higher throughput as possible utilizing an available channel bandwidth. Throughput is a measure in concern with the portion of the data rate that can be used to successfully transfer pure data (not signaling or control messages) across the given network in a given time. The following formula scales the data rate in a WiMAX OFDM physical layer:

$$R=(N_{used} * b_m * c_r) / T_s \quad (1)$$

where,

b_m is the number of bits per symbol, which is 1 for BPSK, 2 for QPSK, 4 for 16-QAM and in general if M is the modulation level in a M-QAM constellation, M= 2^ b_m.

Cr is the coding rate the symbol duration T_S, according to Figure 1, is given by

$$T_S= T_g + T_b$$
$$T_S = [G+1] T_b \quad (2)$$

Where G is the ratio T_g / T_b

The values N_{FFT} and N_{used} can be found in Table 1 and the phrase BW that refers to the channel bandwidth can be found below in Table 2.

Table 2: Mobile WiMAX Frequency parameters

Frequency band (GHz)	Bandwidth (MHz)	OFDM FFT size
(I) 2.3~ 2.4	8.75	1024
	10	1024
(II) 2.302 ~ 2.32 2.345 ~ 2.36	5	512
	10	1024
(III) 2.496 ~ 2.69	5	512
	10	1024
(IV) 3.3 ~ 3.4	5	512
	7	1024
	10	1024
(V) 3.4 ~ 3.8	5	512
	7	1024
	10	1024

As can be seen in the table, additional information such as 5 different Frequency Bands decided by WiMAX Forum for IEEE 802-16e-2005 and the nominal FFT size of each bandwidth is mentioned as well.

More information regarding the distribution of in-use frequency bands in global WiMAX deployments is presented in Figure 4.

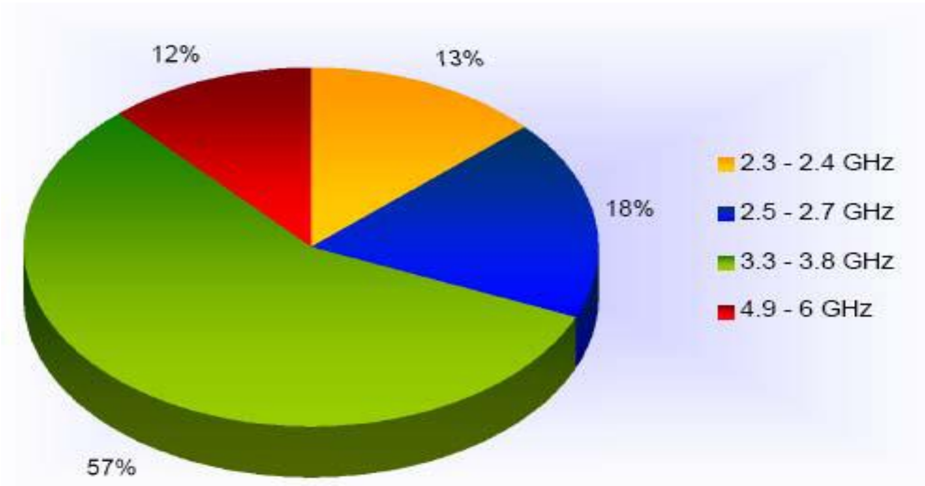

Fig 4. Global percentage of WiMAX deployments per frequency band

Based on the calculation made above, the theoretical throughput can be achieved, but it should be noted that different overhead bits are included in both physical and MAC layer implementations that must be removed to claim the practical throughput. The practical throughput can not be elaborated and all we can do is estimating an approximation.

The overheads that are added in physical layer are as follow: According to the OFDM symbol structure a cyclic prefix is added to the useful symbol duration with a G ratio. So the theoretical calculated throughput must be reduced with a factor of 4/5, 8/9, 16/17 or 32/33 according to CP configuration to extract the actual payload bits. On the other hand, in OFDMA configuration, not all the subcarriers are used to transmit data.

COVERAGE AND CELL RANGE

The following relation holds for all transmission lines included wireless channels.

$$P_r = P_t + G_t - PL + G_r \qquad (3)$$

Where, P_r is the minimum received power in the receiver.

P_t is the transmitted power.

G_t is the gain of the transmitter

G_r is the gain of the receiver.

PL is the Path Loss

QPSK VERSUS QAM

Rather than attempting to be all things to all subscribers, WiMAX delivers a gradation of QoS dependent on distance of the SS from the BS: The greater the distance, the lower the guarantee of QoS. WiMAX utilizes three mechanisms for QoS; from highest to lowest, these mechanisms are 64-QAM, 16-QAM, and QPSK. Figure 5 illustrates modulation schemes.

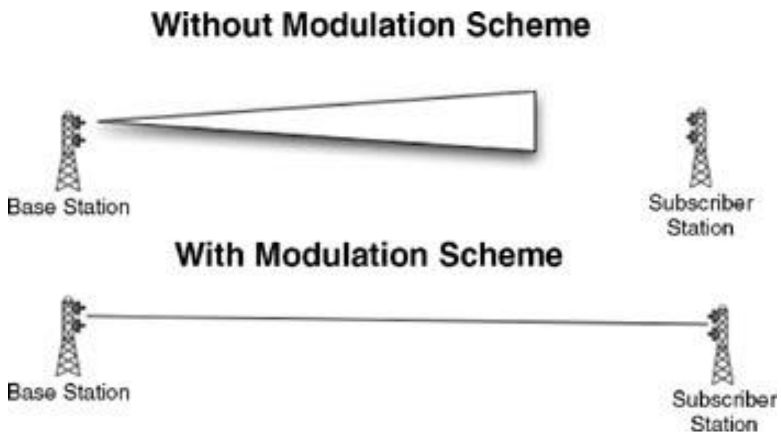

Fig 5. Modulation schemes focus the signal over distance.

By using a robust modulation scheme, WiMAX delivers high throughput at long ranges with a high level of spectral efficiency that is also tolerant of signal reflections. Dynamic adaptive modulation allows the BS to trade throughput for range. For example, if the BS cannot establish a robust link to a distant subscriber using the highest order modulation scheme, 64-QAM, the modulation order is reduced to 16-QAM or QPSK, which reduces throughput and increases effective range. Figure 6 demonstrates how modulation schemes ensure throughput over distance.

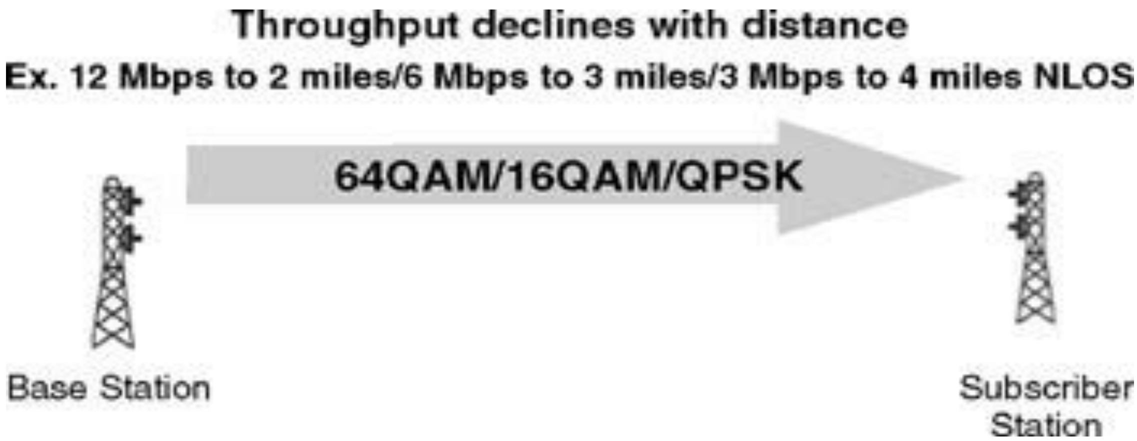

Fig 6. Modulation schemes ensure a quality signal is delivered over distance by decreasing throughput.

QPSK and QAM are the two leading modulation schemes for WiMAX. In general the greater the number of bits transmitted per symbol, the higher the data rate is for a given bandwidth. Thus, when very high data rates are required for a given bandwidth, higher-order QAM systems, such as 16-QAM and 64-QAM, are used. 64-QAM can support up to 28 Mbps peak data transfer rates over a single 6 MHz channel.

Table 3: COMPARSION TABLE

Feature	WiMax (802.16a)	Wi-Fi (802.11b)	Wi-Fi (802.11a/g)
Primary Application	Broadband Wireless Access	Wireless LAN	Wireless LAN
Frequency Band	Licensed/Unlicensed 2 G to 11 GHz	2.4 GHz ISM	2.4 GHz ISM (g) 5 GHz U-NII (a)
Channel Bandwidth	Adjustable 1.25 M to 20 MHz	25 MHz	20 MHz
Half/Full Duplex	Full	Half	Half
Radio Technology	OFDM (256-channels)	Direct Sequence Spread Spectrum	OFDM (64-channels)
Bandwidth Efficiency	<=5 bps/Hz	<=0.44 bps/Hz	<=2.7 bps/Hz
Modulation	BPSK, QPSK, 16-, 64-, 256-QAM	QPSK	BPSK, QPSK, 16-, 64-QAM

LAYER DESIGN ARCHITECTURE

LAYER DESIGN

In the 3-layer design architecture, the entire cell site is presumed to be subdivided into three layer groups depending upon distance and channel SNR parameters together taken into account. For the sake of simplified explanation, the sectorization of the cell is not shown in the diagram. Also for lucid explanation, we consider only one channel that is being allocated to the cell site. But in practice, many such channels are allocated for a cell depending upon its location. For such cases also, this method suits but the number of subscribers will be a multiplicative factor of that of a single channel being considered.

Link adaptation utilizes adaptive modulation and coding technique. According to the information received in the CQICH from the mobile station, the base station changes the modulation technique and the amount of bandwidth allotted adaptively. Thus the link adaptation technique ensures location dependent QoS. The following Figure 7 represents the architectural 3- layer cell design for link adaptation.

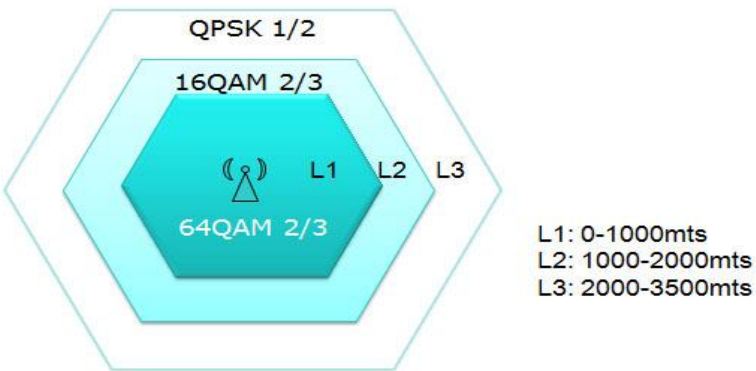

Fig 7. 3- Layer design Architecture for Link Adaptation

LAYER DESIGN

Similar to that of the 3-Layer design architecture, the first two layers beginning from the base station represented as layers L1 and L2 are maintained the same. As there exists a vast variation in the distance and the SNR in the L3 layer of 3-layer design architecture, a single modulation technique as described in the above figure represented as QPSK ½ is not sufficient to meet out the relatively required location based QoS.

Thus in-order to meet out this requirement, an additional modulation technique of the same type but of some higher coding rate can be utilized. following Figure 8 represents the architectural 4- layer cell design for link adaptation.

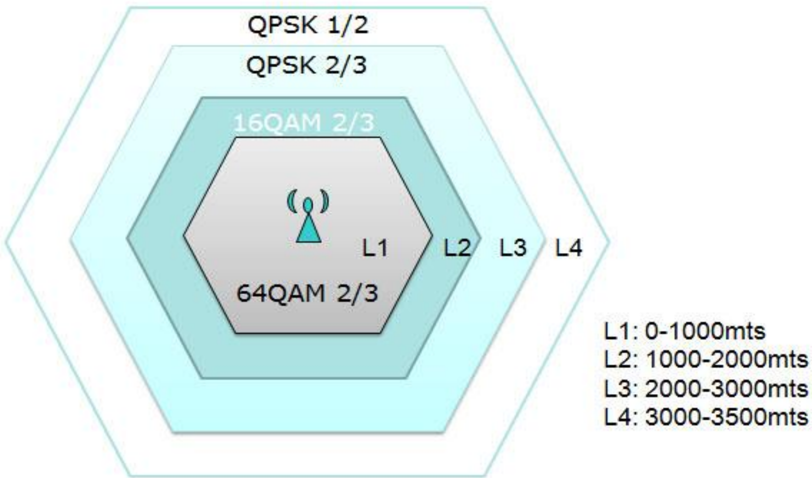

Fig 8. 4- Layer design Architecture for Link Adaptation

Estimation of Proposed Bandwidth

By now, we have introduced two major assumptions based on realistic cases to derive our sector's capacity calculation algorithm. First we defined a model for modulation distribution in order to obtain our system's raw data-rate.

The second assumption is a model for subscribers' traffic demand based on their application distribution. The next step in our algorithm is to define the system's actual throughput by detecting the overheads and removing them to gain the useful (available) data-rate.

Channel Bandwidth: is our first stage input which provides us with a number of critical parameters. Here, 5 and 10 MHz are considered that are the mostly used bandwidths. Knowing the channel width one can decide about the number of the data subcarriers (FFT_{used}) and the sub channels using PUSC permutation in each direction.

DL:UL Ratio: To obtain the Raw BW in each direction as explained in Section2.2 IT is also used to calculate the duration of DL sub frame (T_{DL}) by multiplying it to T_f =5mS (the frame duration) and UL duration as $T_{UL} = UL / (UL+DL) \times T_f$.

UL/DL Traffic Ratio: The traffic ratio is used to obtain the UL traffic demand based on the DL demand, while the system parameters of the DL direction are available.

DOWNLINK

In this section the step by step downlink overheads removal are examined in order to introduce the downlink useful bandwidth. Figure 9 summarizes the approach of DL useful channel width calculation.

The first column of Figure 9 is used to calculate raw bandwidth (BW_1) based on the system parameters obtained from initial inputs as explained procedure at the beginning of this section.

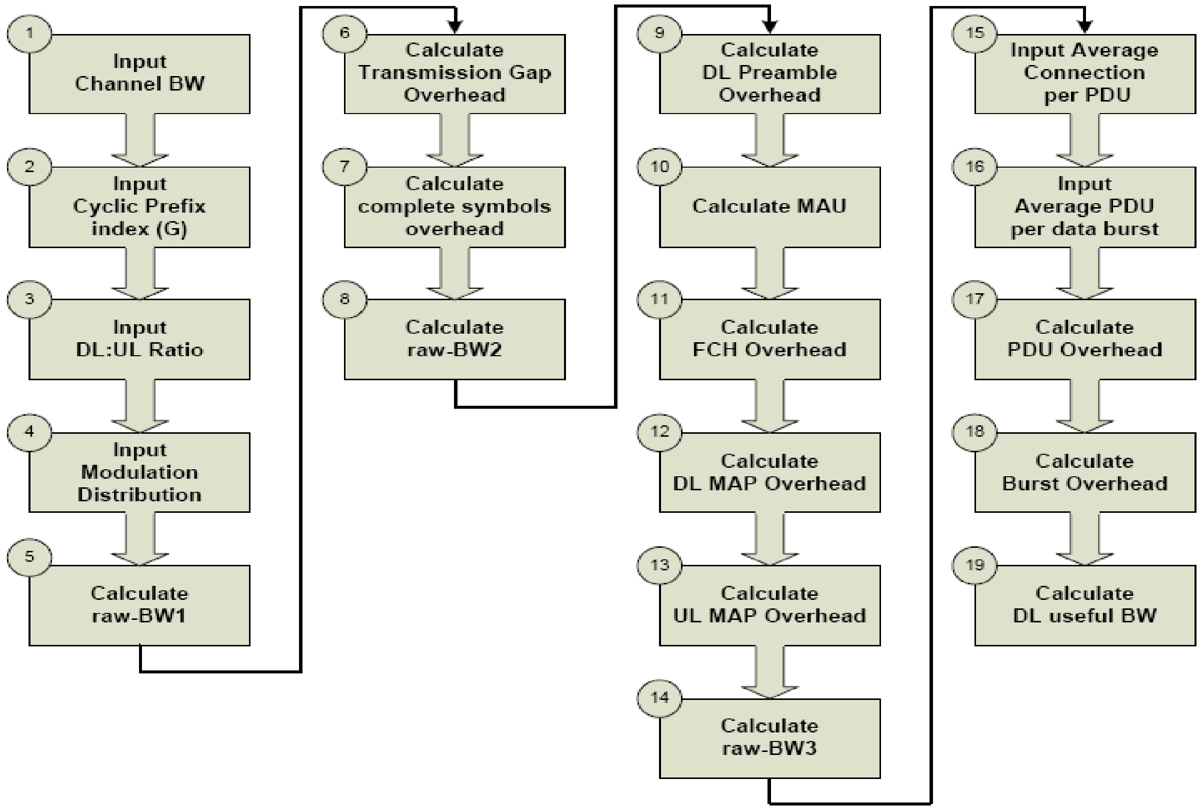

Fig 9. Downlink useful bandwidth calculation algorithm

The size of the SDU packets depends on the subscribers' application characteristics and can vary from short VoIP packets to long file transferring ones. On the other hand, the same procedure can be performed in PHY layer for resource allocation. This time Multiple or segmented MAC-PDUs can be placed in a single burst for data transmission.

This allocation ratio can be determined by introducing an average number of PDUs per data burst. Packing and fragmentation techniques in WiMAX as shown in Figure 10

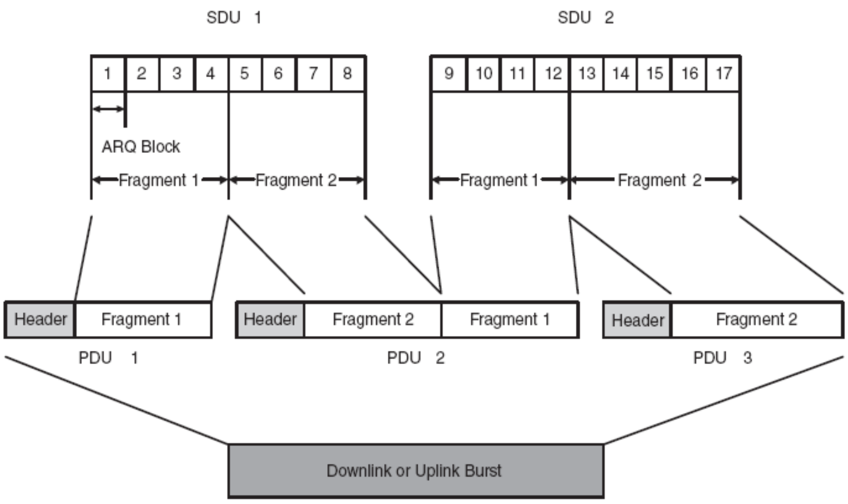

Fig 10. Packing and Fragmentation techniques in WiMAX

UPLINK

As can be observed from Figure 11 the uplink useful bandwidth calculation process is similar to the downlink in many steps.

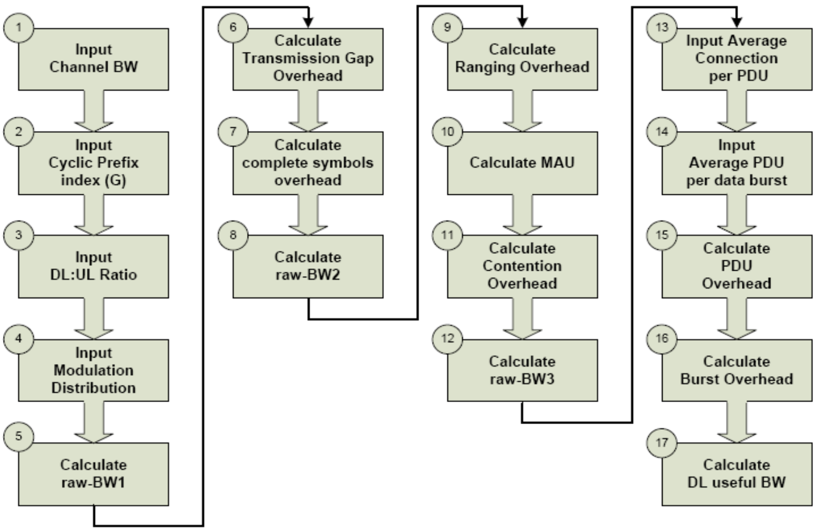

Fig 11. Uplink useful bandwidth calculation algorithm

MAXIMUM USERS PER SECTOR ESTIMATION

In this section we intend to derive an algorithm to calculate the maximum amount for users that can be simultaneously supported by a sector with respect to the previously obtained information. Figure 12 reveals an overview of this methodology.

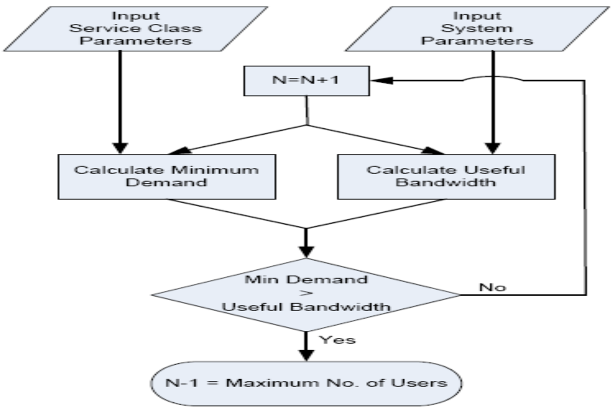

Fig 12. Maximum Number of Users per Sector Calculation Algorithm

If there is enough bandwidth available the number of subscribers' increases by one and the channel availability process is being rechecked by comparing the additional data-rate that this extra user will demand by the overhead that it imposes on the useful bandwidth.

Whenever the minimum demanded data-rate exceeds the amount of available BW in each direction, the algorithm stops and introduces the maximum number of subscribers that can be simultaneously served by the sector with already entered parameters.

SIMULATION OUTPUT

The actual input data as shown in Figure 13.

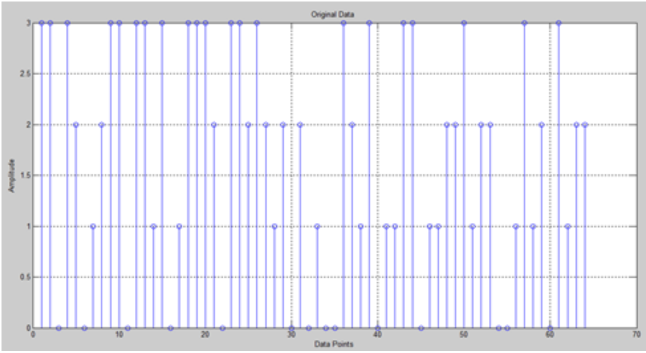

Fig 13. Orginal Data

The no. of bits =64 is added to generate the OFDM signal and have to find how many no of subcarrier the floor is used to rounds towards negative infinity. randsrc used to generate the random scalar .

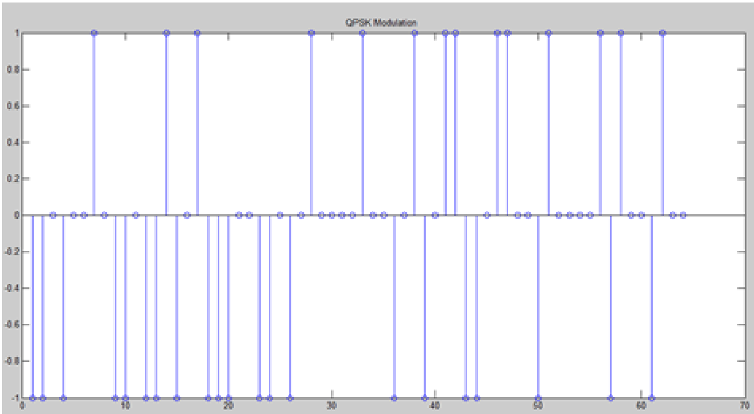

Fig 14. QPSK Modulation

Here we are using the quatemary phase shift modulation from the PSK modulation and the corresponding signal as shown in Figure 14.

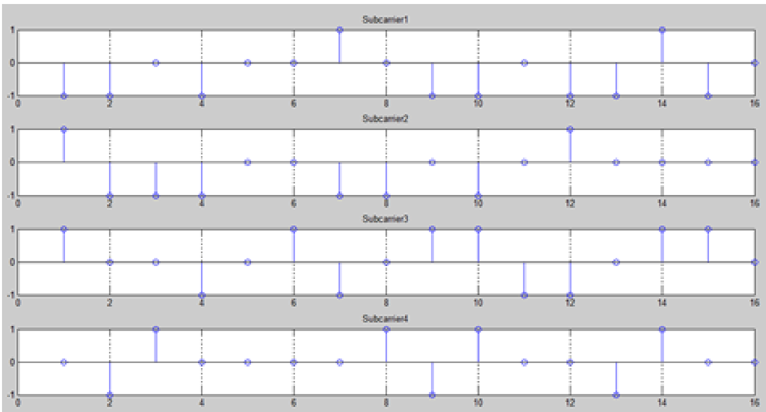

Fig 15. Subcarrier

The serial modulation signal should be convert into parallel for divide the subcarrier as shown in Figure 15.

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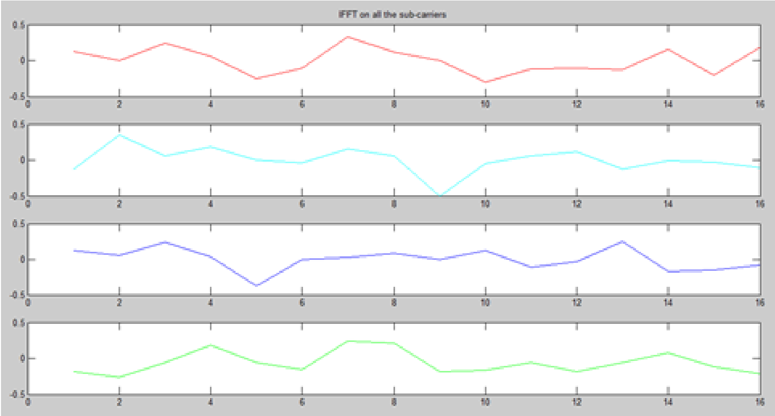

Fig 16. IFFT on all subcarrier

Cyclic starting point is getting by subcarrier the block size cyclic prefix length. The domain of subcarrier is charged by IFFT as shown in Figure 16.

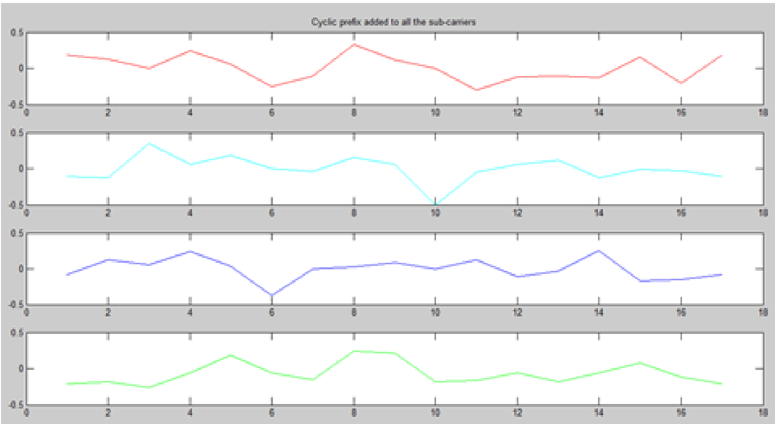

Fig 17. Cyclic Prefix added to all subcarriers

The cyclic prefix and appending prefix concatenate a ways vertically using loop condition.

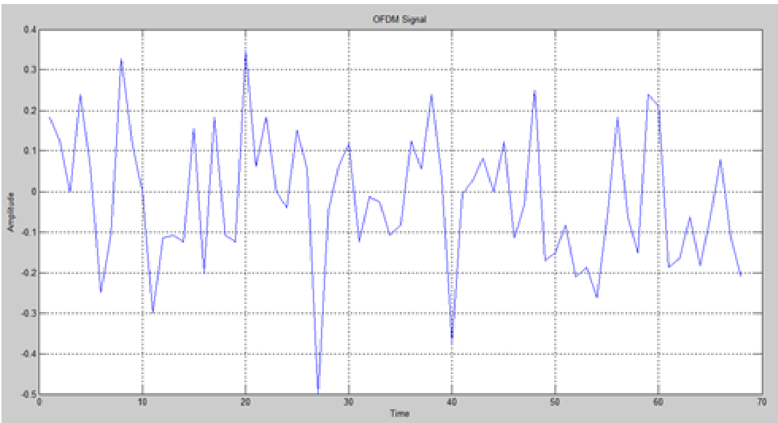

Fig 18. OFDM signal

The OFDMA signal is reshaped the stream for transmitting the OFDM signal as shown in Figure 18.

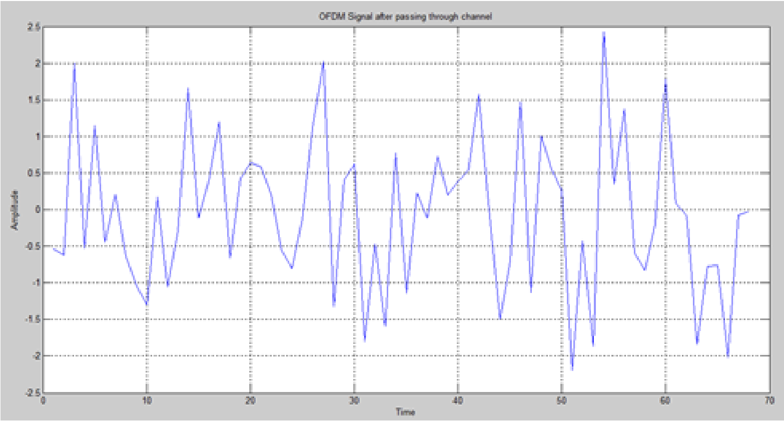

Fig 19. OFDM signal after passing through the channel

Here we are using the AWGN (Additive White Gaussian Noise) channel. Then the channel is filtered. The noise at the channel to be found and finding OFDM signal after passed through the channel as shown in Figure 19.

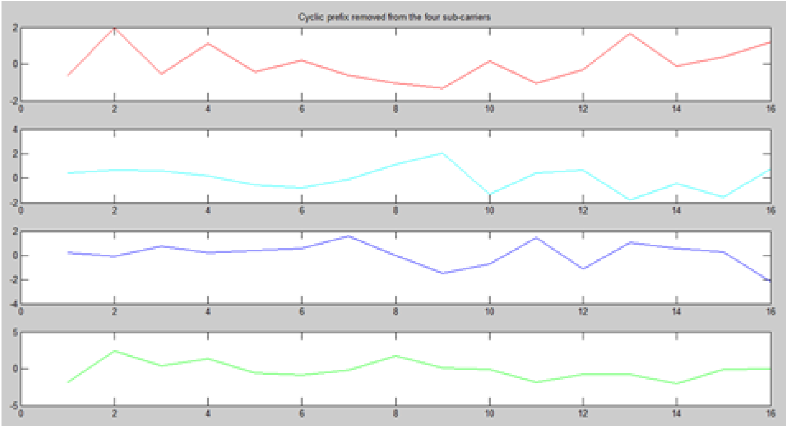

Fig 20. OFDM signal after passing through the channel

The received OFDM signal is in parallel for subcarriers parallel received signal is found as shown in Figure 20. The received subcarriers signal ,fft funcation is to be found as represented in Figure 21.

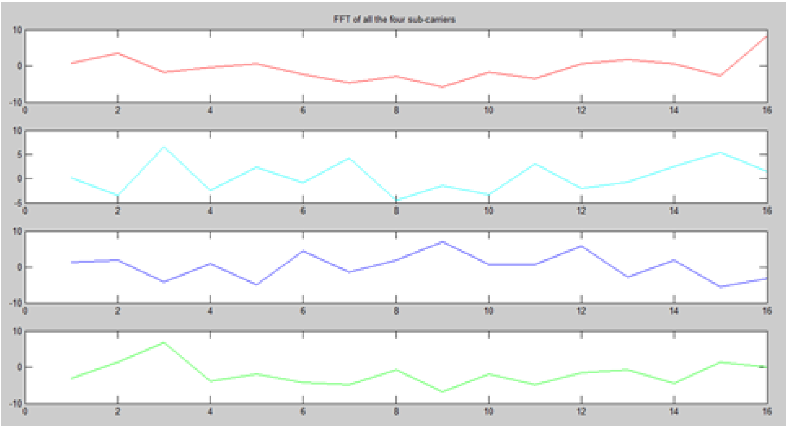

Fig 21. FFT of all the fore subcarrier

Then the QPSK demodulated function generated is get the received signal in a proper manner.

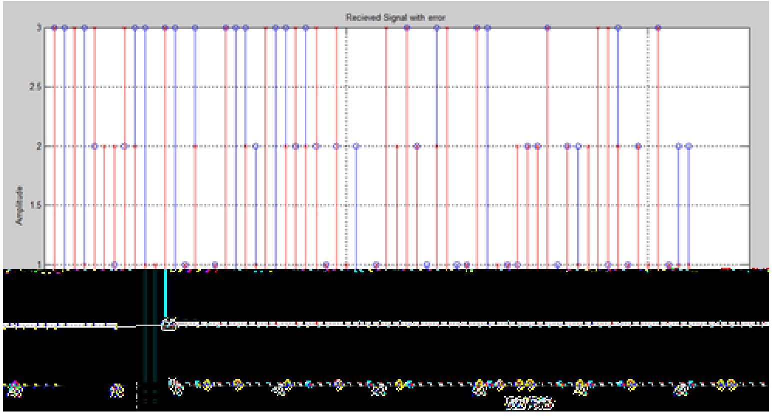

Fig 22. Received signal with error

The received signal with error is also found as shown in Figure 22.

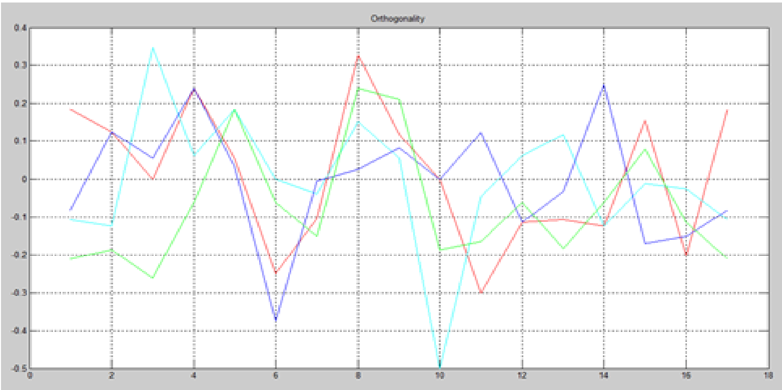

Fig 23. Orthogonality

The serial stream bit is transmitted as shown in Figure 23. The advantage of the proposed feedback mechanism can greatly reduce the signaling overhead while maintain the accurate channel condition report owing to the high data rate.

CONCLUSION

The IEEE 802.16-2004 standard was developed to add NLOS applications support to the basic standard. This standard serves fixed and nomadic users in the frequency range of 2 – 11 GHz. In order to add mobility to wireless access, the WiMAX, IEEE 802.15e-2005 specification was defined, utilizing frequencies below 6 GHz. There are multiple physical-layer choices, within IEEE 802-16 standard. Two different system profiles are demonstrated in this work, one based on IEEE 802.16-2004, OFDM PHY, called the fixed system profile; the other one based on IEEE 802.16e-2005 scalable OFDMA PHY, called the mobility system profile. The Mobile WiMAX standard has been developed to be the best wireless broadband standard for portable devices enabling a new era of high throughput and high delivered bandwidth together with exceptional spectral efficiency when compared to other 3G+ mobile wireless technologies. In this simulation work, location distance based data rate in 4- layer design have to be used and enhance the number of supported subscribers. location distance based data rate is higher in 4- layer design than that exists in 3- layer cell design architecture. Also, the capacity of 4- layer design is found to be higher than that of 3- layer cell design architecture by considerable number of supported subscribers.

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