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RESEARCH ARTICLE

Simulation of WiMAX System Based on OFDM Model with Difference Adaptive Modulation Techniques

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Abstract— This paper presents the simulation of Worldwide Interoperability for Microwave Access (WiMAX) system based on Orthogonal Frequency Division Multiplexing (OFDM) with different adaptive modulation techniques. WiMAX is the next generation broadband wireless technology which offers greater range and bandwidth compared to the other available broadband wireless access technologies such as Wireless Fidelity (WiFi) and Ultra Wideband (UWB) family of standards. The simulation is based on the WiMAX physical layer which adopted an OFDM model in the transmitter and receiver. The Matlab software is used to develop the OFDM model and analysis the performance of WiMAX system. Hence the investigation of the performance of OFDM physical layer in WiMAX system by using different adaptive modulation techniques like Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM) for modulator and demodulator. The performance of system was compared between the model with cyclic prefix and without cylic prefix. The cyclic prefix is added additional bits at the transmitter end. The signal is transmitted through the channel and it is received at the receiver end. Then the receiver removes these additional bits. The purpose of the cyclic prefix is to minimize the inter symbol interference and to improve the bit error rate. The analysis is based on the Bit Error Rate (BER), Signal to Noise Ratio (SNR) and probability error. At the end, the modulation BPSK and QPSK have the lower bit error rate while the 64 QAM has the higher bit error rate at low SNR. For the probability of error, the lower order modulation scheme also has the lower BER at low SNR.

Keywords— WiMAX, OFDM; Cyclic Prefix; Adaptive Modulation Techniques; BER

I. Introduction

Worldwide Interoperability for Microwave Access (WiMAX) is a technology that enables anywhere, anytime access to information and applications at low cost and with a small investment. This technology can reach a theoretical 30 miles coverage radius and achieve data rates up to 75 Mbps, although at extremely long range, throughput is closer to the 1.5 Mbps performance of typical broadband services, similar to that used for wired broadband services [1]. Nowadays, cable and digital subscriber line (DSL) technologies are providing broadband service in residential as well as small and medium size enterprise sectors. But the practical difficulties in deployment have prevented them from reaching many potential broadband internet customers. Many areas throughout the world currently are not under broadband access facilities. Even many urban and suburban locations may not be served by DSL connectivity as it can only reach about three miles from the central office switch. The WiFi standard broadband connection may solve this problem a bit but not possible in everywhere due to coverage limitations. WiFi networks have limited range. A typical WiFi home router might have a range of 45 m (150 ft) indoors and 90 m (300 ft) outdoors. The metropolitan area wireless standard which is called WiMAX can solve these limitations [2]. WiMAX can operate in both Line-Of-Sight (LOS) and Non-Line-Of-Sight (NLOS) environments. WiMAX uses Orthogonal Frequency Division Multiplexing (OFDM) in its physical layer and the OFDM uses adaptive modulation techniques [3]. WiMAX protocol stack layer has physical layer and MAC layer as shown in Fig. 1. Physical layer set up the connection between the communicating devices and is responsible for transmitting the bit sequence. It also defines the type of modulation and demodulation as well as transmission power. The WiMAX physical layer is based on OFDM technique. The MAC layer is to provide an interface between the physical layer and the upper transport layer.

In wireless communication, the concept of parallel transmission of symbols is applied to achieve high throughput and better transmission quality. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques for parallel transmission. The idea of OFDM is to split the total transmission bandwidth into a number of orthogonal sub carriers in order to transmit the symbols using these sub carriers in parallel [4]. Each smaller data stream is then mapped to individual data sub-carrier and modulated using some sorts of Phase Shift Keying (PSK) or Quadrature Amplitude Modulation (QAM) such as QPSK, 16-QAM, 64-QAM. OFDM needs less

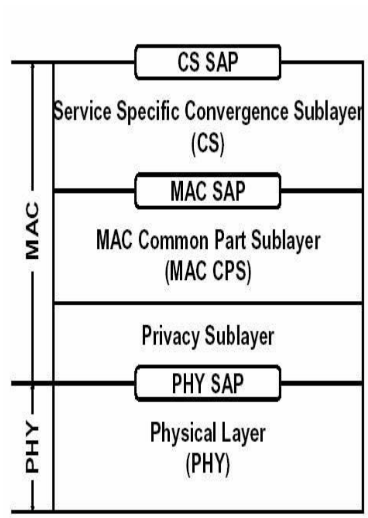

Fig. 1: WiMAX physical and MAC layer architecture

bandwidth than Frequency Division Multiplexing (FDM) to carry the same amount of information which translates to higher spectral efficiency. Besides a high spectral efficiency, an OFDM system such as WiMAX is more suitable in NLOS environment. It can efficiently overcome interference and frequency-selective fading caused by multipath because equalizing is done on a subset of sub-carriers instead of a single broader carrier. The effect of Inter Symbol Interference (ISI) is suppressed by virtue of a longer symbol period of the parallel OFDM sub-carriers than a single carrier system and the use of a cyclic prefix (CP) [5]. This makes an OFDM ideal to handle the mobile wireless environment because OFDM achieves more spectral efficiency.

Many methods are proposed to combat the multipath effects in wireless communication. OFDM is the one of the solutions to combat Inter Symbol Interference (ISI) are multi carrier modulation for data transmission [5-7]. OFDM is better than Code Division Multiple Access (CDMA) which is mostly incorporated in existing 3G systems [5], [6]. The aim of OFDM is to divide the wide frequency selectivity of fading channels into multiple flat fading channels [6]. WiMAX uses a special type of modulation technique which is a mixture of ASK and PSK with a new name called Quadrature Amplitude Modulation (QAM). In QAM, amplitude and phase changes at the same time. Different types of QAM are available for WiMAX networks depending on throughput and range. 64 QAM has higher throughput but the lower range whereas 16 QAM has lower throughput but higher range to cover from the BS. WiMAX has the freedom to select Quadrature Phase Shift Keying (QPSK) and QAM as its modulation techniques depending on the situation.

II. DESIGN METHODOLOGY

The focus of the WiMAX development in the Matlab software is based on the adaptive modulation techniques. Fig. 2 shows the specification of the system. The OFDM model consists of basic model (without cyclic prefx) and model with cyclic prefix. Fig. 3 shows the OFDM simple model which the data stream is first subdivided into a number of sub-streams where each one has to be modulated over a separate carrier signal, called sub carriers. The data bits are directly mapped to the complex modulation symbols by using adaptive modulation techniques which are BPSK, QPSK, 16-QAM or 64-QAM. The resulting modulated signals are then multiplexed before their transmission by applying the Inverse Fast Fourier Transform (IFFT). Thus the multiplexed signal passes through the AWGN channel. In the receiver, OFDM symbols are detected by using adaptive modulation techniques detector and sub carriers are demodulated by the FFT, which is the reverse operation of the IFFT. The values are then de-mapped into binary values and finally parallel to serial converter converts the binary values to the serial and sends out the information bits. For the second model in the Fig. 4, it uses the concept of cyclic prefix that adds additional bits at the transmitter end and then the receiver removes these additional bits in order to minimize the inter symbol interference, improve the bit error rate and reduce the power spectrum.

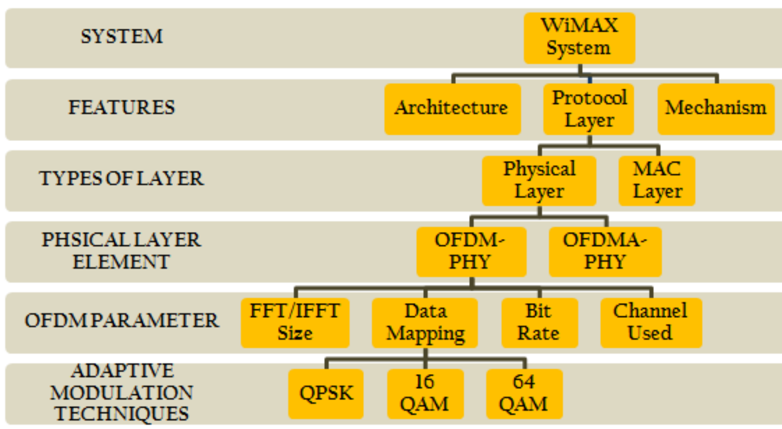

Fig. 2: Specification of WiMAX system

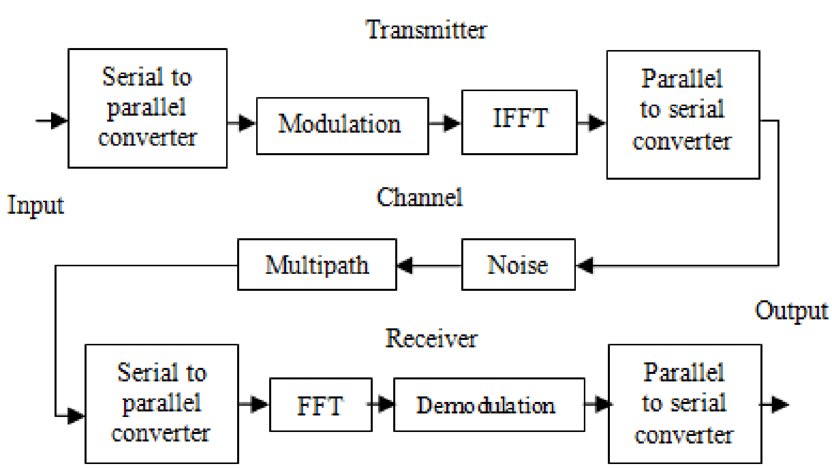

Fig. 3: OFDM Basic Model

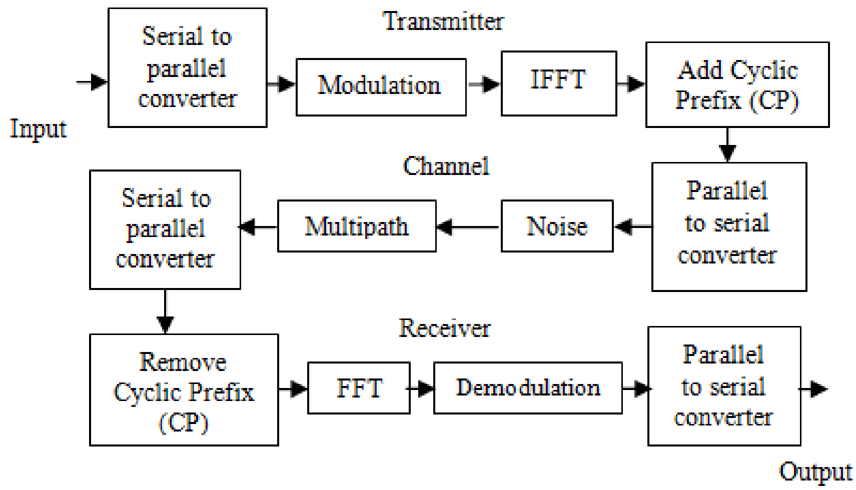

Fig. 4: OFDM Model with Cyclic Prefix

III. RESULT AND ANALYSIS

The simulation of WiMAX system is done by using MATLAB software. The result is based on the BER, SNR and probability of error. The graph BER vs SNR for the basic OFDM model is shown in Fig. 5 which that at the low SNR, modulation BPSK and QPSK have the lower value of BER and 64-QAM has the higher value of BER while 16-QAM is in the middle. At the lower BER, the modulation 64-QAM has the higher value of SNR then followed by 16-QAM, QPSK and BPSK. The BPSK and QPSK are the best modulation techniques for noisy condition compared to 16-QAM and 64-QAM. Fig. 6 shows the BER vs SNR for OFDM model with cyclic prefix. Performance of modulation scheme is similar compared to the OFDM model without cyclic prefix but have a little improvement of SNR value which the quality of signal is better than the basic OFDM model for all modulation schemes. As the SNR is very good near the base station, higher order modulation scheme is used in this area to increase the throughput. However, in areas close to the cell boundary that is further from the base station, the SNR is normally poor. So, the system steps down to a lower order modulation scheme to maintain the connection quality and link stability. The WiMAX system is switched to the decrease order modulation scheme when the distance is increased to keep the connection between base stations and the user or receiver.

Fig. 7 shows that the probability of error for all modulation which is inversely proportional to the SNR. The probability of error decrease as the signal to noise ratio is increased where the probability of error is higher for 64-QAM and then followed by 16-QAM, QPSK and BPSK. So, the higher order modulation scheme does not suitable in the noisy condition rather than lower order modulation scheme. The lower order modulation scheme is the suitable modulation technique at the noisy condition cause of the lower value BER at low SNR. The probability of error is the cause of the noise and fading introducing some error during the process and also due to the cable losses at transmitter and receiver. Based on the weather, interference in the signal and the client distance, the Base Station dynamically selects the modulation scheme. When the link quality is high, WiMAX uses highest modulation with a low coding scheme that increases the system capacity. While the signal has to travel a long distance and experiencing fading, WiMAX can easily shift to the lower order modulation with higher coding scheme. This kind of adaptive modulation gives WiMAX more stable links and good connection quality.

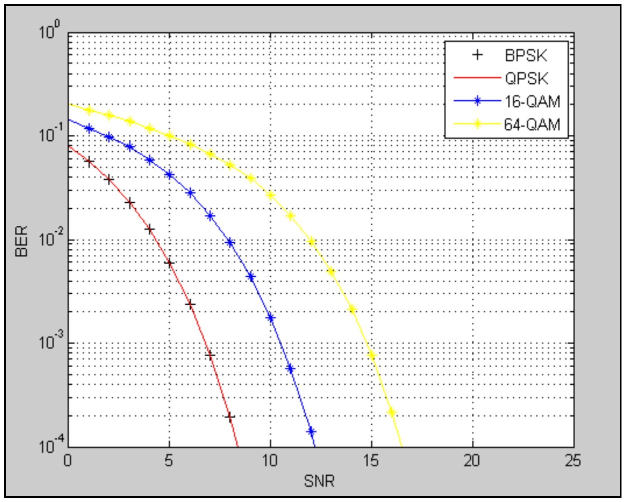

Fig. 5: BER vs SNR for Basic OFDM model (without cyclic prefix)

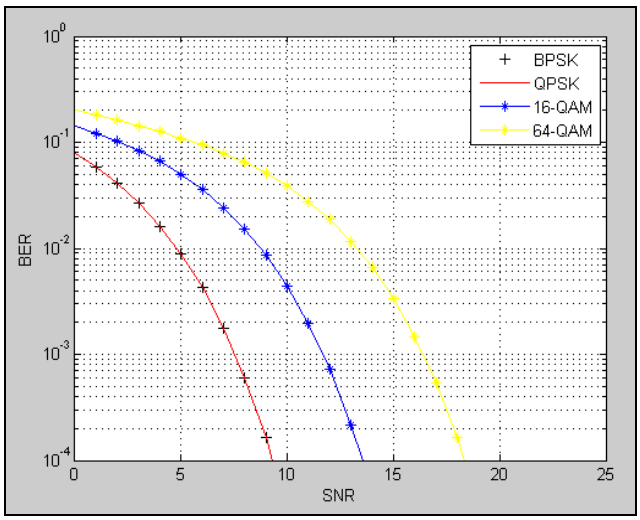

Fig. 6: BER vs SNR for Basic OFDM model (with cyclic prefix)

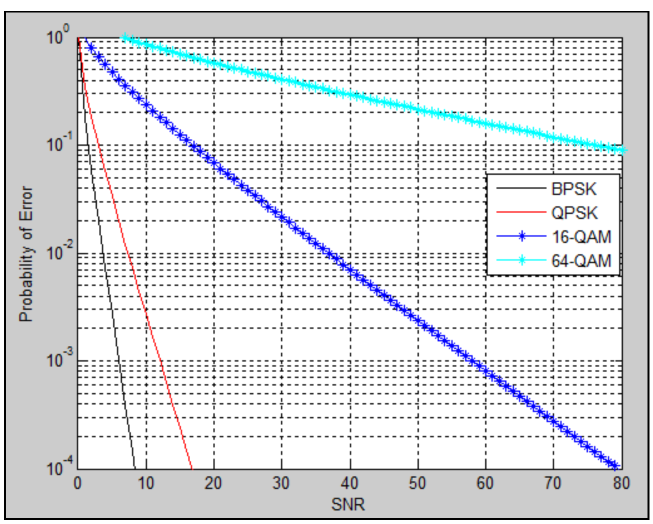

Fig. 7: Probability of error

IV. CONCLUSIONS

The WiMAX system based on OFDM model using adaptive modulation schemes was successfully developed using Matlab software. Adaptive modulation techniques allow to adjust the signal modulation scheme depending on the SNR condition of the radio link which give freedom to the WiMAX system to choose either PSK or QAM. The WiMAX system does not need a fixed scheme that is planned for the worst case situations while cyclic prefix is added in order to minimize the inter symbol interference which occurs in multipath channels and to improve the bit error rate. For the future works, is possible to convert the OFDM transmitter and receiver to the Field Programmable Gate Array (FPGA) hardware which FPGA is a programmable logic device that supports implementations of relatively large logic circuits. The method is the best choice for OFDM implementation cause it gives flexibility to the program design besides the low cost hardware component than others.

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