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Effect of Cyclic Prefix on Data Rates in OFDM Modulation Techniques : An Analysis

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ABSTRACT: 4G – network systems require higher reliability and high spectral efficiency. To achieve this Orthogonal Frequency Division Multiplexing (OFDM) is considered to be the best modulation technique for 4G- networks. OFDM can provide large data rates with sufficient robustness to radio channel impairments. OFDM is designed such a way that it sends data over hundreds of parallel streams which increases the amount of information that can be sent at a time. It can offer high quality performance in terms of bandwidth efficiency, robustness against multipath fading and cost-effective implementation. A guard time, in the form of cyclic prefix (CP), is inserted between OFDM symbols to eliminate both the inter-symbol interference (ISI) and the inter-channel interference (ICI). In this paper we have studied the effect of cyclic prefix on data rate using OFDM modulation techniques. Simulation is performed using MATLAB simulator by taking case of 802.16 networks.

Keywords: *WiMAX, OFDM, Cyclic prefix, Multi-Carrier Modulation, 4G – Networks, etc .*

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing is a method of encoding digital data on multiple carrier frequencies. Since it saves the need for complex equalizers, it is best suited for channels with a non flat frequency response [10]. The OFDM_technique enables a base station to bifurcate a bunch of radio spectrum into sub-channels. And the strength of the sub-channels and the no. of channels assigned to different be adjusted as required. The technique enables high data rates, miles away from a transmitter. Hence it suits with the radio interference that is normaly found in urban areas, where signals reflect off walls and generates confusing echoes [3]. The idea of OFDM is derived from Multi-Carrier Modulation (MCM) transmission technique. The principle of MCM is that to divide the input bit stream into several parallel bit streams and then they are used to modulate several sub carriers. Guard band is used to separate the sub-carrier so that they do not overlap with each other. Band pass filters are used at the receiver side, to separate the spectrum of individual sub-carriers. OFDM is a special form of spectrally efficient MCM technique, which involves densely spaced orthogonal sub-carriers and overlapping spectrums. Due to orthogonality nature of the sub-carriers, the use of band pass filters is not required in OFDM. Hence, the available bandwidth is used very efficiently without causing the Inter-Carrier Interference (ICI) [8]. Multipath produces effects like : frequency selective fading(FSF) and inter-symbol interference (ISI). The "flatness" occupied by a narrow-band channel suppress the frequency selective fading Modulating at a very low symbol rate produces the symbols much longer as compare to the channel impulse response(CIR) and eliminates the effect of ISI. Introducing suitable error correcting codes along with time and frequency interleaving gives extra robustness against frequency selective fading(FSF) and the introduction of an extra guard interval between neighbor OFDM symbols can suppress the effects of ISI. Thus, an the need of equalizer in the receiver isn't necessary [2]. The wireless communication systems are susceptible to multipath channel reflections, and due to this reason a cyclic prefix technique is to reduce ISI. cyclic prefix is nothing but a iteration of the first bunch of a symbols that is appended to the end of the symbols. It is realy important because it makes possible the multipath representations of the message to fade so that they do not interfere with the adjacent symbol.

A. Working Principle of OFDM

The fundamental of this technique is to split down a high rate message stream into a number of lower rate data streams and transmitted simultaneously on a number of subcarriers . due to the symbol duration increases for lower data rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Intersymbol interference is eliminated almost completely by introducing a guard time in every OFDM symbol. In the guard time, the symbol is cyclically extended to avoid intercarrier interference [11].

An OFDM signal is a sum of subcarriers that are individually modulated by using phase shift keying (PSK) or quadrature amplitude modulation (QAM). The symbol can be written as:

$$s(t) = Re\left\{\sum_{i=-\frac{N_s}{2}}^{\frac{N_s}{2}-1} d_{i+N_s/2} \exp\left(j2\pi\left(f_c - \frac{i+0.5}{T}\right)(t-t_s)\right)\right\}$$

There has been an increasing interest in providing high data rate services such as video conference and multimedia over wideband wireless channels. In wideband wireless channels, the symbol period becomes smaller relative to the channel delay spread, and consequently, the transmitted signals experience frequency-selective fading. Therefore, it is desirable to investigate the effect of frequency-selective fading. OFDM is a technique for combating the effects of multi-path propagation in frequency selective fading channels [5,9].

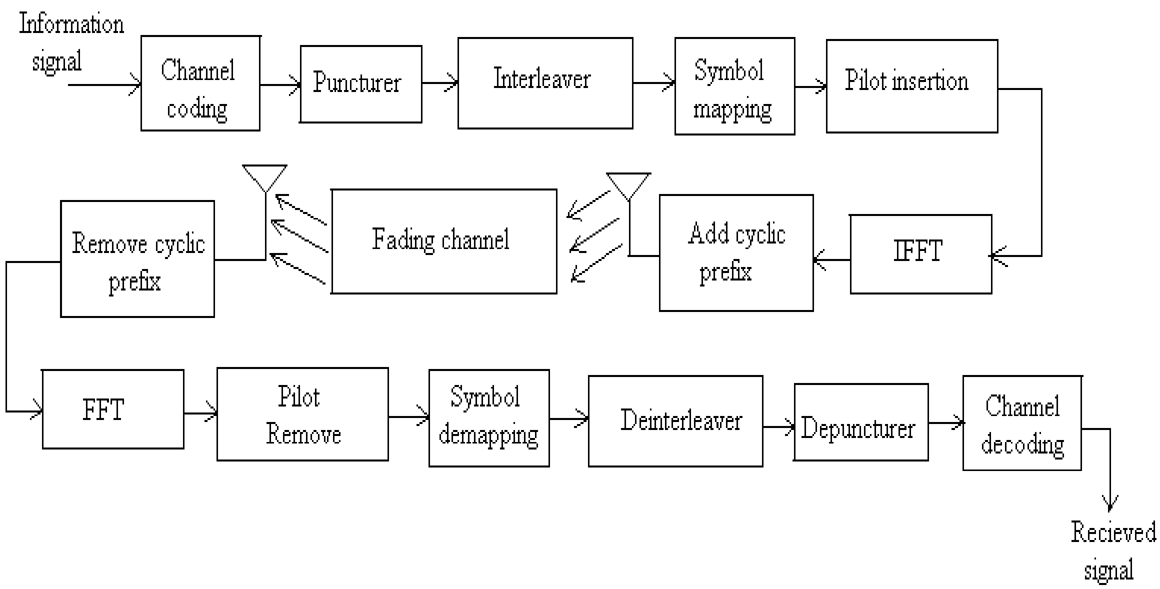

Fig. 1. OFDM system diagram.

OFDM technique is a multi-carrier transmission technique, which is being recognized as an excellent method for high-speed bi-directional wireless data communication. The prime idea is that all queuing data in buffer are uniformly allocated on small sub-carriers which are orthogonal to each other. The OFDM converts a frequency-selective fading channel into a parallel collection of frequency flat-fading sub channels, in which the available bandwidth is very efficiently used. OFDM efficiently squeezes multiple modulated carriers tightly together reducing the required bandwidth but keeping the modulated signals orthogonal so that they do not interfere with each other. OFDM that is highly efficient technique shows favorable properties such as robustness to channel fading and inter symbol interference (ISI) and is more immune to noise. OFDM system is capable of mitigating a frequency selective fading channel to a set of parallel flat fading channels, which need relatively simple processes for channel equalization. The OFDM technique has been adopted in several wireless standards such as digital audio and video broadcasting, the IEEE 802.11a standard, the IEEE 802.16a metropolitan area network standard, and the local area network standard [11].In the past, the communication systems like telephony and telegraphy etc, were all analog and use electrical wires. They are hence the examples of wired communication system. With further development, the focus shifted towards digitization of the communication system. A major breakthrough in this field with the advent of the wireless technology due to the invention of radio system. Since then, wireless technology has evolved at a fast pace and hence revolutionized the field of wireless communication system. Initially, wireless communication was used for military and other non commercialized applications but when the wireless communication links are commercialized then it results in the rapid advancement and development of the physical layer design issues for providing high and error free signal transmission, which makes the foundation of second-generation technology (2G) and subsequently the development of third-generation technology (3G).

The second generation technology (2G) has been in use mainly for voice, data and slow transmission of the signal. And now with the introduction of GPRS, video signal transmission, high data rates services etc, the base of third generation technology (3G) has been confirmed and the research and development is already aiming for the successful development and deployment of fourth generation technology (4G). New systems are integrated with the high speed internet applications, data services, broadband services, telephony, multimedia communications and many more features [1]. The explosive growth of wireless communications is creating the demand for high-speed, reliable, and spectrally efficient communication over the wireless medium. There are several challenges in attempts to provide high-quality service in this dynamic environment. These pertain to channel time-variation and the limited spectral bandwidth available for transmission [2]. This is also a measure of the bit rate reduction required by a cyclic prefix. That is, if each subcarrier can transmit b bits, the overall bit rate in an OFDM system is $Nb/(NT+\Delta)$ bits per second as compared to the bit rate of *b/T* in a system without a cyclic prefix. If latency requirements allow, these losses can be made small by choosing a symbol period *NT* much longer than the length of the cyclic prefix

II SIMULATION METHOD

The simulation is done using MATLAB simulator. Network simulation is commonly used for the evaluation of wireless network protocols. Discrete event simulators typically model the network activities on a packet-by-packet basis, in time granularity of terms of microseconds, and include a model for each layer of the entire protocol stack. NS is a discrete event simulator written in C++, with an OTcl interpreter shell as the user interface that allows the input model files that is, Tcl scripts, to be executed. NS provides support for simulation of TCP, routing, and multicast protocols over wired and wireless networks.

In our simulation NS2.29 version is used and it is performed by on WiMAX network. The parameters used are as shown below:

The parameter of wireless channel in tcl script is as given below:

```
#channel type
Phy/WirelessPhy/OFDM set value
#500m radius
Phy/WirelessPh set RXThresh_ 2.025e-12;
# Parameter for wireless nodes
# channel type
set opt(chan)        Channel/WirelessChannel;
# radio-propagation model
set opt(prop)        Propagation/TwoRayGround;
# network interface type
set opt(netif)       Phy/WirelessPhy/OFDM;
# MAC type
set opt(mac)         Mac/802_16;
# interface queue type
set opt(ifq)         Queue/DropTail/PriQueue;
# link layer type
set opt(ll)          LL;
# antenna model
set  opt(ant)        Antenna/OmniAntenna;
# max packet in ifq
set opt(ifqlen)      50;
# routing protocol
set opt(adhocRouting)   DSDV;
```

During our simulation we used cyclic prefix to minimize the Inter Symbol Interference (ISI) on the basis of following adaptive modulation techniques –

- Binary Phase Shift Keying (BPSK)
- Quadrature Phase Shift Keying (QPSK)
- 16-Quadrature Amplitude Modulation (16-QAM)
- 64-Quadrature Amplitude Modulation (64-QAM)

Quadrature amplitude modulation Quadrature amplitude modulation (QAM) is a modulation scheme which conveys two digital bit streams or two analog message signals by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. These two waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components — hence the name of the scheme. The modulated waves are summarized, and the resulting waveform is a combination of both phase shift keying (PSK) and amplitude-shift keying (ASK), or in the analog case of phase modulation (PM) and amplitude modulation (AM). In the digital QAM case, a finite number of at least two phases, and at least two amplitudes are used. PSK modulators are often designed using the QAM principle, but are not considered as QAM since the amplitude of the resulting signal is constant. Overview Like all modulation schemes, QAM conveys data by changing some aspect of a carrier signal, or the carrier wave, (usually a sinusoid) in response to a data signal. In the case of QAM, the amplitude of two waves, 90 degrees out-of-phase with each other (in quadrature) are changed (modulated or keyed) to represent the data signal.

Amplitude modulating two carriers in quadrature can be equivalently viewed as both amplitude modulating and phase modulating a single carrier. Phase modulation (analog PM) and phase-shift keying (digital PSK) can be regarded as a special case of QAM, where the magnitude of the modulating signal is a constant, with only the phase varying. This can also be extended to frequency modulation (FM) and frequency-shift keying (FSK), for these can be regarded as a special case of phase modulation. Analog QAM When transmitting two signals by modulating them with QAM, the transmitted signal will be of the form: 4 generation systems will support multimedia services like high-speed internet access & broadcast services from information sites. Data traffic in the downlink is expected to be much more than that in the uplink because number of substation at downlink frequency is more than the uplink frequency. Therefore, high data rates are especially necessary for 4G in the downlink. The main purpose of the 4th generation (4G) mobile communication is provide high rate data serves 100Mbps, especially in the downlink over wide coverage. Various wireless access schemes have in telecommunication is to con- vey as much information as possible through limited spectral width. Orthogonal frequency division multiplexing (OFDM) introduces the concept of allocating more traffic channels within limited bandwidth of physical channel. Here the available bandwidth is split into several narrow band channels for simultaneous transmission. In frequency division multiplexing (FDM) a guard band is provided between individual channels, which separates the spectrum of different channels, and enables a practical band pass filter to detect individual channel. But the situation is completely different in OFDM where spectrums of adjacent channels are overlapped which resembles adjacent channel interference, but interference is avoided by maintaining orthogonal relation between sub-carriers. First of all high speed serial data is converted to low speed parallel data, a Therefore transmitted signal is a vector addition of orthogonal modulated carriers, makes large peak to average power ratio, therefore dynamic range of devices should be large enough, as summarized in [3,5]. Output of each parallel line is modulated; here two different types of modulation quadrature amplitude shift keying (QPSK) and 16-quadrature amplitude modulation (16-QAM) are selected for this paper, whose constellations are shown in. QPSK waves have constant peaked sinusoidal wave but phase angle is different for four different combinations of 2 bits. In 16-QAM both amplitude and phase of the wave varies according to 16 different combination of 4 bits.

III. RESULTS

The graph drawn cyclic prefix vs. data rate is as shown below. The technique Cyclic Prefix is an important player in Wi-MAX Network. It is observed that the modulation scheme and Cyclic Prefix have the significant effect on the performance of Wi-MAX network. The Cyclic Prefix plays an important role to increase and decrease the data rate in Wi-MAX. By using different cyclic prefixes it is possible to increase or decrease the data rate in Wi-MAX network. By increasing the value of Cyclic Prefix the data rate of Wi-MAX network decreases.

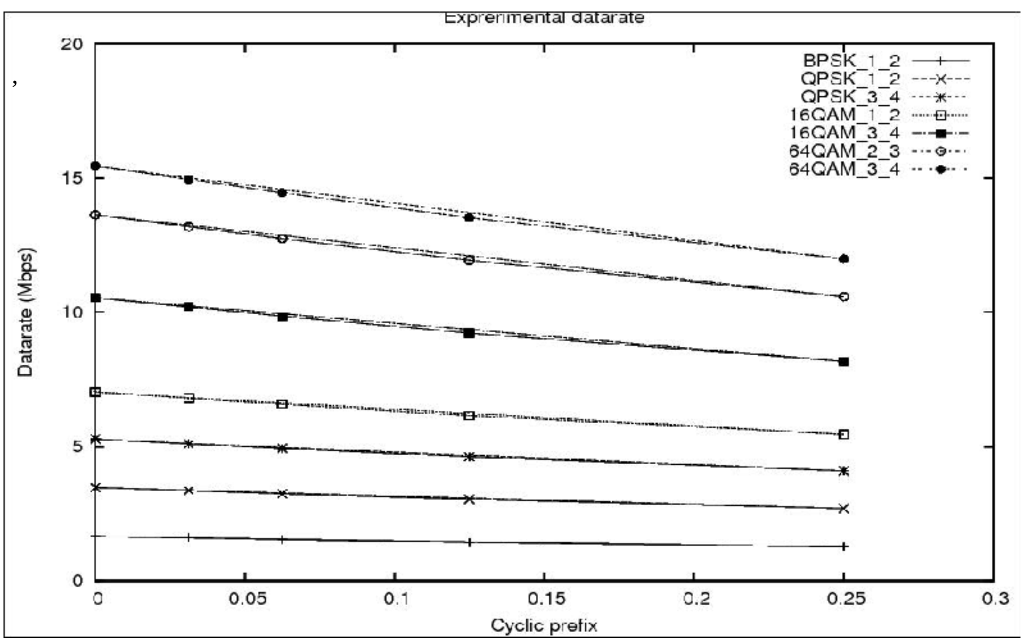

Fig. 2. Graph of cyclic prefix vs. data rate.

In other words by decreasing the value of cyclic prefix it is possible to increase the data rate. Higher Cyclic Prefix means large time gap between two frames and large Cyclic Prefix give extra time to receive signal from multipath channel. So the selection of Cyclic Prefix value is based on the coverage area that would be covered by the signal and keeping data rate parameter in consideration.

IV. CONCLUSION

In this paper we have discussed issues related to cyclic prefix in OFDM and simulated the effect of cyclic prefix on data rate in IEEE 802.16. Orthogonal frequency division multiplex (OFDM) modulation is being used mostly in telecommunication, wired and wireless. OFDM can be implemented easily, it is spectrally efficient and can provide high data rates with sufficient robustness to channel imperfections. Due to these reasons OFDM playing an important role in 4G – Networks as it requires higher data rates. It is a block modulation scheme where a block of N information symbols is transmitted in parallel on N sub-carriers. A guard time, usually in the form of cyclic prefix (CP), is inserted between OFDM symbols to eliminate both the inter-symbol interference (ISI) and the inter-channel interference (ICI). Transmission of cyclic prefix reduces the data rate. From the graph it is clear that as cyclic prefix duration increases the data rate decreases; hence the cyclic prefix duration should not be much more than the duration of the maximum expected multipath channel.

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