Study of the Effect of Cyclic Prefix on Different QoS Parameters in WiMax Network

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ABSTRACT

The Intersymbol Interference (ISI) is a common problem in high data rate communication. In OFDM transmission technique ISI is a common problem. So, Guard time length (GT) which is implemented as Cyclic Prefix (CP) to mitigate Intersymbol Interference (ISI) and to preserve orthogonality among OFDM subcarriers, plays a key parameters in OFDM. The guard time length is sufficiently greater than channel delay spread. Conventional OFDM system uses a fix GT length. This technique, however, degrades the overall spectral efficiency as well as consumes transmitter energy proportional to the length of the guard time. In this paper, the overall system performance and packet error rate (PER) are slightly improved as function of the guard time length.

General Terms

Performance study of WiMAX network as function of the guard time length.

Keywords

ISI, GT, Cyclic Prefix, WiMAX, OPNET (Optimized Network Engineering Tools) Modeler 14.5.A.

1. INTRODUCTION

IEEE 802.16 WiMAX [1] (Worldwide Interoperability for Microwave Access) technology has attracted a lot of attention in wireless networking research and applications. This technology can offer high speed voice, video and multimedia services over mobile platform evolving towards all IP networks. More importantly this technology become popular for it's flexible, cost-effective and real time supported deployment. The challenges to service providers lie with Quality of Service (QoS) under varied fading environment at the same time maximizing for resource utilization.

The WiMAX physical layer is based on Orthogonal Frequency Division Multiplexing [2] (OFDM). For high-speed data, voice, video and multimedia communications OFDM is a transmission technique. In OFDM technique high-rate data stream divide into a number of low-rate data streams that are transmitted over parallel, narrowband channels and can be easily equalized [3]. OFDM can reduce the adverse effects of frequency selective multi-path fading and efficiently mitigate the inter-symbol and inter carrier interferences. In OFDM technique to mitigate ISI guard interval is used. In WiMAX this guard interval is implemented as cyclic prefix.

Guard time length (GT) is the key parameter in OFDMA [4]. This length is a copy of the last portion of each transmitted symbol to completely reduce Intersymbol Interference (ISI) as long as the GT is greater than delay spread of the channel. By implementing the GT as cyclic prefix (CP) the system being protect to Intercarrier Interference (ICI) that causes a severe degradation of Quality of Service in OFDMA systems. Conventional OFDM transmission system uses a fixed-length cyclic prefix. This may cause considerable performance degradation when the CP length is less than the channel Root-Mean-Squared (RMS) [5] delay spread, or may decrease the system power and spectrum efficiency when it is much larger. Paper [5] and paper [6] show that Adaptive Cyclic Prefix (ACP) has become a recent approach in WiMAX PHY layer design for enhancing system performance. Recent papers[5], [7] provide some of the alternatives to standard CP design. So, varying the cyclic prefix significant improvement in the data throughput can be obtained. In these papers, it is mentioned that the influence of varying cyclic prefix on mobile WiMAX system.

2. OPNET Modeler 14.5.A set up for a WiMAX Scenario

OPNET modeler 14.5.A provides a comprehensive development environment supporting the modeling of communication networks and distributed systems [8]. Both behavior and performance of modeled systems or scenarios can be analyzed by performing discrete event simulations. A typical OPNET environment incorporates tool for all phases of a study, including model design, simulation, data collection, and data analysis. It also provides GUI of model wherever possible; using graphical editors. Moreover, OPNET provides several important editors among which four editors are used extensively in our research work. Editors like Network model, Node model, Process model and Parameter Editor are modified accordingly to generate a new simulation model. These editors are organized in a hierarchical fashion, which supports the concept of model level reuse. Models developed at one layer can be used by another model at a higher layer. Fig. 1 represents a typical WiMAX scenario developed in OPNET 14.5A Modeler. The Wireless Deployment Wizard of OPNET is used to deploy a 7 cell WiMAX network, with multiple subscriber stations in the range of a base station .The base stations are connected to the core network by an IP backbone. The IP backbone is connected to the server. The network configuration parameters in OPNET are summarized as shown in Table I and the attributes of the network components are shown in Table II.

3. Derivation of WiMAX parameters

The nominal channel bandwidth (BW), number of used subcarriers which includes the DC subcarrier (N_{used}), Sampling factor (n) and the guard factor (G) are the primitive parameters to characterized the OFDMA symbol[3] . From this primitive parameters some WiMAX parameters are derived. In OPNET, there is no option to use cyclic prefix directly. So, here, we modify the WiMAX configuration node from where we can varying the cyclic prefix. As per WiMAX standardization, there are four types of cyclic prefix such as 1/4, 1/8, 1/16, 1/32. The OFDMA symbol consists of subchannels that carry data subcarriers carrying information, pilot subcarriers that are dedicated for synchronization and channel estimation purposes, DC subcarrier and guard subcarriers to provide high inter-channel interference margin. To determine subcarrier spacing and useful symbol time, sampling factor n is commonly set to be 8/7 for OFDMA PHY.

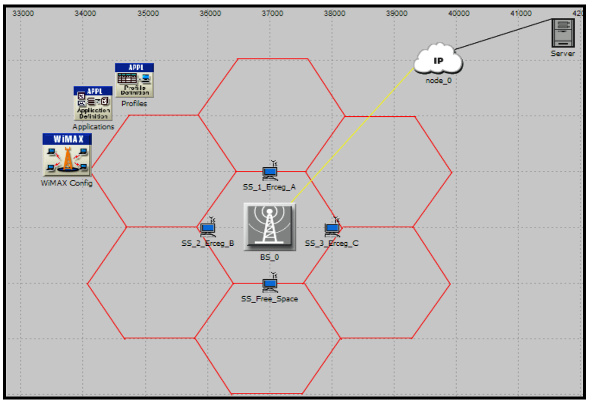

Fig 1: A typical WiMAX scenario developed in OPNET 14.5A Modeler

Table 1. The network configuration parameters

Parameters	Value
Carrier frequency	5 GHZ
System channel bandwidth(BW)	10MHZ
Sampling frequency	11.2MHZ
FFT size(NFFT)	1024
Subcarrier frequency spacing (KHz)	10.94
Useful symbol time(µs)[Tb]	91.4
Guard time (µs)[Tg]	Variable
Frame duration (ms)	5ms
Modulation scheme	Qpsk
Overall coding rate	½
Data subcarriers	560
Pilot subcarriers	280
Guard subcarriers	184

Here, sampling frequency fs plays a key role to the overall calculation.Considering the Bandwidth (BW) and over sampling ratio (n) sampling frequency (fs) is calculated as,

$$f_s=\text{floor}(n*\text{BW}/8000)*8000 \qquad (1)$$

Further, subcarrier spacing $f_{spacing}$ entirely depend on the Sampling Frequency (f_s) allocated for the total number of subcarrier and is represented as,

$$f_{spacing}=fs\,/\,N_{FFT} \qquad (2)$$

Table 2. The attributes of the network components

Network Configuration Parameter	Values
Network cell numbers	7
Cell Radius	3 km
No. of Base Stations	1
No. of Subscriber Stations per BS	4
Speed of the mobile nodes	50km/hr
Base Station Model	wimax_bs_router
Subscriber Station Model	wimax_ss_wkstn
IP Backbone Model	ip32_cloud
Voice Server Model	ppp_server
Link Model (BS-Backbone)	PPP_DS3
Simulation time	600 Sec

here N_{FFT} is the FFT points associated with the total number of subcarrier.
Tb is the inverse of the subcarrier spacing $f_{spacing}$ that further calculates T_b.
Guard time length (T_g) is

$$T_g = G \times T_b \qquad (3)$$

Where, guard factor G is Tg/ Tb ratio.
OFDMA symbol time (T_s) , the guard time length (T_g) and useful symbol length (T_b).

$$T_s = T_b + T_g \qquad (4)$$

Table 3. Derived Symbol duration for different Cyclic Prefix

Cyclic Prefix	Symbol duration(µs)
1/4	114.25
1/8	102.9
1/16	97.1125
1/32	94.256

4. Performance Evaluation

The QoS parameters such as throughput, packet end to end delay gives a significant improvement in WiMAX network. Again, the system performance is often analyzed by the Bit Error Rate or Packet Error Rate. Many mobile communication systems today are sending and receiving information in terms of packets. The probability of packet error depends on the probability of bit error, the packet length and the channel coherence time, i.e. the time over which the channel stays approximately constant. Therefore, the packet error rate is also important parameter indicating the performance of the system with a given packet length.

To show the influence of varying cyclic prefix to the link quality for WiMAX system, some simulations have done and the results are shown in Figure 2, figure 3. As per WiMAX standardization, there are four types of cyclic prefix such as 1/4, 1/8, 1/16, 1/32. Without CP system can theoretically transmit up to 30Mbrps using 64QAM but more ISI occurs. While 25% of the symbol time spent on the CP, receivers are capable to collect longer multipath fading but at the cost paid to SNR. The FFT size determines the number of available subcarriers and OFDM symbol duration. This is determined the fact that generally for a given bandwidth, a larger FFT size guarantees larger number of available subcarriers and a longer OFDM symbol duration. Further, under variable FFT points the effective End to End delay performance of a mobile WiMAX scenario is simulated. It is quite evident from Figure 3 that End to End delay of a mobile WiMAX scenario increases to a substantial high value for an increased FFT size. This result is quite obvious as with ever increasing FFT.

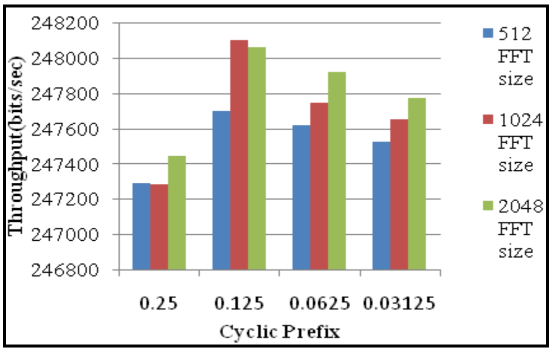

Fig 2: Effect of Cyclic prefix on throughput

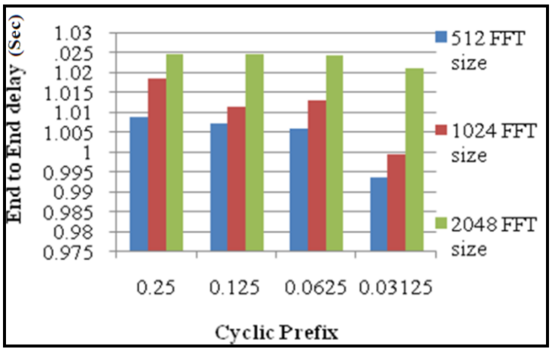

Fig 3: Effect of Cyclic prefix on packet end to end delay

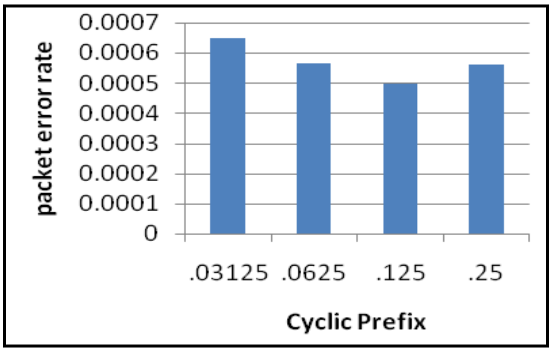

Fig 4: Effect of cyclic prefix on PER

size the delay in transmitting number of subcarrier must increase. Figure 2 and Figure 3 depicts the throughput and End to End delay performance of a WiMAX set up under fixed FFT size with varying CP scenarios respectively.

The results clearly suggest that for a smaller guard interval both Throughput and End-to-End delay of the network improves significantly. Thus to use a larger FFT size, a smaller CP is preferred while smaller FFT size demands use of a larger guard period. From Figure 4, it can be seen that Packet Error Rate (PER) does decrease as CP increases. Here, FFT size is 1024 and modulation type is QPSK-1/2. From this graph it also reveals that CP ratio of 0.125(1/8) slightly outperforms the other lengths in PER reduction.

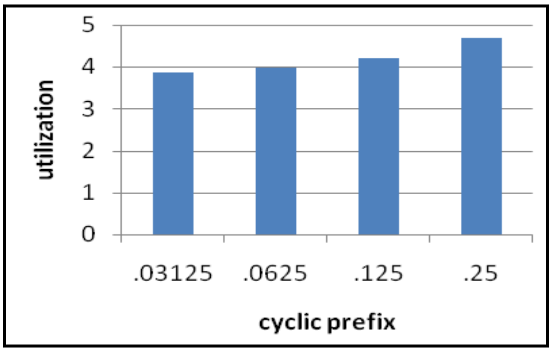

Fig 5: Effect of cyclic prefix on utilization

From this graph it is also reveals when CP is 1/8 PER is minimum. Accordingly, from these graph it is noticed when CP length is 1/8 PER is minimum as well as throughput is also increased. Again from Figure 5, it is noticed that increasing the CP utilization, consumption of bandwidth also increases.

5. CONCLUTION

Mobile WiMAX system performance as a function of guard time length has been simulated. The result proves that variable guard time length is useful for OFDMA system operating on time dispersive channel. In this paper, it is also found that the optimal CP length is 1/8. It is also known from the WiMAX standard [2] that 1/8 CP length is considered as optimal. From this paper it is also reflected that PER decreases as CP increases. But when CP length is 1/8, PER is minimum as well as throughput is also increased.

6. ACKNOWLEDGMENTS

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