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Simulation and Performance Analysis of Partial Usage Subchannels in WiMAX IEEE802.16e

Dahiru Sani Shuabu[1], Sharifah Kamilah[2], Norsheila Faisal[3] and Yakubu S. Baguda[4]
[1,2,3,4] *Department of Telematics & Communication Engineering,*
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
Johor, Malaysia.
Tel: 601-27940525, Fax: +607556-6272

Email: rurumone@yahoo.ca
Email: {kamilah, sheila, baguda_pg}@fke.utm.my

Abstract**—** This paper primarily describes the Partial Usage Subchannel (PUSC) slot of IEEE802.16e PHY modeling and mapping subcarriers to the frame. The OFDMA symbol was divided into odd number and even number symbols for simulation purpose. Cyclic prefix was inserted and its effect has been observed. The symbol signal was re-sampled with a higher frequency so that it can be configure for implementation on a medium density device (FPGA). Finally, the performance of other features of PUSC slot was simulated using MATLAB.

Index Terms**—** IEEE802.16e, PUSC slot, FPGA, Permutation

I. INTRODUCTION

The worldwide Interoperability for Microwave Access (WiMAX) has been the leading technology for broadband wireless communication network which provides different services. The technology of WiMAX uses OFDMA which is OFDM modulation techniques. In an OFDM system, resources are available in the time domain by means of OFDM symbols and in frequency domain by means of subcarriers. The time and the frequency resources can be organized in to sub-channels for allocation to users [1]. OFDM splits the radio signals into multiple smaller sub-signals called subcarriers [2],[3],[4]. The channel extends a flat fading response to these subcarriers [4]. The subcarrier permutation types can be divided in to distributed and adjacent subcarrier permutation [4],[5]. In the distributed subcarrier permutation types the subcarriers are randomly distributed across the bandwidth so that there is good frequency diversity under the distributed subcarriers we have the Partial Usage of Subchannels (PUSC) and the Full Usage of Subchannels (FUSC) permutation type.

The PUSC is available in both Downlink and Uplink sub-frame where as FUSC is only available in the Downlink sub-frame. The process of distributing the subcarriers for PUSC Downlink, PUSC Uplink and FUSC Downlink sub-frame is different. In adjacent subcarrier permutation the subcarrier are arrange in a group adjacent to each other in this case there is very good channel estimation by the pilot subcarriers example of this is the Adaptive Modulation Coding (AMC) permutation type. The WiMAX frame support different types of subcarriers permutations in both the Downlink and the Uplink sub-frame.

A slot on a frame is the minimum resource that can be allocated to a user [5]. A set of subcarriers form subchannels, the arrangements of the subcarriers in the subchannel depends on the type of permutation. A slot is made up of one OFDM symbol by one subchannel for FUSC, two OFDM symbols by one subchannel for PUSC Downlink, three OFDM symbols by one subchannel in PUSC Uplink. In adjacent permutation type four different types of slots exist [4], the default one is made up of six contiguous bins by one OFDM symbol, the second is two bins by three OFDM symbols, the third is three bins by two OFDM symbols and the last is one bin by six OFDM symbols. A WiMAX frame supports all these types of permutations with different slots.

Basically, base station (BS) can switch from one permutation (zone) to another, once switched to the zone of adjacent subcarrier permutation mode in a frame; BS shall continue to transmit/receive data using the adjacent subcarrier permutation mode. It shall return to the distributed subcarrier permutation at the beginning of a new DL sub frame [3],[4]. In general distributed subcarrier perform very well in Mobile application while adjacent subcarrier is good for fixed or low mobility application [1]. The rest of the paper is structured as fallows the Physical layer specification of IEEE802.16e PUSC slot is given in section 2, section 3 give the modules and simulation section 4 contains results discussion and the last conclude the report.

II AN OVERVIEW OF PARTIAL USAGE SUBCHANNELS

A Partial Usage Subchannel is the type of subcarrier distribution, in which the subchannels are available in the downlink and uplink sub-frame [1],[3],[4],[5]. One slot of PUSC is two OFDMA symbols by one subchannel in the down link sub-frame. In the uplink one slot is three OFDMA symbols by one subchannel. In 2048-FFT, used bandwidth is 20MHz and has a total number of 2048 subcarriers, comprises of 1440 data subcarriers, 240 pilot subcarriers and 368 null or guard band subcarriers [6]. The subcarriers are arrange adjacent to each other, after removing the null subcarriers in a group of 14 to form physical clusters; each physical cluster has 12 data subcarriers and 2 pilot subcarriers. A total of 120 physical clusters are form, which are renumbered according to renumbering sequence to form logical clusters. The renumbering sequence is the outer permutation [4].

Logical Cluster = Renumbering Sequence (Physical Cluster)+13*DL_PermBase (1)

The renumbering sequence is set of 120 random integers from 0 to 119 which has been described in [2],[5]

The DL-PermBase is a number ranging from 0 to 31 for the downlink which is used to identify a particular Base Station segment and is specified by MAC layer. The logical clusters are group to form 6 major groups consisting of old and even number group. The old number group (1, 3, 5) each has 8 logical clusters. The even number group (0, 2, 4) each has 12 logical clusters [2],[5],[6]. The pilot and data subcarriers are allocated to form subchannel, pilots are allocated first then the data. A total of 60 subchannels per OFDMA symbol are available in the downlink, each with 24 data subcarriers and 4 pilots. For the downlink PUSC, each major group is used separately in order to have a number of subchannels i.e one subchannel does not have subcarriers in more than one major group [5]. All subcarriers of one subchannel belong to the same OFDMA symbol. The subcarriers can be determine mathematically using the formula below

$$\text{Subcarrier}(k, s) = N_{subchls} * n_K + \{P_S[n_K \bmod N_{subchls}] + \text{DL\_PermBase}\} \bmod N_{subchls} \quad (2)$$

Where subcarrier (k, s) is the subcarrier index of subcarrier k (0 to 23) in subchannel s. $N_{subchls}$ represents the number of subchannels in major group, 6 for even and 4 for odd. $P_s[j]$ is the series obtained by rotating the basic permutation sequence cyclically to the left s times. The sequence is given in [2] for even and old number group. The variable n_k is given by the equation;-

$$n_k = (k+13s) \bmod N_{subchls} \quad (3)$$

III SYSTEM MODULES AND PARAMETERS DESCRIPTION OF PUSC

The IEEE 802.16e OFDMA PHY is based on OFDMA modulation, which comprises of OFDM modulation as well as subcarrier allocation. The simulation of this paper was based on the fallowing block diagram.

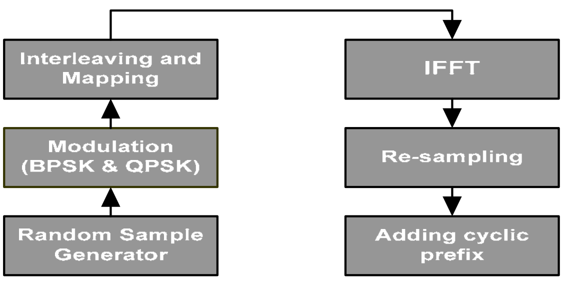

Figure 1. Simulation Diagram

A. *Random Symbol Generator*

The information symbols are generated using MATLAB function *randsrc* we specified the length and the range of the symbol in this case [0, 1, 2, 3] for QPSK, it generate random symbol which represent the message information to be transmitted on all the OFDMA symbols. BPSK uses the MATLAB command *randint* to generate random symbol or bits for transmission across the preamble.

B. *Modulation*

BPSK and QPSK modulation techniques are used in our simulation. BPSK was used in modulating the preamble just to ensure reliability while QPSK with phase offset of pi/4 was used in modulating both OFDMA symbols this also is a little bit more reliable then 16-QAM and 64-QAM, although the later have more data rate than the former. The total number of the downlink OFDMA symbols used is 29 which about 60% of the total frame symbols. The remaining 40% are considered to be in uplink.

C. *Interleaving and Mapping*

The inter-leaver block combines all the subcarriers type, data, pilot and null or guard. The arrangements of the subcarriers are the first 184 and the last 183 are zero pads i.e transmitting nothing. The center (1024) is a DC subcarrier also carrying no transmitting signal. The data subcarriers (1440) and the pilot subcarriers (240) and are arranged such that in every 14 subcarriers 12 are data and 2 are pilots. In odd number OFDMA symbol the pilot are in position 5 and 9 while in even number OFDMA symbol position 1 and 13 are pilot. Throughout the OFDMA symbols with exception of the first OFDMA symbol which is preamble, the pilot subcarriers were located first followed by the data subcarriers.

D. *Inverse Fast Fourier Transform (IFFT)*

The Inverse Fast Fourier Transform of the data message was calculated the inputs to this block are the modulated OFDMA symbols the IFFT was done for all the downlink symbols. The IFFT of the preamble was also was also computed. The cyclic prefix was added after the IFFT and after the signal has been resample so that the effect of inter symbol interference can be reduce.

E. *Resampling*

The OFDMA symbol message was resample at a frequency higher than the WiMAX system sampling frequency this is to ensure that it can be implemented in a medium density device. First it’s up sample then down sample. This is done before adding the cyclic prefix.

F. *Cyclic Prefix*

Cyclic prefix was added before the transmission. It significantly reduced the inter-symbol interference between odd and even symbol the guard interval (cyclic prefix) is a fraction of the OFDMA symbol duration. The recommended in WiMAX are 1/4 , 1/8, 1/16 and 1/32. However 1/8 is the only mandatory value in the mobile WiMAX system profile. So our simulation uses 1/8 for the cyclic prefix.

IV SIMULATION RESULTS AND DISCUSSION

The scenario has been experimented based on the following simulation parameters. The paper mainly focuses on DL PUSC operation and link performance is shown on various graphs.

TABLE I.
SIMULATION PARAMETERS

Parameters	Setting
FFT Size	2048
Left Guard Interval	184
Right Guard Interval	183
DC Carrier	Index1024 (counting from 0)
Data Subcarriers	1440
Pilot subcarriers	240
Downlink Subchannels	60
Cyclic prefix proportion	1/8
Frame duration	5mS
OFDMA Symbol duration	100.8uS
OFDMA Symbols per Frame	47
Sampling frequency	22.4MHz
Re-Sampling frequency (FPGA)	25MHz
Memory size (FPGA)	256
Modulation	BPSK, QPSK

The preamble which is the first OFDMA symbols is modulated with BPSK to ensure reliability because this necessary in every frame and it is responsible for synchronization of the frame. After the preamble we then group the rest of the symbol in to odd and even number group. The 2048 carries were populated with random symbols then QPSK modulated. Then the odd and even symbols were separated. Pilot subcarriers were inserted for the even symbols in every 14 subcarriers position 1 and 13 are pilot subcarriers while for odd symbols position 5 and 9 are pilot subcarriers. The 240 pilots were inserted across the frame and in every symbol. The guard interval was zero pads of 184 from left and 183 at the right, positioning 1024 was zero pad to account for DC carrier. The pilot subcarriers were boosted with 3dB since there are responsible for channel estimation as shown in figure 2. We can see that the pilots has been boosted and are having amplitude of 2 while the left and right guards' subcarriers and the DC subcarriers are at dc level (amplitude 0). The data subcarriers are having amplitude between -1 and +1, both subcarriers were so much concentrated in their position it appears like a solid line in the simulation results as shown in figure 2. The graph shows amplitude of the modulated symbol on y-axis and the subcarrier index on x-axis.

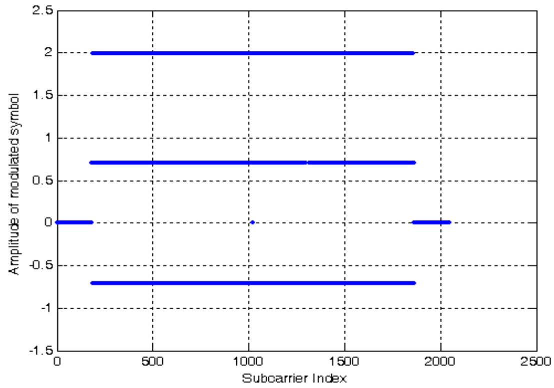

Figure 2. Subcarrier mapping

The subcarrier was then re-mapped and we than find the FFT of the signal then the signal was shifted using FFT shift the amplitude and the sampling frequency were normalized as shown in figure 3.

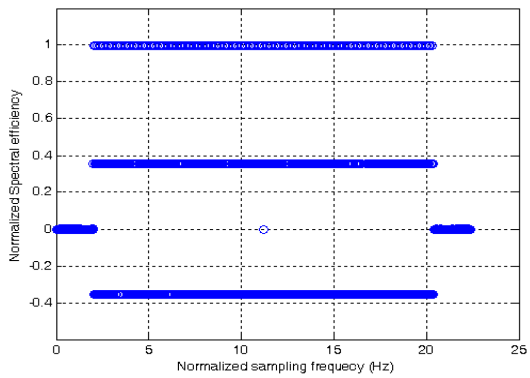

Figure 3. Normalized spectral efficiency and frequency

In order to relatively simplify the implementation process on FPGA, the signal was re-sampled at a frequency of 25MHz with up sample factor of 125 and down sample with 112. Figure 3 is the sample after conversion before the FFTshift and after the FFTshift we have figure 5.

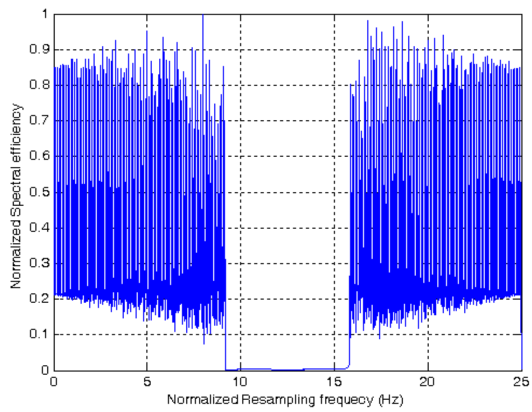

Figure 4. Post-FFT before shifting

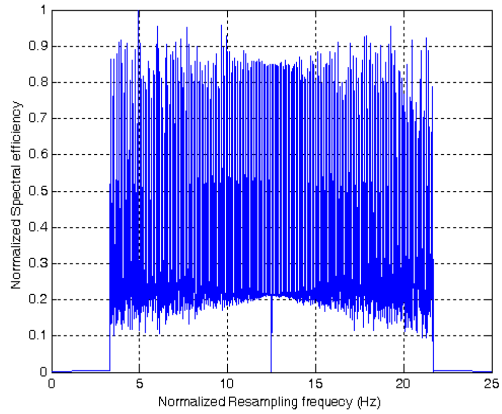

Figure 5. Post-FFT after shift

We then compare the performance of the signal after FFT, before and after the Re-sampling as show in the figure 6 we can see that they almost fallow the same pattern.

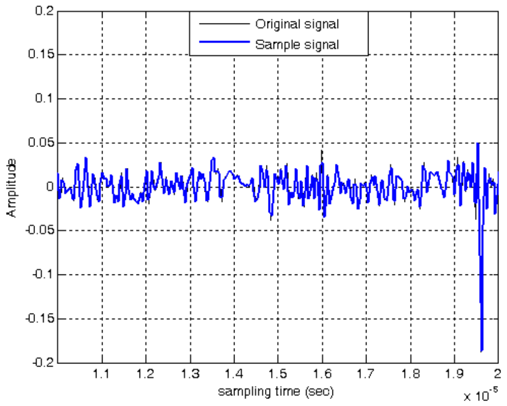

Figure 6. Comparisons between in phase and quadrature before and after re-sampling.

Cyclic prefix was inserted after the each symbol in the downlink. The Transmit Receive Transition Gap is about 2-OFDM symbol duration in PUSC, so we try to adjust it in the final spectrum so that it an integer of Memory size of a particular medium density device were its targeted to be accommodated. Figure 7 show the effect of the CP insertion. The signal was finally clip to reduce the peak to average power ratio.

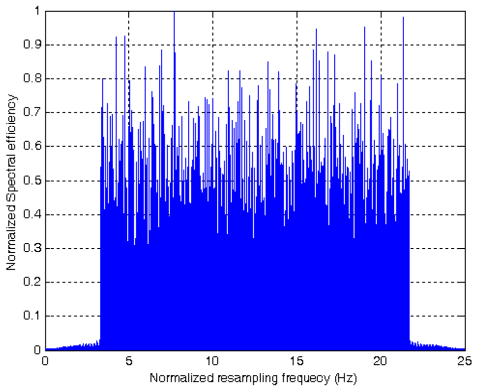

Figure7 Re-sample signal after cyclic prefix insertion

V. CONCLUSION

In this paper, we presented the simulation of PUSC permutation using MATLAB the preamble was modulated with BPSK and the remaining symbols were modulated using QPSK in order to ensure reliability. We show the possibility of implementing some of the simulation in the medium density device FPGA. Our future research will focus mainly FUSC AMC and TUSC in order to fully analyse and explore the channel usage in WiMAX IEEE802.16e. Subsequently, more efficient and sophisticated resource allocation schemes will be develop in order to effectively utilize the available resources to ultimately achieve high performance.

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