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EFFICIENT POWER ALLOCATION STRATEGY USING WATER FILLING ALGORITHM WITH CHANNEL CAPACITY ESTIMATION FOR WPM BASED WIMAX

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Abstract –

This work deals with the implementation of wavelet packet modulation over Wimax so as to fulfill the requirement of high bandwidth efficiency and flexibility. Wavelet modulation technique is a viable multicarrier modulation technique. This feature makes it eminently suitable for future generation of communication systems. WPM optimizes the bit error rate (BER) performance of WIMAX system. For the BER performance various adaptive modulation techniques are analyzed. Water filling algorithm is also implemented over WPM based WIMAX and an efficient power allocation scheme is proposed. The performance of the proposed technique is evaluated using a software simulation.

***Key Words*: Wavelet transform, WIMAX, Wavelet Packet Modulation, water filling algorithm, power allocation, Bit error rate(BER), Signal to Noise Ratio (SNR).**

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I. INTRODUCTION

The digital networks are used for the design of new communication networks with higher capacity. With a demand for a greater range of services, telecommunication industries are also changing yet, for example like video conferences, or applications with multimedia contents. Computer networking and the Internet has resulted in a wider demand for connectivity to be provided "anywhere, anytime", so it has to be a rise in the requirements for higher capacity and high reliability broadband wireless telecommunication systems.

Broadband availability brings high performance connectivity to over a billion users' worldwide, thus developing new wireless broadband standards and technologies that will rapidly span wireless coverage. Wireless digital communication is an emerging field that has experienced a spectacular expansion during the last several years. Moreover, the huge uptake rate of mobile phone technology, WLAN (Wireless Local Area Network) and the exponential growth of Internet have resulted in an increased demand for new methods of obtaining high capacity wireless networks [1].

WiMAX is discribed as Worldwide Interoperability for Microwave Access; it is a wireless networking standard which aims for addressing interoperability across IEEE 802.16 standard-based products. WiMAX defines a WMAN2, a kind of a huge hot-spot that provides interoperable broadband wireless connectivity to fixed, portable, and nomadic users. It allows communications which have no direct visibility, coming up as an alternative connection for cable, DSL3, and T1/E1 systems, as well as a possible transport network for Wi-Fi4 hot-spots, thus becoming a solution to develop broadband industry platforms. Likewise, products based on WiMAX technology can be combined with other technologies to offer broadband access in many of the possible scenarios of utilization, as shown in figure 1.

WiMAX will substitute other broadband technologies competing in the same segment and will become an excellent solution for the deployment of the well-known last mile infrastructures in places where it is very difficult to get with other technologies, such as cable or DSL, and where the costs of deployment and maintenance of such technologies would not be profitable. In this way, WiMAX will connect rural areas in developing countries as well as underserved metropolitan areas. It can even be used to deliver backhaul for carrier structures, enterprise campus, and Wi-Fi hot-spots. WiMAX offers a good solution for these challenges because it provides a cost-effective, rapidly deployable solution.

Wavelet Packet Modulation (WPM) with wavelet transform bases other than sine functions could similarly be used for multicarrier systems in order to provide an alternative to Orthogonal Frequency Division Multiplexing (OFDM). The WPM is a viable multicarrier modulation technique with high bandwidth efficiency and flexibility in adaptive channel coding schemes. This feature makes it eminently suitable for future generation of communication systems [1]. The idea of using wavelet transform instead of Fourier transform was first proposed in some researches such as [2-5]. The fundamental theories of OFDM and WPM have many similarities in their functions and performance but there are some significant differences which give two systems to be distinctive[5]. OFDM signals only overlap in the frequency domain while the wavelet signals overlap in both time and frequency domain. Due to time overlap, WPM system cannot use of cyclic prefix (CP) while it is commonly used in OFDM systems to overcome inter symbol interference (ISI)[6]. Wavelet based multicarrier does not need the CP [7].

In this paper, waterfilling algorithm is implemented over WPM based Wimax and its performance is analyzed for different modulation schemes. BPSK, QPSK and QAM are simulated and compared for the above mentioned scenario.

The rest of the paper is laid out as follows. Section II describes the preliminary background of OFDM system model. In section III WIMAX system based on WPM is discussed. Section IV describes the Water filling algorithm. The simulation study is presented in section V and section VI concludes the paper.

II. OFDM System Model

It is a promising candidate for next generation wired and mobile wireless system. In OFDM the basic principal is to split a high data rate stream into a number of low data rate stream so that the lower data rate can be transmitted simultaneously over a number of subcarriers. In OFDM, the amount of dispersion in time caused by multipath delay spread is decreased due to increased symbol duration for lower rate parallel subcarriers [7]. Use of closer channel space the spectrum of OFDM is more efficient. Interference is prevented by making all subcarrier orthogonal to one another. MIMO system utilizes space multiplex by using antenna array to enhance the efficiency in the used bandwidth.

An OFDM communication system is shown in Fig. 1. In this system the IFFT is used in modulator and FFT in demodulator. The IFFT/FFT can be replaced by IDWT and DWT respectively to change the system to WPM. The output of the transmitter in OFDM can be expressed as:

$$OP_{OFDM}(\mathrm{m}) = \sum_{k=0}^{N-1} c_k e^{2jm\pi\frac{k}{N}} \quad (1)$$

The output is discrete time domain and has *N* subcarrier with symbol period T. *ck* denotes the data symbols and *k*/*N* is the frequency of the *kth* subcarrier. Each OFDM symbol is a vector of *N*+*NC* samples, which *N* is the number of data samples and *NC* is the number of CP samples. The CP is added to remove the Inter Symbol Interference (ISI). In the receiver, the CP is removed and the process is reversed to obtain decoded data in the frequency domain.

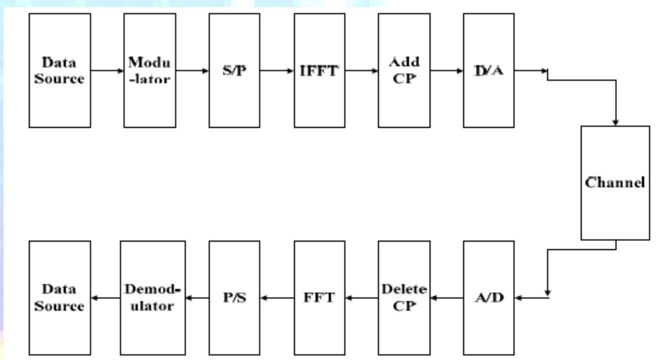

Fig 1. OFDM system model

III. WIMAX SYSTEM BASED ON WPM

The key point for multi-carrier modulation is orthogonality of the multiple carriers that helps to separate data in the receiver. The wavelet transform is usually represented as multi resolution analysis (MRA) [9]. The idea which links OFDM and wavelets is based on the fact that, similar to OFDM in which the same manner, that complex exponentials are orthogonal to each other, the members of wavelet family will also satisfy the same property[8]

$$.\langle \psi_{j,k}(t), \psi_{m,n}(t) \rangle = \begin{cases} 1 & j = m, k = n \\ 0 & otherwise \end{cases} \quad (2)$$

$\psi(t)$ Called wavelet mother function and can decompose signal with translating and scaling[10]. The discrete wavelet transform of a sequence with length N is a circular convolution between the sequence and the mother wavelet. Consequently the wavelet-based multicarrier modulation does not need to CP. For transmitting the data $s[n] \in \{s[0], s[1], s[2], \ldots\}$, the coefficient at the first level of decomposition can be written as

$$c_1[n] = s[n]$$

$$c_2[k] = \sum_{k=0}^{N-1} c_1[n] * h[n-2k]$$

$$d_2[k] = \sum_{k=0}^{N-1} c_1[n] * g[n-2k] \quad (3)$$

Where $k = 0,1,\ldots,\left(N/2\right)-1$.

The equation can be iterated by level where $N = 2^j$.

$$c_j[k] = \sum_{k=0}^{N-1} c_{j-1}[n] * h[n-2k]$$

$$d_j[k] = \sum_{k=0}^{N-1} c_{j-1}[n] * g[n-2k] \quad (4)$$

In this equation c_j is the scaling coefficient, d_j is wavelet coefficient and $h[n]$ *and* $g[n]$ are low pass and high pass filter coefficients, respectively.

In the reconstruction side, the original sequence is recovering from c_j *and* d_j. Therefore the equation of inverse process can be written as

$$c_{j-1}[k] = \sum_{k=0}^{N-1} c_j[n] * h[n-2k] + d_j[n] * g[n-2k]$$

The relation between low pass and high pass filter is

$$g[k] = (-1)^{-k} h[N-k]$$

The WPM functional block is shown in Fig. 2. At transmission end, the original signal sequence is constellated to symbol sequence. Then, the serial data stream is split into M lower-rate parallel streams. After that, the data in each parallel branch is modulated by Inverse Discrete Wavelet Packet Transform (IDWPT) using wavelet packet basis which is generated by filter banks. The modulated signal $y[k]$ can be expressed in the discrete domain as [9-10]

$$\sum y[k] = \sum_{i} \sum_{j}^{M-1} \left(x_{i,j} \varphi[k - iM] \right) \quad (5)$$

Where $x_{i,j}$ denotes a constellation encode i^{th} data symbol modulating the j^{th} waveform. M represents the number of channels in the system. $\varphi_j[k]$ is a wavelet packet basis function. The orthogonality of the subcarriers is given as

$$\langle \varphi_{j1}[k], \varphi_{j2}[k] \rangle = \delta[j_1 - j_2]$$

Where $\langle . \rangle$ represents an inner product operation and $\delta[.]$ is the dirac-delta function.

At receive end, the received signal is demodulated by Discrete Wavelet Packet Transform (DWPT). In the case of Gaussian channel, the received symbols $s[k]$ are

$$s[k] = y[k] + b[k]$$

For k[th] subcarrier *b[k]* is the noise function.

The demodulated symbols are de-mapped and parallel to serial. As result, the estimates of $x_{i,j}$ are obtained which can be expressed as:

$$\hat{x}_{i,j} = \sum_{i} \sum_{j}^{M-1} \left(s[k] * \varphi_j[k - iM] \right) \quad (6)$$

The block diagram of proposed model is shown in Fig.3. This block is divided to three main sections: the transmitter, the channel and the receiver. In the transmitter, a random binary sequence is generated as the source[13]. Then the randomizer block used to minimize the possibility of transmission of non-modulated subcarriers and avoid long sequence of continues one and zeroes. This helps to obtain easier decoding and time synchronization at the receiver. The FEC block consists of the concatenation of Reed-Solomon (RS) and Convolution Codes (CC) [12-14].

WIMAX system uses the phase-shift keying (BPSK), quadrature phase shift keying (QPSK), 16-QAM quadrature amplitude modulation), and 64-QAM. This system can switch between different modulations constellations depends on channel condition [12]. In WPM, the modulated data transmitted on wavelet subcarriers, which are orthogonal to each other. One of the advantages of this new scheme is that it does not need to CP which can increase the bit error rate performance of the systems. The maximum distance between WIMAX transmitter and receiver depends on the frequency band used, the environment, propagation conditions, antenna gain, modulation and coding schemes.

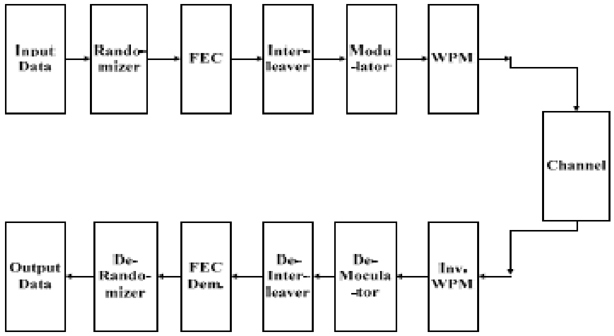

Fig 2. Block Diagram of the WIMAX based WPM

IV. WATER FILLING ALGORITHM

The process of water filling algorithm is similar to pouring the water in the vessel. The unshaded portion of the graph represents the inverse of the power gain of a specific channel. The Shadow portion represents the power allocated or the water. The total amount on water filled (power allocated) is proportional to the Signal to Noise Ratio of channel.

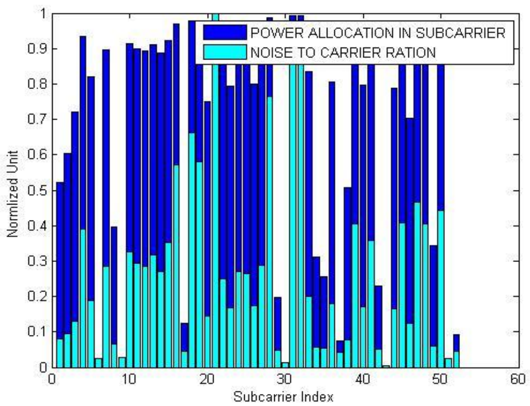

Fig 3. Water Filling Algorithm Model

Power allocated by individual channel is given by the equation 5, as shown in the following formula

$$\text{Power allocated} = \frac{pt + \sum \frac{1}{H_i}}{\sum channel} - \frac{1}{H_i}$$

(7)

Where Pt is the Total power of MIMO system which is allocated among the different channels and H is the channel matrix of system. The capacity of a MIMO is the algebraic sum of the capacities of all channels and given by the formula below.

$$\text{Capacity} = \sum_{i=1}^{n} \log\left(1 + PowerAllocation * H\right) \tag{8}$$

We have to maximize the total number of bits to be transported, .As per the scheme following steps are followed to carry out the water filling algorithm.

Algorithm Steps:-

1. Take the inverse of the channel gains.
2. Water filling has non uniform step structure due to the inverse of the channel gain.
3. Initially take the sum of the total power Pt and the inverse of the channel gain. It gives the complete area in the water filling and inverse power gain.

$$Pt + \sum_{i=1}^{n} \frac{1}{H_i} \tag{9}$$

4. Decide the initial water level by the formula given below by taking the average power allocated

$$\frac{Pt + \sum_{i=1}^{n} \frac{1}{H_i}}{\sum channel} \tag{10}$$

5. The power values of each sub channel are calculated by subtracting the inverse channel gain of each channel.

$$\text{Power allocated} = \frac{pt + \sum \frac{1}{H_i}}{\sum channel} - \frac{1}{H_i} \tag{11}$$

In case the power allocated value become negative stop iteration.

V. Simulation Results

Simulation is performed to verify the effectiveness of wavelet packet modulation over WIMAX. Water filling algorithm has been simulated in order to enhance the capacity and SNR performance of WIMAX system. In the comparison of Fourier transform and wavelet transform, we test the BER performance of conventional OFDM with Wavelet-based multicarrier in AWGN channel. For this simulation, the energy of signal before the AWGN channel is the same for both techniques. We have presented an improved method for subcarrier and power allocation in multicarrier and multi-antenna systems with the aim of maximizing the capacity.

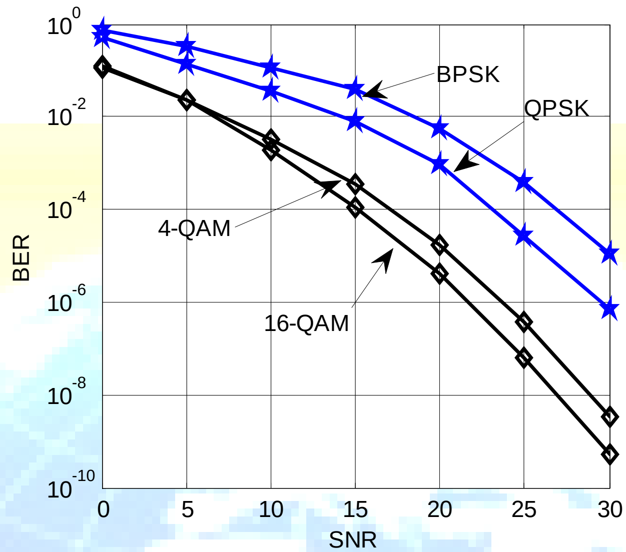

Fig 4. BER Performance of WPM based WIMAX

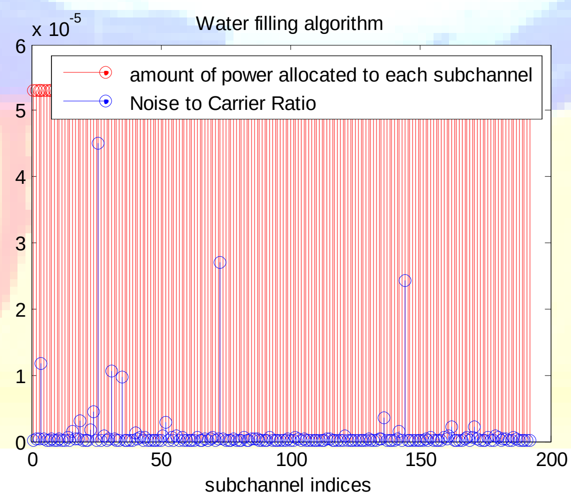

Fig.5 Power allocation using Waterfilling algorithm

VI. CONCLUSION

WPM has been implemented over WIMAX in this work and its BER performance has been evaluated with respect to SNR. The efficacy of the proposed work has been verified through simulation study. Also the capacity and powerr allocation is evaluated using waterfilling algorithm for the subcarriers of WIMAX system. The results of simulation show BER performance of WPM system is better than OFDM in AWGN channel, because of higher SNR needed in OFDM due to cyclic prefix. A comparison of ICI in both technique shows the wavelet transform-based multicarrier is better than Fourier transform based multicarrier.

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