Energy Optimization in Wireless MIMO Systems

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Abstract— In a multi input multi output (MIMO) system bit rate is increased due to multiple antennas but at the same time energy consumed also increases. In this paper, optimum solutions to that problem are addressed and their comparison is done in terms of total energy consumed and their processing times. The technique employed in those algorithms is using adaptive bit allocation to OFDM subcarriers in a frequency selective fast fading channels. To perform adaptive Modulation in OFDM systems requires Channel Estimation in prior to Adaptive modulation.

Key words: OFDM, Channel estimation, adaptive modulation, pilots

I. INTRODUCTION

Wireless communications has become essential in day to day life. Users in a wireless network are increasing day by day aand there is a big demand for higher data rates.The data rates in wireless systems can be increased by using multiple antennas at the transmitter and receiver because data can be transmitted over the antennas in a parallel way. OFDM is very popular and widely used modulation schemes in wireless communications systems because of its high rate transmission capability with high bandwidth efficiency and its robustness with respect to multi-path fading and delay. It is being used in digital audio broadcasting (DAB) systems, digital video broadcasting (DVB) systems and wireless LAN standards such as the American IEEE Std. 802.11. It is also proposed for wireless broadband access standards such as IEEE Std. 802.16 which is wimax and acts as a best technique for the fourth generation wireless mobile communications. Currently, technology is peaking interest towards OFDM as it combines the pros of high data rates and easy implementation. This result is shown by the many standards that adopted OFDM for Digital Audio Broadcast (DAB) and Digital video Broadcast (DVB), high speed modems over digital subscriber lines, and Wireless Local Area Network (WLAN) broadband systems as of IEEE802.11a, 802.11b and 802.11g.

The channel state information (CSI) should be very accurate because it greatly influences the overall system performance. The main challenges associated with OFDM systems today are- channel identification and tracking, channel coding and equalization. In wideband mobile channels, pilot-based signal correction schemes are feasible method for OFDM systems. Most channel estimation methods for OFDM transmission systems have been developed under the assumption of a slow fading channel, where the channel transfer function is assumed stationary within one OFDM data block.

In Section II, we describe the system model. In Section III comb type pilot insertion for channel estimation is presented .In section IV, Hughes hartogs algorithm and peter, chow, cioffi,Binghams practical algorithm is presented. Their comparison in terms of total energy and processing times. In section V, the bit allocation and energy allocation of two algorithms are presented.

II. SYSTEM MODEL

We will consider the system shown in Fig. 1, where xk are the transmitted symbols, g(t) is the channel impulse response, en(t) is the white complex Gaussian channel noise and yk are the received symbol vectors. The transmitted symbols xk are taken from a single amplitude signal constellation with a different phase. The D/A and A/D converters contain ideal low-pass filters with bandwidth 1/Ts, where Ts is the sampling interval. A cyclic extension of time length Tg is used to eliminate inter-block interference and preserve the orthogonality of the tones.

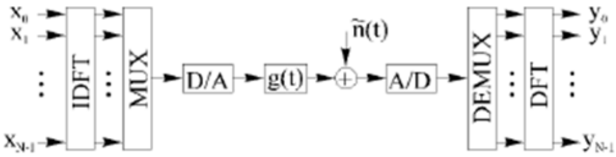


Fig. 1: Base-band OFDM System

In OFDM large bandwidth signal is decomposed into low bandwidth smaller signals so as to reduce intersymbol interference (ISI).Using OFDM increases bandwidth efficiency when compared to FDMA. Hence the main advantage of OFDM is to reduce inter symbol interference due to multipath fading and also to have good bandwidth efficiency over FDMA. In OFDM instead of guard bands, cyclic prefix is used to avoid inter symbol interference. Cyclic prefi makes the system looks like circular convolution instead of linear convolution.

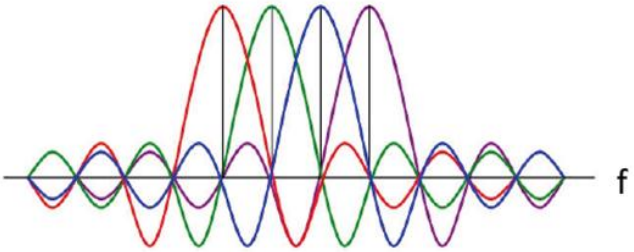


Fig. 2:

Figure 2 represents the arrangement of OFDM subcarriers in an orthogonal manner. Each OFDM subcarrier is modulated with a particular carrier frequency. However each subcarrier in OFDM symbol is itself a baseband signal. By using the same carrier frequency of a particular subcarrier at receiver we can demodulate the signal.

III. CHANNEL ESTIMATION

Channel estimation of OFDM subcarriers can be performed using comb type and block type pilots. In this paper we assume channel to be frequency selective fast fading channel. pilots are the data that is known to both transmitter and receiver.in this paper we go for comb type pilot estimation because of fast fading channel. Block type channel estimation is preferred in slow fading channels.

A. COMB Type Pilots Channel Estimation:

In the comb type pilot channel estimation, pilots are introduced after particular number of subcarriers within the same OFDM symbol. Since the channel is assumed to be fast fading, so there is need to introduce pilots within the OFDM symbol at regular subcarrier intervals. In this case channel is assumed to be constant within two successive pilot insertion duration.

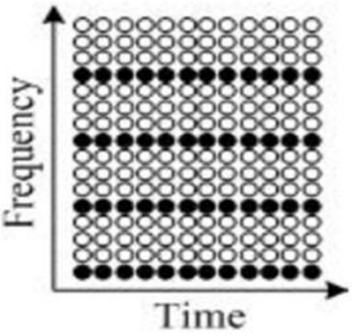


Fig. 3: comb type pilot insertion

In the figure3, we see that within one OFDM symbol itself pilots are introduced at regular subcarrier intervals. Channel is assumed to be constant within the successive pilot interval in the same OFDM symbol.

The block diagram for pilot based channel estimation is

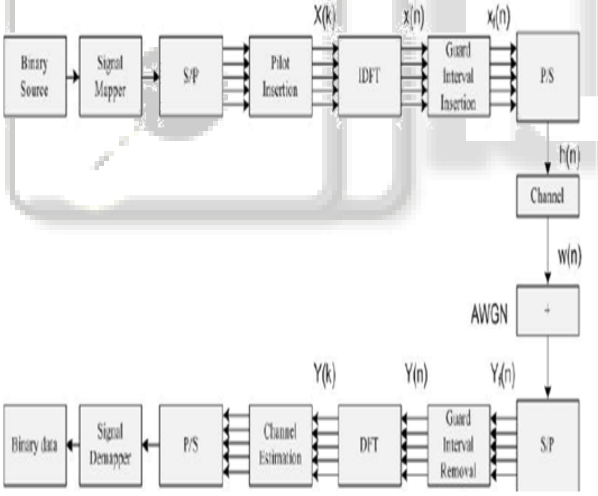


Fig. 4:

The binary information is first grouped and mapped according to the modulation in signal mapper. In modern OFDM systems, usually QAM is used as the modulation technique. After inserting pilots either to all sub-carriers with a specific period or uniformly between the information data sequence, IDFT block is used to transform the data sequence of length into time domain signal using the following equation:

$$X(n)=IDFT\{X(k)\}=\sum_{k=0}^{N-1} X(k)e^{j2\pi kn/N}$$

Where N is the DFT length. Following IDFT block, guard time, which is chosen to be larger than the expected delay spread, is inserted to prevent inter-symbol interference. This guard time helps eliminating the inter-carrier interfernce. The transmitted signal will pass through the frequency selective time varying fading channel with additive noise. The received signal is given by

$$y_f(n) = x_f(n) \otimes h(n) + w(n)$$

Where $w(n)$ is AWGN and $h(n)$ is the channel impulse response. Thus, the overall channel response can be represented as:

$$H(n)=\sum_{i=0}^{r-1} h_i\, e^{j\left(\frac{2\pi}{N}\right)f_{di}t_n}\delta(\lambda-\tau_i) \qquad n=0,1,2,\ldots.N-1$$

Where r is the total number of propagation paths, h_i is the complex impulse response of the i_{th} path, f_{di} is the i_{th} path Doppler frequency shift, λ is delay spread index, T is the sample period and is the i_{th} path delay normalized by the sampling time.

The received signal y(n) is then sent to DFT block to yield

$$Y(k)=DFT(Y(n))=\frac{1}{N}\sum_{n=0}^{N-1} y(n)\ e^{-j2\pi kn/N} \qquad k=0,1,2,\ldots.N-1$$

Assuming there is no ISI, the relation of the resulting Y(k) to H(k)=DFT{h(n)} and W(k)=DFT{w(n)}, is given by

$$Y(k)=X(k).H(k)+W(k)$$

The transmitted data can be estimated by

$$\hat{X} = \frac{Y(k)}{H(k)}$$

Then the binary information data is obtained back in signal demapper block. Based on principle of OFDM transmission scheme, it is easy to assign the pilot both in time domain and in frequency domain.

IV. ENERGY OPTIMIZATION ALGORITHMS

In this paper Huges hartogs algorithm and peter, chow, cioffi, Binghams practical algorithms are implemented and their comparision is done interms of energy and processing times.

Before proceeding to algorithms adaptive bit allocation is done prior to them. Bit allocation is done based on the channel gain of each subcarrier i.e a subcarrier with low channel gain gets less number of bits allocated and the subcarrier with high channel gain gets more bits allocated thus distributing the power in an efficient manner.

A. Intial Conditions:

The algorithms used in this paper for power minimization problem were tried for the same channel and noise conditions:

1) The required bit rate was B_{target}=256 bits per OFDM symbol.
2) The noise variance of each sub-carrier was $s^2 = 10^{-4}$ (white broadband noise assumed).
3) The required error probability was P_e=10^{-5}
4) Maximum number of bits per QAM subcarrier b_{max}=10.
5) Uncoded system (integer QAM constellations with b ∊ {0,1,2…,b_{max}} bits per symbol).

Gap factor for the given probability of error is given by

$$\gamma = \frac{1}{3}\left[Q^{-1}\left(\frac{P_s}{4}\right)\right]^2$$

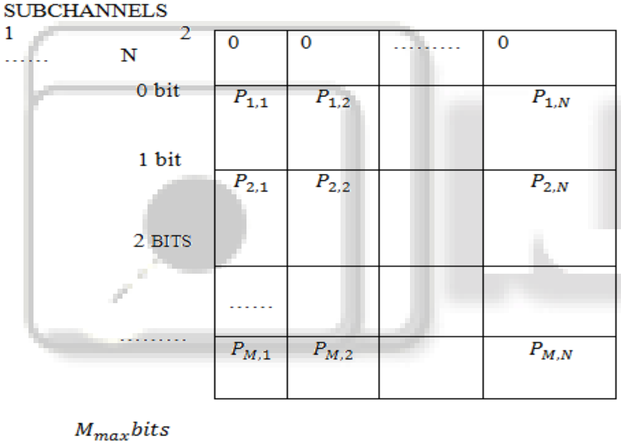
The relationship between number of bits allocated to a subcarrier and channel gain is given by

$$B(n)=log_2\left(1+\frac{{H_v}^2}{s^2\gamma}\right).$$

We see that bits allocation and channel gain are proportional logathimacally.

B. Greedy Algorithm-Huges Hartogs Algorithm:

In Hughes-Hartogs's patent (Hughes-Hartogs, 1987-1989), an algorithm based on greedy idea was proposed. That is, every incremental power to transmit one additional bit is allocated to the subchannel that can use it most economically. For example, assume considering only two subchannels *A* and *B*. Subchannel *A* bears N_A bits now, and the incremental power required to transmit N_A+1 bits is ΔP_A. For subchannel *B* that bears $N_{\boldsymbol{B}}$ bits, the incremental power is $\Delta P_{\boldsymbol{B}}$. If $\Delta P_A < \Delta P_B$, subchannel *A* will be selected to transmit the additional bit and gets the incremental power allocation. The power requirement for all Sub channels to transmit all possible number of bits could be calculated in advance, and be saved in a matrix P as show in Fig. 5. The element Pm,n in the matrix represents the power needed to transmit *m* bits in subchannel *n*. The values in first row are zeros obviously.The incremental power required to transmit one additional bit is calculated by subtracting the first row from the second row. The result ΔP is same as the second row in the first iteration. The subchannel *n* that has minimum value in ΔP is selected to get the additional bit. In the next iteration, the elements of column *n* in matrix P are shifted upward for one position. The following subtractions are still performed on the row one and row two, until the power budget is fully consumed.



SUBCHANNELS	1	2	......	N
0 bit	0	0	....	0
1 bit	$P_{1,1}$	$P_{1,2}$		$P_{1,N}$
2 BITS	$P_{2,1}$	$P_{2,2}$		$P_{2,N}$
....	......			
$M_{max}bits$	$P_{M,1}$	$P_{M,2}$		$P_{M,N}$

Fig. 5:

C. Peter,Chow,Cioffi And Binghams Practical Algorithm:

Chow, Cioffi, and Bingham proposed a practical DMT loading algorithm based on the rounded bit number and performance margin adjustment. The idea is to make a round operation on the resulting bit loading value, which is expressed as

$$b(n)=log_2\left(1+\frac{SNR(n)}{\gamma+\gamma_{margin}}\right)$$

where γ_{margin} represents the performance margin, and has the initial value of 0. The zero value of γ_{margin} causes the $b(n)$ to get the maximum value. $b(n)$ is then rounded to the nearest integer value $b\hat{}(n)$. In regular condition, the summation of rounded values $b\hat{}(n)$, n from 1to N, will exceed the target total bit number. In next step, the algorithm increases the margin by using the formula:

$$\gamma_{margin} = \gamma_{margin} + 3.010*\left(\frac{B_{target}-B_{total}}{no.of\ sub\ carriers}\right)$$

With the updated γ_{margin} b(n) is calculated and rounded again.

The process continues until the total number of bits reaches the target.

V. COMPARISION AND SIMULATION RESULTS

The described algorithms were implemented in Matlab, and an OFDM link over Hiperlan/2 channels was assumed (64 carriers and model-A channels [ETS98] were used). The path-loss in the channel model was not included since it does not alter the frequency-selectivity of the channel realizations (it only rescalesthe amount of total used power).Figure 6 displays channel realization and the bit and power allocations that the different algorithms computed for this CSI.

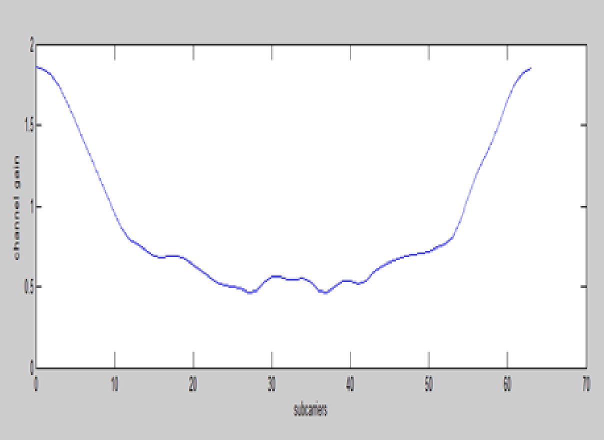


Fig. 6: Subcarriers Vs Channel Gain

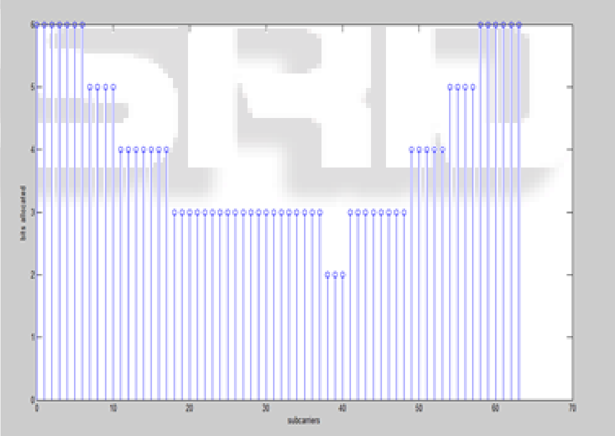


Fig. 7: Huges Hartogs Bit Allocation

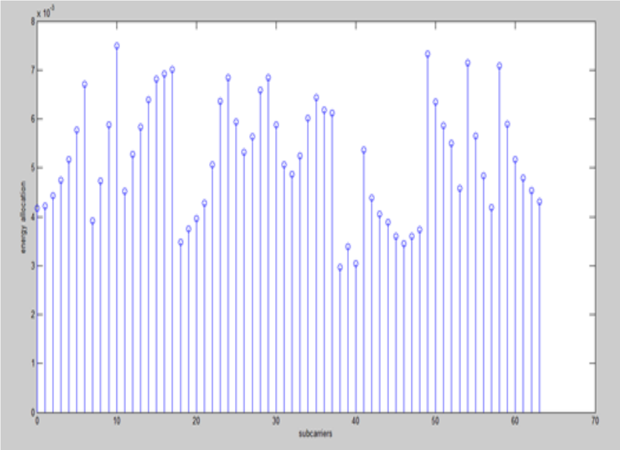


Fig. 8: Huges Hartogs Energy Allocation

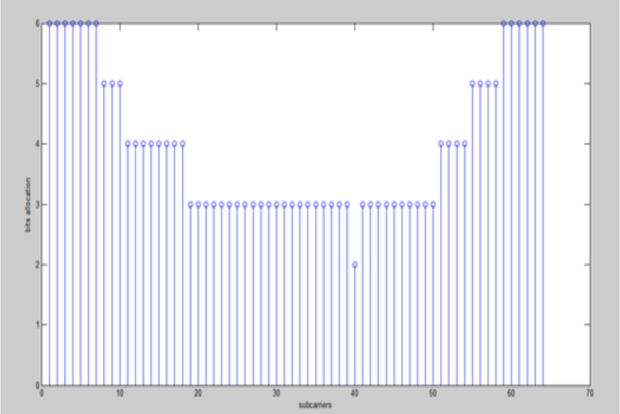


Fig. 9: Bit Allocation in Chow Peter Cioffi and Binghams Algorithm

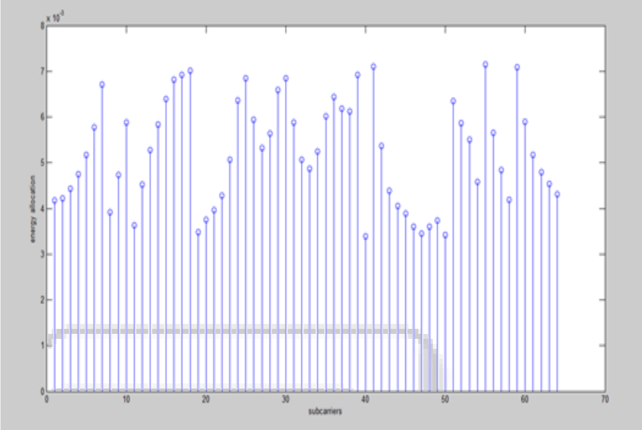


Fig. 10: Energy Allocation In Chow, Pete, Cioffi And Binghams Algorithm

VI. COMPARISON

The two algorithms produce almost similar results but vary slightly in energy consumption and processing time.

Sl no	ALGORTIHM	TOTAL ENERGY PER OFDM SYMBOLIN DB	PROCESSING TIME
1	HUGHES-HARTOGS	2.1348 JOULE	21.50 MILLISECONDS
2	CHOW,PETER, CIOFFI,BINGHAM	2.1419 JOULE	6.539 MILLI SECONDS

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