Performance Analysis of AOFDM Systems

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Abstract: **The goal for the fourth generation (4G) of mobilecommunications system is to seamlessly integrate a wide variety of communication services such as high speed data, video and multimedia traffic as well as voice signals. One of the promising approaches to 4G is adaptive OFDM (AOFDM). In AOFDM, adaptive transmission scheme is employed according to channel fading condition with OFDM to improve the performance. In this paper, we have considered only adaptive modulation. First we have investigated the OFDM system performance of uncoded adaptive modulation using quadrature amplitude modulation (QAM) and phase shift keying (PSK). To further enhance the system, we employ convolutional coding to OFDM system. The obtained results show that a significant improvements in terms of bit error rate (BER) and throughput can be achieved demonstrating the superiority of the adaptive modulation schemes compared to fixed transmission schemes.**

Keywords: **Adaptive modulation, orthogonal frequency division multiplexing (OFDM), channel coding, bit error rate (BER), throughput.**

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multi-carrier transmission technique in which a single high rate data stream is divided into multiple low rate data streams. These data streams are then modulated using subcarriers which are orthogonal to each other. In this way the symbol rate on each subchannel is greatly reduced, and hence the effect of intersymbol interference (ISI) due to channel dispersion in time caused by multipath delay spread is reduced.

Guard interval can also be inserted between OFDM symbols to reduce ISI further. The orthogonality between subcarriers can be maintained, even though the signal passes through a time-dispersive channel by cyclically extending the OFDM symbols into guard interval.

The main advantages of OFDM are its multipath delay spread tolerance and efficient spectral usage by allowing overlapping in the frequency domain. Another significant advantage is that the modulation and demodulation can be done using inverse Fast Fourier Transformation (IFFT) and Fast Fourier Transformation (FFT) operations, which are computationally efficient.

In an OFDM transmission system, each subcarrier is attenuated individually under the frequency-selective and fast fading channel. The channel performance may be highly fluctuating across the subcarriers and varies from symbol to symbol [1]. If the same fixed transmission scheme is used for all OFDM subcarriers, the error probability is dominated by the OFDM subcarriers with highest attenuation resulting in a poor performance. Therefore, in case of frequencyselective fading the error probability decreases very slowly with increasing average signal-to-noise ratio (SNR) [2].

This problem can be mitigated if different modulation schemes are employed for the individual OFDM subcarriers. Unlike adaptive serial systems, which employ the same set of parameters for all data symbols in a transmission frame, adaptive OFDM schemes have to be adapted to the SNR of the individual subcarriers. This will substantially improve the performance and data throughput of an OFDM system. For example if the subcarriers that will exhibit high bit error probabilities in the OFDM symbol to be transmitted can be identified and excluded from data transmission, the overall BER can be improved in exchange for a slight loss of system throughput. However the potential loss of throughput due to seclusion of faded subcarriers can be mitigated by employing higher order modulation modes on the subcarriers exhibiting high SNR values.

Many adaptive transmission techniques have been presented in the literature. The combination of adaptive modulation with OFDM was proposed as early as 1989 by Kalet which was further developed by Chow [3] and Czylwik [2]. Specifically the results obtained by Czylwik showed that the required SNR for the BER target 10-3 can be reduced by 5dB to 15dB compared to fixed OFDM depending on the scenario of radio propagation.

The performance of turbo-coded adaptive modulation are investigated in [4]. Three different modulation mode allocation algorithms were discussed and compared. Further studies on the application of turbo code in adaptive modulation and coding is conducted in [5]. This paper proposed an optimal approach based on prediction of the average BER over all subcarriers.

In [6], an adaptive OFDM system with changeable pilot spacing has been proposed. The results showed that a significant improvement in the BER performance is achieved with sacrificing a small value of the total throughput of the system. A work is done on several strategies on bit and power allocation for multi-antenna assisted OFDM systems in [7]. They found out that sometimes power and bit adaptation is required for efficient exploitation of wireless channels in some system conditions.

The performance analysis of OFDM systems with adaptive subcarrier bandwidth is investigated by [8]. Further investigations on subcarrier adaptive modulation scheme of precoded OFDM is presented in [9] under multipath channels.

2. System Model

In this paper, subband adaptive transmission schemes are employed to reduce the complexity. In subband adaptive OFDM transmission, all subcarriers in an AOFDM symbol are split into blocks of adjacent subcarriers referred to as subbands. The same mode is employed for all subcarriers of the same subband.[10]. The choice of the modes to be used by the transmitter for its next OFDM symbol is determined by the channel quality estimate of the receiver based on the current OFDM symbol. Perfect channel estimation is assumed in this paper. In this simulation the instantaneous

SNR of the subcarrier is measured at the receiver. The channels quality varies across the different subcarriers for frequency selective channels. The received signal at any subcarrier can be expressed as :

$$Rn=HnXn+Wn \quad (1)$$

Where, Hn is the channel coefficient at any subcarrier, Xn is the transmitted symbol and Wn is the Gaussian noise sample. So the instantaneous SNR can be calculated using

$$SNR_n=H_n^2/N_0 \quad (2)$$

where N_0 is the noise variance [7].

The conservative approach in threshold based adaptation is by using the lowest quality subcarrier in each subband for controlling the adaptation algorithm [11]. It means that the lowest value of SNR will be used in mode selection. By using this method, the overall BER in one subband is normally lower than the BER target. If the overall BER can be closer to the BER target by choosing a more suitable modulation mode or code rate, the throughput of the system will be higher [5].

Therefore a better adaptation algorithm is used in this paper to provide a better trade off between throughput and overall BER by choosing a more suitable scheme for each subband. Instead of using the lowest SNR in each subband, the average value of the SNR of the subcarriers in the subband is going to be used.

2.1 Block diagram

The block diagram of this system is shown in Figure 1. The channel estimation and mode selection are done at the receiver side and the information is sent to the transmitter using a feedback channel [12]. In this model the adaptation is done frame by frame.

The channel estimator is used to estimate the instantaneous SNR of the received signal. Based on the instantaneous SNR calculated, the best mode will be chosen for the next transmission frame. This task is done by the mode selector block. At the transmitter the adaptive modulator block consists of different modulators which are used to provide different modulation modes. The switching between these modulators will depend on the instantaneous SNR

This block diagram is used to describe two types of adaptive modulation schemes which is based on MQAM and MPSK scheme. The goal of adaptive modulation is to choose the appropriate modulation mode for transmission in each subband, given the local SNR, in order to achieve good trade-off between spectral efficiency and overall BER.

2.2 Switching Thresholds.

The switching threshold for activating different modes can be determined by extensive simulation of the fixed mode modulation system. The switching algorithm used for the adaptive modulation schemes are presented in Table 1 till Table 2 .The design parameters used in the simulation are listed in Table 3.

In this simulation, two types of adaptation modes will be used. The first one is adaptive modulation without transmission blocking and the second one is adaptive modulation with transmission blocking.

In adaptive modulation without transmission blocking, data will be constantly transmitted in this scheme even though thechannel is in deep fades. If the channel quality is very bad, arobust modulation mode will be used and when the channel quality is good a spectrally efficient modulation will be used.

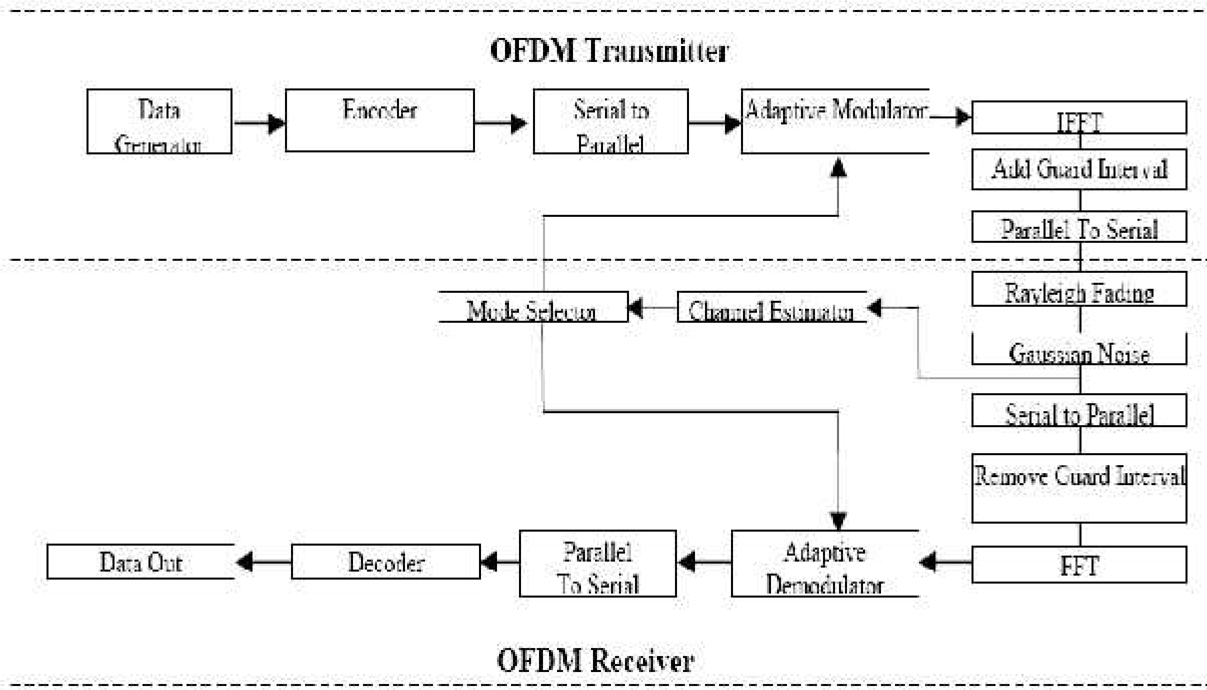

Figure1: Block Diagram

Mode	Modulation	Thresholds
1	No Tx	SNR< 10dB
2	4QAM	10 dB<SNR≤15.6 dB
3	8QAM	15.6 dB<SNR<18.6 dB
4	16QAM	18.6 dB<SNR≤21.5 dB
5	32QAM	21.5 dB<SNR<24.6 dB
6	64QAM	SNR>24.6 dB

Table1: switching threshold for MQAM with transmission blocking

Mode	Modulation	Thresholds
1	No Tx	SNR< 11 dB
2	QPSK	11 dB<SNR≤16.6 dB
3	8PSK	16.6 dB<SNR≤22 dB
4	16PSK	22 dB<SNR≤28.2 dB
5	32PSK	SNR>28.2 dB

Table2: switching threshold for MPSK with transmission blocking

In adaptive modulation with transmission blocking, transmission will be disabled when the channel is in deep fade. This mode is introduced because the signal quality is too bad to guarantee a required transmission [13]. Data will be transmitted if the channel quality improved.

Parameter	Value
IFFT Size	512
Number of subcarriers	512
Number of subband	32
Number of subcarriers per subband	16
Guard Time Duration	128
Frame size	6
SNR	1-30 dB
Modulation scheme	MPSK, MQAM
Coding rate	2/3, 1/2 ,1/3 and 1/4
Bandwidth	5MHz
Carrier Frequency	2 GHz
Sampling Frequency	5.4MHz

Table 3: System Parameters

3. Simulation Results and Discussion

In this simulation, the performance of adaptive modulation is investigated in terms of throughput and BER performance. To highlight the advantages of adaptive modulation comparison is made to fixed modulation system. Initially the uncoded performance of adaptive modulation based on MQAM and MPSK scheme are investigated. Next convolution coding is employed to the adaptive modulation system. Finally comparison is made between the proposed system and the conservative adaptation system.

3.1 Adaptive Modulation for MQAM systems.

3.1.1 Adaptive Modulation with Transmission Blocking (AMQAM-Blocking)

Figure 2 presents the BER performance AM scheme utilizing transmission blocking. As seen clearly a significant improvement in BER performance for AM with transmission blocking is achieved. The BER performance for all SNR values is successfully decreased to meet the BER target 10^{-3}. At low SNR, the system will enter transmission blocking mode and this will results in no error. Therefore the overall BER can be reduced to meet the BER target. The BER performance is not recorded for the SNR range of (0 - 4dB) because no bits are transmitted at all.

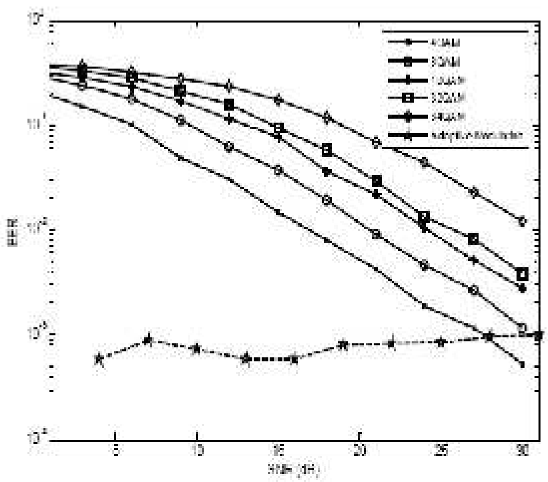

Figure 2: BER performance for adaptive modulation (AMQAM-Blocking)

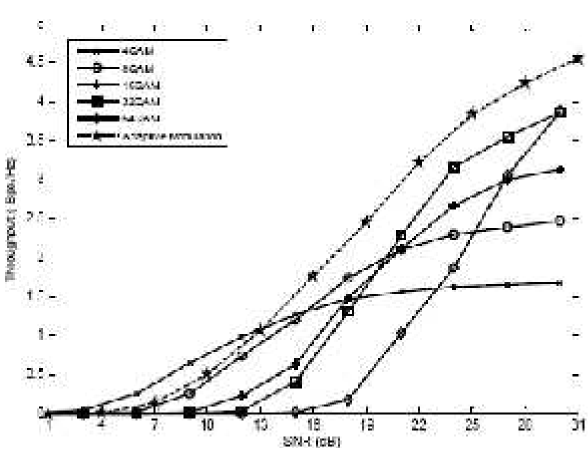

Figure 3: Throught performance for adaptive modulation (AMQAM-Blocking)

3.2 Adaptive Modulation for MPSK systems

3.2.1 Adaptive Modulation with Transmission Blocking (AMPSK-Blocking)

Figure 4 shows the performance of adaptive modulation with transmission blocking based on MPSK system (AMPSKblocking). It is found that the BER performance of adaptive MPSK scheme nearly meet the BER target 10-3. It can be seen that the required SNR to achieve the BER target is quite high which is more than 25 dB .

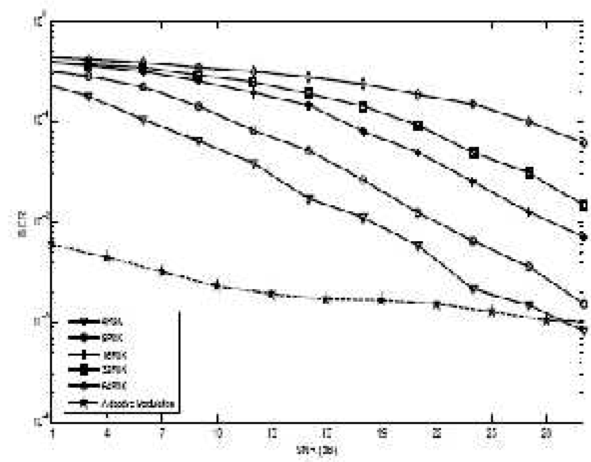

Figure 4: BER performance for adaptive modulation (AMPSK-Blocking)

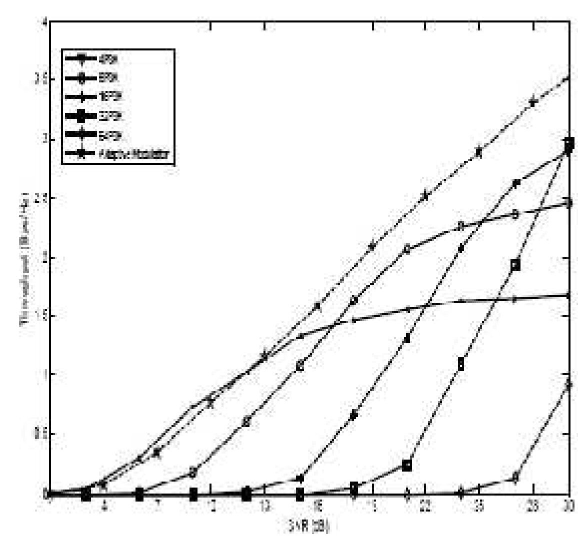

Figure 5: Throught performance for adaptive modulation (AMPSK-Blocking)

3.3 Coded Adaptive Modulation Schemes

In this section the employment of convolutional code in

Adaptive modulation system will be investigated. From Figure 6, it can be seen that the BER performance improve tremendously. Specifically when rate 1/4 code is used, the BER performance decreases below 10^{-4} for SNR more than 13 dB. These results suggest that more reduction in the BER can be obtained by using channel coding.

Figure 7 shows the throughput performance for Coded AMQAM-Blocking scheme. A decrease in the maximum throughput is observed due to the convolutional coding employed. Even though Coded AMQAM-Blocking scheme achieves a good BER performance, there is a trade off where the maximum throughput being limited.

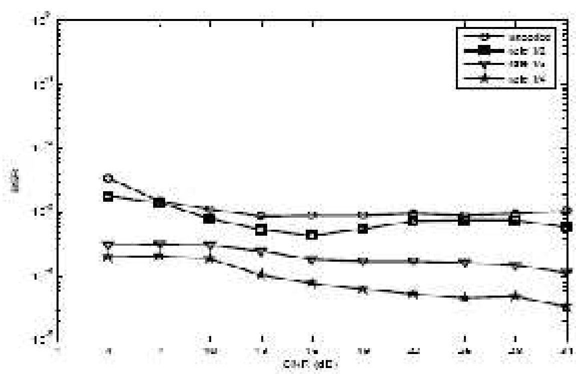

Figure 6: BER performance for coded adaptive modulation (coded AMQAM-Blocking)

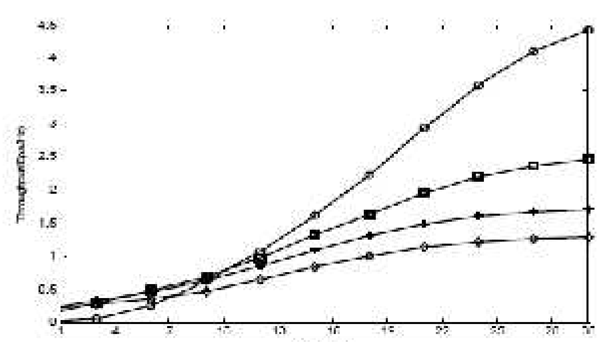

Figure 7: Throught performance for coded adaptive modulation (AMQAM-Blocking)

4. Conclusions

In this paper, the performances of adaptive transmission

scheme for OFDM have been investigated. The advantage of employing adaptive transmission scheme is described by comparing their performance with fixed transmission system. A better adaptation algorithm is used to improve the throughput performance. This algorithm utilizes the average value of the instantaneous SNR of the subcarriers in the subband as the switching parameter. The results show an improved throughput performance with considerable BER performance.

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