Combination of Adaptive Subcarrier Allocation for OFDMA using WiMAX

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Abstract— WiMAX is one of the latest techniques for providing Broadband Wireless Access in metropolitan area. Phenomenal growth in the demand for higher bandwidth increases the importance of subcarrier allocation. WiMAX uses OFDMA techniques based on multiuser diversity such as Adaptive Modulation Coding. Resource Allocation Algorithm improves performance based on user channel condition. Fair Allocation Algorithm maximizes the minimum data rate and allocates equal bandwidth to all users. However this allocation reduces the bandwidth efficiency of the system. In order to overcome this drawback Heuristics allocation such as Proportional Allocation and Equal Capacity Increment are introduced. To improve their performance, both allocations are combined. The other objective is to share better trade off between bandwidth efficiency and fairness. Performance has been compared on the basis of bit error rate with respect to signal to noise ratio and various user distances from base station.

Keywords— Adaptive Modulation Coding, Subcarrier allocation, WiMAX, OFDMA.

I. INTRODUCTION

The consumer demand in multimedia applications for high data rate services, has led to the growth of the expansion of wireless communication systems. Major companies such as Intel and Motorola are promoting the WiMAX interfaces. Deregulation of the telecom industry and rapid growth of the internet, evaluated in favour of WiMAX. According to WiMAX forum, Physical represents Broadband Wireless Access Techniques. WiMAX operates in both LOS and NLOS operation such as 10-66 GHz and 2-11 GHz.

Multipath fading occurs mostly in NLOS operation region, since each frequency arrives at the receiving point via a different radio path. This can be reduced by increasing delay spread. Frequency selective fading can also be equalized or reduced at the subcarrier level. Inter Symbol Interference is reduced by cyclic prefix and longer symbol period. Fading can be completely removed using diversity techniques where multiple antennas are connected at transmitter and receiver ends. This paper deals with Multiuser Diversity such as Adaptive Modulation Coding for OFDMA [1], where different constellations are being used at different level operation.

According to the IEEE 802.16 standard OFDM is to divide the available higher data rate into several low parallel data rate and these low data rate are mapped to individual subcarrier and being modulated. Orthogonal Frequency Division Multiplexing Access (OFDMA) uses multiuser diversity for adjacent subcarriers. Symbols are allocated to different users based on different data rate and channel condition. In OFDMA[2], these subcarriers are divided to smaller group of subcarrier called sub channel.

Scheduling [3] of the multimedia traffic has become recent trend for research community. In this paper various adaptive modulation schemes are being identified and adapted to improve the bandwidth efficiency of the system according to the various channel condition.

To have more flexibility and higher efficiency, adaptive OFDM schemes are adopted to maximize the system capacity and maintain the desired system performance in the inherent multi-carrier nature of OFDM allows the use of link adaptation techniques according to the narrow-band channel gains. Performance improvement [4] in Bit Error Rate and users various distances from base station has been simulated in this paper. Techniques for transmission which does not adapt for the transmission parameters to the fading channel are designed to maintain at acceptable performance under the worst-case channel conditions with a consequent of insufficient utilization of the available resources. Hence if the channels fade level is known at the transmitter then the Shannon capacity can be approached by matching transmission parameters to time-varying channel.
In wireless systems, power control is preferred for link rate adaptation, where transmitted signal is adjusted in order to maintain the quality of the received signal. Therefore, the transmit power is kept low when a user is close to the Base Station; it increases when the user distance is far from the Base Station. Most of the algorithm proposed in the literature are based on the water filling principle [5].

This provides the optimal power allocation of spectrally shaped radio channel for either maximizing the channel capacity under the constrained of transmit power or minimizing the transmit power for providing fixed bit error rate. The main drawback of power control is that it cannot use when the modulation is fixed. To overcome this drawback, adaptive modulation and coding (AMC) schemes have been introduced. In a system where the AMC is adopted, the modulation and coding orders are changed to match the actual channel gain: users close to the BS usually see high channel gains so that they are typically assigned higher-order modulations and higher code-rates but the modulation-order and/or the code-rate usually decrease when the user distance from the BS increases.

Based on slot allocation the Channel State Information (fig1&2) is calculated for multicarrier transmission and their performance is evaluated for fixed and adaptive modulation schemes [5].

II. SYSTEM MODEL

Our system uses Mobile WiMAX OFDMA-PHY where K users communicate with the base station using a group of subcarrier called as sub channel or slot. Each subcarrier is assigned power, user bit modulation to QAM symbols. These symbols are combined using IFFT, then they are transmitted to time varying, frequency selective channel, with each user experiencing an independent channel. Important to know that Channel State Information (CSI) are known at the transmitter level so that transmitter can adapt to the time varying channel condition and attempts to use available resource in efficient way[6].

According to Mobile WiMAX, slot or sub channel is formed by group of adjacent subcarrier which is subdivided into 48 data subcarrier and 6 pilot subcarrier for a total of 54 sub carriers. This structure uses TDD hence uplink and downlink is same. In this paper a bin is formed which has 6 subcarrier in which 5 data subcarrier and 1 pilot subcarrier. Total of 54 bits per channel transmitted, hence 6x54=324 bits are being transmitted. Fig 3 represents OFDMA sub channels..

Mobile WiMAX uses SOFDMA which scales FFT size to the channel bandwidth and also keeping frequency spacing constant 10.94 kHz. Sub carrier spacing is obtained by channel bandwidth multiplied by sampling rate where sampling rate is 28/25 i.e. 10*(28/25)/1024=10.94 kHz. Frame duration is 8ms and 1024FFT for 10 MHz channel bandwidth. Total OFDMA Symbol time is 102.8 ms, i.e. symbol time 91.4 + guard time.11.4.

TDD structure has guard time 5 µs for uplink and 5 µs for downlink. This structure is solution for...
data traffic such as IP based multi rate and multi-QoS services. 40 OFDM symbols for downlink sub frame and 39 OFDM symbol for uplink. Total of 79 OFDMA symbols per frame.

III. ADAPTIVE MODULATION CODING

Adaptive Modulation Coding chooses best modulation and channel coding schemes according to the propagation condition of radio link channel known at the transmitter end. In our paper channel degradation is due to path loss and multipath fading. Throughput maximization (Fig 4) is without any constraint of data reliability.

Using Shannon capacity formula as the throughput measure, MSR algorithm maximizes the quantity by

\[
\max_k \sum_{l=1}^{L} \frac{B}{L} \log \left(1 + \text{SINR}_{k,l}\right)
\]

With Total Power constraint is given by

\[
\sum_{k=1}^{K} \sum_{l=1}^{L} P_{k,l}^2 \leq P_{tot}
\]

The sum capacity is maximized if total throughput is maximized. Hence maximum sum capacity optimization problem can be decoupled into L simpler problem, one for each sub carrier. Further, capacity in subcarrier \( I \) is denoted as \( \mathcal{C}_I \) written as

\[
\mathcal{C}_I = \sum_{k=1}^{K} \log \left(1 + \frac{P_{k,I}}{P_{tot,I} - P_{k,I} + \sigma^2 B h_{k,I}^2} \right)
\]

A. FAIR ALLOCATION

In Fair allocation a slot is assigned the user in order to maximize the minimum number of users with user capacity \( C_k \). This can be obtained by searching for each slot allocation matrix \( X_k \) that guarantees the minimum of \( C_k \) for \( k=1,2,\ldots,K \). For example if 100 user are available then all available resources are allocated to them equally. The main drawback is more bandwidth is wasted for poor channel condition and Complexity. The fair allocation problem is formulated as follows

\[
\arg \max_{x^k} \left( \min_{k \in \mathcal{K}} \mathcal{C}_k \right)
\]

Subjected to

\[
\sum_{k \in \mathcal{K}} x_{i,j}^k = 1 \forall i,j
\]

\[
\sum_{i=0}^{A-1} \sum_{j=0}^{B-1} x_{i,j}^k \geq 1 \forall k \in \mathcal{K}
\]

B. PROPORTIONAL ALLOCATION
User with the best channel condition obtains lower number of resource with respect to the user with worst channel condition and hence channel capacity condition is not fully exploited. This is one of the drawbacks of Fair allocation this can be overcome by different allocation strategy by assuming the user with the best channel condition obtains larger amount of capacity. Being Maximum capacity is allocated to the each user given by (7), the slot allocation for the algorithm consideration searches for the capacity values for each user

\[ C_1; C_2; \ldots; C_k = C_{\text{max},1}; C_{\text{max},2}; \ldots; C_{\text{max},K} \]

Problem formulation i.e. maximization of ergodic rates is not instantaneous rate. This allocation is based on priority based allocation algorithm.

\[ \arg\max_{x^k} \left( \min_{k \in \Xi} \frac{C_k}{C_{\text{max},k}} \right) \]

Subjected to

\[ \sum_{k \in \Xi} x_{i,j}^k = 1 \quad \forall i, j \]

\[ \sum_{i=0}^{A-1} \sum_{j=0}^{B-1} x_{i,j}^k \geq 1 \quad \forall k \in \Xi \]

The main difference between fair and this allocation algorithm is that in this case the selected user is the one who has the minimum ratio between the actual capacity value and maximum obtainable capacity value. For the fair allocation case suboptimal allocation achieves result close to optimal solution with low complexity.

C. EQUAL CAPACITY INCREMENT ALLOCATION

The equal increment of capacity for the entire user with respect to non adaptive strategy. For example 100 user are active in a network under some circumstances 10 user became inactive then for these user power is divided equally among them self. Thus bandwidth is not wasted. Slot is belonging to the different user can be distinguished only by the position in the time domain different channel condition has different frequency are averaged and the amount of capacity assigned to the Kth user results to be

\[ C_k' = \frac{1}{k} C_{\text{max},k} = \frac{1}{k} \sum_{i=0}^{A-1} \sum_{j=0}^{B-1} C_{\text{slots}i,j}^k \]

This value is used to estimation of capacity of non adaptive algorithm. Gk is the difference between assigned capacity assigned to the k-th user and C'k

\[ G_k = R_k - C_k' \]

Equal capacity increment allocation scheme is consider in maximizing the minimum Gk for all the users. It follows optimal slot allocation problem accordingly.

\[ \arg\max_{x^k} \left( \min_{k \in \Xi} G_k \right) = \arg\max_{x^k} \left( \min_{k \in \Xi} (R_k - C_k) \right) \]

Subjected to

\[ \sum_{k \in \Xi} x_{i,j}^k = 1 \quad \forall i, j \]

\[ \sum_{i=0}^{A-1} \sum_{j=0}^{B-1} x_{i,j}^k \geq 1 \quad \forall k \in \Xi \]

D. COMBINATION ALLOCATION ALGORITHM

In this paper we combine proportional allocation algorithm in equal capacity increment allocation algorithm by allocating priority in adaptive manner for equal capacity increment algorithm. This allocation is done by BPSK modulation schemes. The computational complexity is low and suboptimal solution is obtained. The same equations are being carried for proportional and equal capacity increment.

V. SIMULATION RESULT AND DISCUSSION

In this section result of MATLAB simulation is presented and the system performance is assumed in carrying out our analysis.

Simulation results are based on
1. OFDMA system based on 1024 FFT
2. Channel bandwidth of 10Mz
3. Rayleigh channel fading is assumed
4. No of active user is 20
5. Radio carrier frequency Fc =3.5Ghz
6. Guard band is 1/8 of OFDMA symbols duration

Neglecting path loss on the performance of consideration of allocation schemes when users are at the same distance from base station the total number of active user is 20 and maximum throughput is achieved by adaptive modulation and coding. The path loss formula [8] and [9] is given by
Where $D$ is the distance between user and base station, $D_0$ is the reference base station (100 meters) $\gamma$ is the path loss exponent (set to 4.375 accordingly to an urban environment) and $L$ equal to $20 \log_{10} (\frac{4\pi D}{\lambda})$ is the path loss value at the reference distance (with respect to the wavelength $\lambda$) that, in this case, is equal to 83.32 dB. Cell radius of 10 km has been considered and the system provides SNR 7dB at the edge of the cell.

Figure 7 shows best performance of throughput vs. snr.upto 20 db above that both allocation has same performance.

Figure 8 represents users are at the same distance to the base station, fixed QAM modulation measures throughput with respect to distance. Hence adaptive allocation allows improving performance with respect to non adaptive allocation schemes.

Figure 9 shows when user close to the base station the

Figure 6 shows the best performance of throughput up to 7 km for combination allocation .This shows more spectral efficient. Fair allocation produces constant throughput at any distance, resulting disadvantages for the user near to the base station (because it has lower throughput than combined allocation) and
throughput is same (high) up to 3km after that throughput reduces as the distance proceeds.

Figure 10 shows when the user are far from the base station throughput is high at the near end in combination allocation case as distance increases fair allocation regains throughput this is mainly due to the fact that fair allocation algorithm allocates subcarrier in the fair manner while the other combination allocation allocates in order to maximize the cell capacity by damaging far user.

Finally, figure 11 shows better performance in BER for combination algorithm than fair allocation for fixed QAM modulation.

VI. CONCLUSION

The proposed resource allocation algorithm is followed in adaptive manner for the different user based on the different channel condition. By combining the equal capacity and proportional fair allocation bandwidth efficiency and better trade-off between fair and efficiency is obtained. Thus the performance is compared with respect to bit error rate vs signal to noise ratio & user with different distance from base station.

REFERENCES


