DOWNLINK RADIO RESOURCE ALLOCATION SCHEME FOR OFDMA CELLULAR NETWORK

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ABSTRACT

This paper presents radio resource allocation scheme to maximize ergodic rates for OFDMA cellular network .Purpose behind this is to improve multiuser diversity. Objective of this paper is to improve multiuser diversity along with maximum ergodic rates.SNR is considered to maximize erotic rates, along with that packet size is also considered. In this paper an algorithm is proposed in which criteria for allocating a resource is based on prioritization. Prioritization is based on different parameters such as SNR, maximum power, maximum distance of user from base station, maximum frequency available within a band etc. Simulation results show excellent performance.

Keywords: OFDMA, Cellular Network, Radio Resource Allocation, Ergodic Rates.

I. INTRODUCTION

The future cellular network should support a large number of users with maximum flexibility in a quality of service. The real challenge is to fulfill all these requirements and allocate resources to user with limited availability of frequency of frequency band. The ergodic capacity is defined as the maximum data rate which can be sent over the channel with asymptotically small error probability [2].

OFDM divides the transmission bandwidth into non-overlapping narrowband sub-channels. Every narrowband sub-channel may carry data, a signal. Sub-channels with excessive noise and interference may degrade quality of signal. Objective is to more bits to be send on sub-channels with higher signal-to-noise ratios. Along with that signal power and speed of transmission should be maximum. By considering all these condition an algorithm is proposed which will allocate at least one resource for transmission of data from base station to users, this is called downlink resource allocation and as transmission is wireless, so it is downlink radio resource allocation.

In current OFDM systems, only a single user can transmit on all of the subcarriers at any given time, and time division or frequency division multiple access is employed to support multiple users. The major setback to this static multiple access scheme is the fact that the different users see the wireless channel differently is not being utilized. OFDMA, on the other hand, allows multiple users to transmit at a same time on the different subcarriers per OFDM. Since the probability that every users experience a deep fade in a particular subcarrier is very much low, it is assured that at least one resource assigned to the users with good throughput.

II. CONVENTIONAL ALGORITHMS

Multi-user scheduling relates between the interface of information theory and queuing theory, in the theory of capacity to maximizing resource allocation. Before using such an algorithm, a capacity-related metric is first designed and then optimized across all possible resource allocation solutions which satisfies a set of predetermined constraints. Such constraints may be physical (e.g. bandwidth and total power) or QoS-related. Information theory helps to predict a range of possible capacity metrics which are relevant in different system operation scenarios. Two prominent algorithms are explained here, namely the so-called *ergodic capacity* and *delay limited capacity*, corresponding respectively to soft and hard forms of rate guarantee for the user to get resources.

2.1 Maximum Rate Scheduling

It has been shown that the maximum total ergodic sum rate where R_k is the total rate allocated to user *k*, is achieved with a transmission power given by

$$P_k(m,f) = \begin{cases} \left[\frac{1}{\lambda_k} - \frac{N_0}{|H_k(m,f)|^2}\right]^+ & if\ |H_k(m,f \\ 0 & \end{cases} \quad (1)$$

Where $[x]^+ = max(0,x)$, $H_k(m,f)$ is the channel gain of user *k* in RB *m* of sub frame *f* and λk are constants which are chosen so that to satisfy an average per-user power constraint. This approach is known in the literature as *maximum rate scheduling*. The result in Equation (1) shows that the maximum sum rate is achieved by orthogonal multiplexing scheduling algorithm; where in each sub-channel only the user with the best channel gain is scheduled.

2.2 Fast Algorithm for RNC

The RNC(Radio network Controller) algorithm uses a very different approach and thus it is able to assign a traffic channel to the user which has the highest throughput marginal utility (TMU) value (denoted as Ω_m in the algorithm) within certain BS. TMU is defined as a system throughput improvement by assignment of the current channel to a user. The channel assignment is to provide the most improvement to a system throughput so as to improve network response. Main Drawback of this system is if no user in the BS has a positive TMU value, then the no channel is assigned to this particular BS.

2.3 Fast Algorithm for BSs

Once each Base Station (BS) receives its channel assignment from Radio Network Controller within a particular super-frame, then it will take instantaneous decisions on pairing the traffic bearers and users. The recommended user by RNC may not always have traffic to send data in each frame. In such case, the BS assigns user for each slot in current frame. Once RNC has decided on which channel is used by which BS, the interference from BSs to users is possible to pre-determine for that super-frame. Therefore reallocation the channel to a user who has to send data, suggested by RNC that channel who has an empty queue, will always improve the throughput for the Base Station.

2.4 Proportional Fair Scheduling

The ergodic sum rate corresponds to the optimal rate for traffic which does not consider any delay constraints. This results in an unfair sharing of the channel resources. When the QoS required by the application includes latency constraints, such a scheduling strategy is not suitable and other fairer approaches need to be considered. One such approach is discussed here. Fair Scheduling (PFS) algorithm. PFS schedules a user when its instantaneous channel quality is high relative to its own average channel condition over time.

It allocates user *k*in RB*m* in any given sub frame *f if*

where

$$\widetilde{k_m} = \underset{k' = 1,..,K}{argmax} \frac{R_{k'}(m,f)}{T_{k'}(f)} \qquad (2)$$

Where $T_k(f)$ denotes the long term average throughput of user *k* computed in sub frame *f* and *Rk(m, f)* = log[1 + SNR*k(m, f)*] is the achievable rate by user *k* in RB *m* and sub frame *f* . The long-term average user throughputs are recursively computed by

$$T_k(f) \quad = \left(1 - \frac{1}{t_c}\right) T_k(f-1) + \frac{1}{t_c} \sum_{m=1}^{M} R_k(m,f) I\{\widetilde{k_m} = k\} \qquad (3)$$

Where t_c is the time window over which fairness is imposed and $I\{\cdot\}$ is the indicator function equal to one if and zero otherwise. A large time window *tc* tends to maximize the total average throughput; where it is the the limit of a very long time window, PFS and maximum-rate constant-power scheduling result in the same allocation of resources For small t_c the PFS tends towards a round-robin scheduling algorithm of users in the system.

III. OFDMA BASICS

The practical implementation of an OFDMA network is based on digital technology and more specifically on the use of Discrete Fourier Transform (DFT) and the inverse operation (IDFT) to move data between time and frequency domain representation. The resulting signal feeding is a sinusoidal wave to the Fast Fourier Transform (FFT) block is illustrated in figure practical implementations use the FFT.

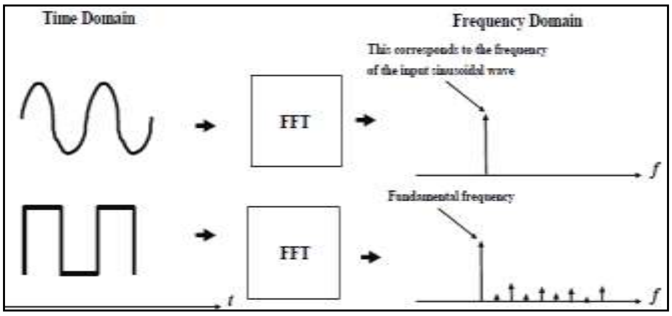

Fig 1.Signal Conversion from Time Domain to Frequency Domain

The FFT operation moves the signal from time domain to frequency domain representation. The Inverse Fast Fourier Transform (IFFT) does the operation in the opposite way. For the sinusoidal wave, the FFT operation's output will have a peak at the corresponding frequency and zero output elsewhere. If the input is a square wave, then the frequency domain output is peaks at multiple frequencies as such wave contains several frequencies which are covered by FFT operation. If an impulse as an input to FFT will have a peak on all frequencies. As the square wave has a regular interval *T*, there is a bigger peak at the frequency 1/*T* which represents the fundamental frequency of the waveform, and a smaller peak at odd harmonics of a fundamental frequency. The FFT operation can be carried out in both way in forward and reverse direction without loss of any original data, along with an assumption that the requirements for digital signal processing in terms of minimum sampling rates and packet lengths must be fulfilled. Thus for LTE the necessary FFT lengths also tend to be powers of two, such as 512, 1024, etc. From the implementation for example, a FFT size of 1024 even if only 600 outputs are used, than try to have another length for FFT between 600 and 1024.

The transmitter's principle in any OFDMA system is to use narrow, mutually orthogonal subcarriers. For ex. subcarrier spacing is 20 KHz regardless of the total transmission bandwidth. Different subcarriers are orthogonal to each other, as at the sampling instant of a single subcarrier the other sub-carriers will have a zero value. The transmitter of an OFDMA system uses IFFT to create the signal and the data source feeds to the serial to parallel conversion and further to the IFFT block. Input for the IFFT block corresponds to the input representing a particular subcarrier and it can be modulated independently of other sub-carriers. Cyclic extension must be added to avoid inter symbol interference. When the transmitter adds a cyclic extension which is longer than the channel impulse response, the effect of the previous symbol must be avoided by ignoring the cyclic extension at the receiver.

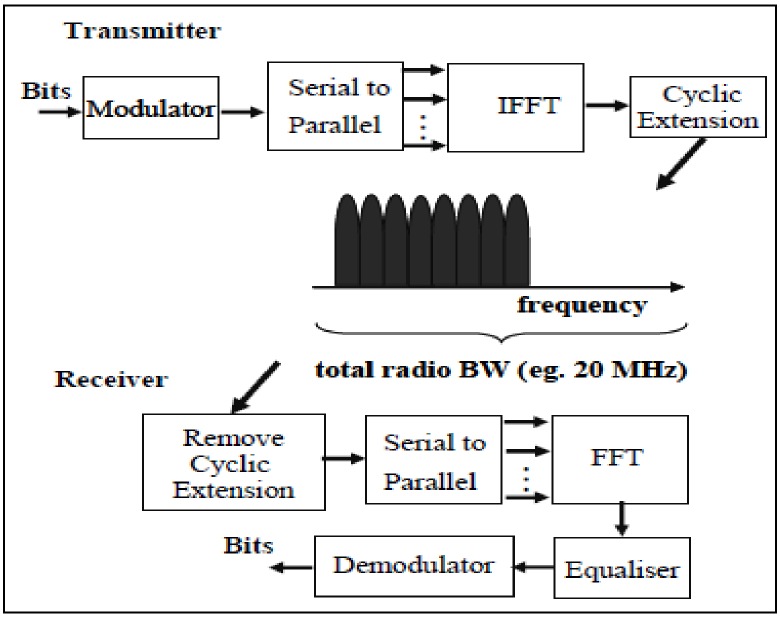

Fig2. OFDMA Transmitter and Receiver

The cyclic prefix is added by copying a part of the symbol at the end and attaching it to the beginning of the symbol, as shown in figure. The use of cyclic extension is preferable to simply as a break in the transmission (guard interval) as the OFDM symbol then it seems to be periodic. Thus the OFDMA symbol now appears as periodic due to cyclic extension, this impact of the channel ends up corresponding to a multiplication by a scalar, by assuming that the cyclic extension is much sufficiently long. The periodic nature of the signals allows system for a discrete Fourier spectrum enabling the use of DFT and IDFT in the receiver and transmitter respectively. Typically the guard interval is designed for the purpose that it exceeds the delay spread in the environment where the system is intended to be operated. In addition to the channel delay spread, the impact of transmitter and receiver filtering also be considered the guard interval design. The OFDMA receiver sees the OFDMA symbol coming as through a FIR filter, without separating individual frequency components. This is similar to the channel delay spread, the length of a filter applied to a signal in a receiver and transmitter side will also make this overall 'filtering' effect longer than just the delay spread.

IV. SCHEDULING AND RESOURCE ALLOCATION IN OFDMA SYSTEMS

Scheduling is another technique to deal with the radio resources which supports multi-user's in a high speed wireless communication network. In Time Division Multiplexed (TDM) systems, time is divided into several time- slots and the scheduling algorithms decision is simply which user to schedule in a time-slot. This decision is made based on the users' current channel conditions and quality of service requirements by users. Scheduling can be combined with other multiplexing techniques. When scheduling combined with OFDM, for an instance, along with addition to choose an active users in a time-slot, the subcarriers and the power must be allocated to the scheduled users. Problem of resource allocation was formulated for each transmission network. When scheduling is considered, the time consideration is first taken under consideration and time is divided into TDM time-slots that contain an integer number of OFDM symbols; then, the solution is formulated for each time-slot. The targeted data rate for each user is selected from a feasible rate regions which are based on the channel condition in that time-slot; the resources are then allocated to the users to reach at the targeted data rates. If a user is not scheduled in that time-slot, then the corresponding data rate would be zero, hence no power is allocated to an unscheduled user. Thus, the problem of scheduling and resource allocation is also referred to as *power scheduling*. Many scheduling algorithms have been proposed .In these algorithms, a utility function is defined for each user to achieve fairness and other quality of service considerations in each time-slot. The main aim is an increasing concave function of each user's average throughput up to decided time-slot. A targeted rate vector is then selected such that its projection the system's total utility is maximized. These algorithms are named as "gradient-based". Recently, various resource allocation and scheduling schemes have been developed for wireless networks. These resource allocation algorithms are classified as either "single-server" or "multi server" based on the underlying multiple access scheme used. An example of emerging wireless systems which uses a combination of TDM and OFDM is IEEE 802.16e (WiMAX) where scheduling and resource allocation is still an open research issue.

V. SYSTEM MODEL

We consider the downlink of a single OFDMA base station with *K*-subcarriers and *M*-users is represented by the set *K* ={1, . . . , *k*, . . . , *K*} and *M* = {1, . . . , *m*, . . . , *M*} (typically *K* _ *M*) respectively. We shall assume an average transmit power of ¯*P* > 0, bandwidth *B*, and noise density *N*0. The received signal vector for the m^{th} user at the n^{th} OFDM is

ym[*n*] = **G***m*[*n*]**H***m*[*n*]***xm***[*n*] + ***wm***[*n*] (4)

where ***ym***[*n*] and ***xm***[*n*] are the *K*-length received and transmitted complex-valued signal vectors with noise variance given as follows;

$$\sigma_w^2 = \frac{N_0 B}{K} \quad (5)$$

is the white zero-mean, circular-symmetric, complex Gaussian noise vector; and **H***m*[*n*] =diag {*hm*,1[*n*], . . . , *hm*,*K*[*n*]} is the diagonal channel response matrix, where

$$\bar{h}_{m,k}[n] = \sum_{i=1}^{N} \bar{G}_{m,i[n]} e^{-j2\pi\tau k\Delta f} \quad (6)$$

Where is time-delay and Δ*f* is subcarrier spacing. *Let*

$$\square_m = [\square_{m,1}, \dots \dots \square_{m,k}]^T \quad (7)$$

where

$$\square_{m,k} = |h_{m,k}|^2/\sigma_w^2 \quad (8)$$

which denote the instantaneous channel-to-noise ratio (CNR).

The capacity of user m on subcarrier k assuming independent and identically distributed Gaussian signaling under IID Gaussian noise is given as

$$R(p_{m,k}\gamma_{m,k}) = log_2(1 + p_{m,k}\gamma_{m,k}) \tag{9}$$

$\boldsymbol{p}(\gamma)$ as a function of the realization of the fading CNR(Channel to noise ratio) of all users. Thus ergodic weighted sum capacity maximization is then given by

$$f^* = \max_{p\epsilon P} \sum_{m\epsilon M} \omega_m \sum_{k\epsilon K} R(p_{m,k}\gamma_{m,k}) \tag{10}$$

VI. PERFORMANCE ANALYSIS

This system is designed to maximize possibility of resource allocation in downlink using OFDMA in cellular area network. We consider following system parameters.

Parameter	Value
Base Station	1
Maximum Subcarriers	128
Maximum Users	76
Maximum Bandwidth	1.2GHz
Distance	200Km

This system designed to allocate at least one resource to user from base station, so that user will be able to get information. We evaluate performance of system to allocate resource to user based on following metrics.

6.1 Frequency Allocation

6.2 Power and Noise Constraints

6.3 Multiuser Diversity

6.4 Variable Data Rates

6.5 Traffic Diversity Gain (TD Gain)

6.1 Frequency Allocation

This algorithm helps user to get frequency from specified frequency band so that user will able to get information from base station. Frequency gets selected from frequency matrix. Frequency matrix contains available frequencies to user out of which suitable frequency get selected for data reception.

6.2 Power and Noise Constraints

In this algorithm power and noise constraints are considered which maximize possibility of data will get received correctly.

6.3 Multiuser Diversity

Multiuser diversity is also considered in this system, Multiuser diversity means user is allowed to change location and user is also allowed to change cellular area network also.

6.4 Variable Data Rate

Variable data rate is considered in this system design.

6.5 Traffic Diversity Gain

Traffic diversity gain and the partial channel fading diversity gain exploited by, base station we now consider non-real-time service where traffics arrives at Base Stations in bursty fashions.

We define dropping probability as

$$\text{dropping probability} = \frac{\text{dropped bits due to buffer overflow}}{\text{total number of bits for transmission}}$$

VII. RESULTS

Our designed Algorithm builds an efficient resource allocation scheme to maximize ergodic rates for downlink OFDMA cellular network. This algorithm considers multiuser diversity, power and noise constraints and variable data rates by considering all these parameters frequency is allocated to user from available frequencies. This helps to allocate resources to user. This improves ergodic rates as well as throughput. Variable data rate are also considered in this network. Following figures shows power and frequency allocation to each user.

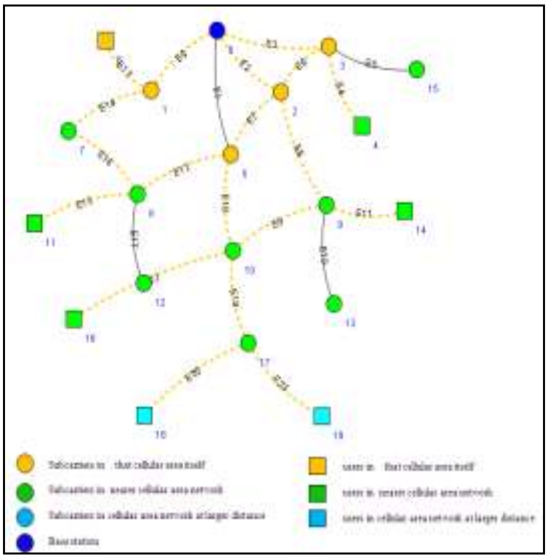

Fig.3. Simulation Results for Resource Allocation to User

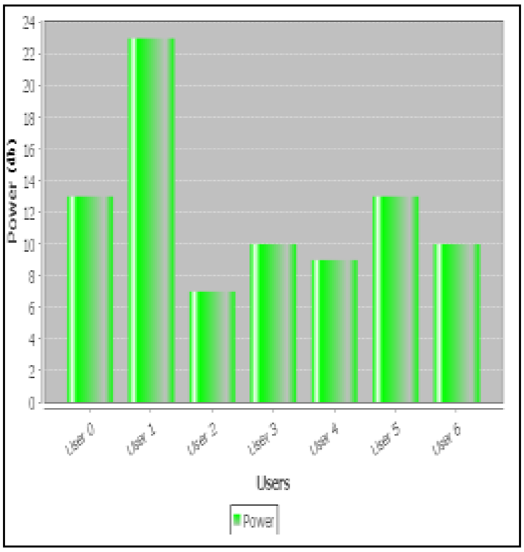

Fig 4. Power Graph

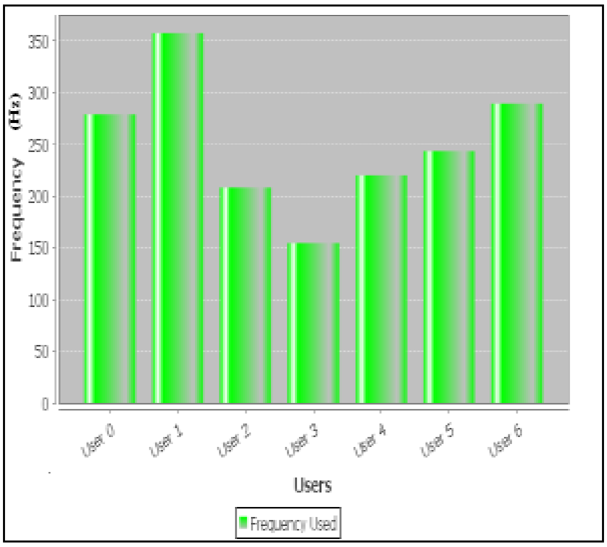

Fig 5. Frequency Allocation to Each User

VIII. CURRENT RESEARCH AREAS

Resource allocation methods have shown to offer higher user data rates due to the additional degree of freedom provided by multichannel systems. One way to create multiple channels is in frequency domain using multiple carrier frequencies with the methods and algorithms discussed in paper. The another way is in the spatial domain with multiple transmition and reception antennas. The is referred to as multiple-input multiple-output (MIMO).

8.1 Multiple-Input-Multiple-Output (MIMO) OFDMA

In the downlink MIMO-OFDMA system, a base station is contacting simultaneously to multiple users while both the base stations and the users are equipped with multiple subcarriers. The problem of resource allocation in a multiuser MIMO OFDMA system is similarly formulated but more challenging due to multiple subcarriers. The performance of MIMO-OFDMA systems is an interesting topic for research.

Subcarrier and power allocation algorithms may get developed to significantly improve the spectral and power efficiency in a MIMO-OFDMA system network compared to conventional fixed subcarrier and power allocation network algorithm. Simpler algorithms to reach the sum capacity of a Gaussian MIMO channel may get proposed in feature. A comparison of the potential maximum sum capacity of downlink cellular network (MIMOMC-CDMA) in a single cell multiuser network has been presented in some domains of research. It has been shown that for large number of subcarriers in some cases, the benefits of OFDMA over MCCDMA may get reduced. As in single-input single-output systems, several papers have discussed the impact of imperfect channel information on the performance of MIMO-OFDMA systems and proposed new algorithms. Further research should be carried out to develop low complexity resource allocation algorithms considering practical issues such as multi-cell environment.

8.2 Resource Allocation In Multi-Cell Systems

In a single cell, when the average SNR of some users requires very high data rates, their rate requirements can not be met. If the user’s average SNR received from its neighboring cell is much higher due to positive shadowing, such user may able to communicate with neighboring base stations. This additional degree of freedom may decrease the probability of outage, for instance, cell selection to reduce the probability of outage for those users having low SNR that happen to be located near the boundary regions of the cell as mentioned earlier, other issues such as power control in downlink become crucial when considering multi-cell environments.

IX. CONCLUSION

In This work we present radio resource allocation scheme for downlink OFDMA cellular network, which improves ergodic rates and possibility of getting available resources in the cellular area network. It improves quality of service of cellular area network, so that maximum throughput is achieved.

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