An Optimized Power Allocation Approach in Multi Carrier Communication System

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Abstract

Wireless communication systems are tending towards progressive data transfer over a long range of transmission. With the raise in required quality of services, the allocation of the available resource is to be maintained efficiently. A load matrix approach for multi cellular architecture is proposed, which allocate the communication power based on channel estimated SINR. The allocation of power resource is one of the prime factors in communication. Though the approach of Load Matrix is defined for multi-cellular interference, the proposed approach was tested over a single user communication. The effect of interference under multi-carrier system is considered in this paper. The approach of power allocation based on multiple transmissions and its effect on resource allocation is evaluated.

Keywords: Resource allocation, SINR, power, allocation, multi-carrier system.

1. Introduction

Nowadays, the key goal in wireless communication is to increase data rate and improve transmission reliability. In other words, because of the increasing demand for higher data rates, better quality of service, fewer dropped calls, higher network capacity and user coverage calls for innovative techniques that improve spectral efficiency and link reliability, new technologies in wireless communication are introduced, in which multi-carrier communication is growing at faster rate. High data-rate wireless access is demanded by many applications. Traditionally, more bandwidth is required for higher data-rate transmission. However, due to spectral limitations, it is often impractical or sometimes very expensive to increase bandwidth. In this case, using multiple transmit and receive antennas for spectrally efficient transmission is an alternative solution. Multiple transmit antennas can be used either to obtain transmit diversity, or to form a multi-carrier communication model. Many researchers have studied using multiple transmit antennas for diversity in wireless systems. Transmit diversity may be based on linear transforms [1] or space-time coding [2]. In particular, space-time coding is characterized by high code efficiency and good performance; hence, it is a promising technique to improve the efficiency and performance of a multi-carrier communication system based on effective resource allocation approaches. On the other hand, the system capacity can be significantly improved if multiple transmit and receive antennas are used to form multi-carrier channels [3]–[6]. It is proven in [4] that compared with a single-channel communication system with flat Rayleigh fading or narrowband channels. A multi-carrier system can improve the capacity by a factor of the minimum number of transmit and receive antennas. For wideband transmission [7], space–time processing must be used to mitigate inter-symbol interference (ISI). However, the complexity of the space–time processing increases with the bandwidth, and the performance substantially degrades when estimated channel parameters are used [8]. In multi carrier [9]–[12], the entire channel is divided into many narrow parallel sub channels, thereby increasing the symbol duration and reducing or eliminating the ISI caused by the multipath. Multiple transmit and receive antennas can be used with different carrier to further improve system performance. A multi carrier system with adaptive resource allocation for co-channel interference suppression [13] and transmit

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diversity based on space–time coding, delayed transmission, and permutation [14]–[16] is evaluated. In particular, a channel parameter estimator for multi carrier systems with multiple transmit antennas was proposed in [14] and simplified in [16]. In this paper, a multi-carrier communication system is evaluated by the optimal utilization of power resource. The resource allocation in cellular system based on SINR and available power resource is outlined as a Load Matrix concept in [1]. The extent of working of Multi-carrier communication model is outlined in this paper. The remaining of this paper is organized into eight sections, wherein Section II gives the basic system model of multicarrier system with the observing channel model. The complete illustration about the resource allocation problem in both single user and multi user communication system is illustrated in Section III. Section IV gives the load matrix concept. This concept has the facility to joint management of interference within a cell while allocating radio resources to users and this concept proposed intakes the inter cell interference information. The approach of adaptive resource allocation approach is proposed evaluated over a multi carrier system is outlined in section VI. Finally performance evaluation is carried out in Section VI and conclusions are made in section VII.

2. System Model

Multi-Carrier technology has aroused interest because of its possible applications in digital television, wireless local area networks, metropolitan area networks and mobile communication. Multi-carrier system greatly increases the channel capacity, which is in proportional to the total number of transmitter and receiver arrays. Second, multi-carrier system provides the advantage of spatial variety: each one transmitting signal is detected by the whole detector array, which not only improved system robustness and reliability, but also reduces the impact of ISI (inter symbol interference) and the channel fading since each signal determination is based on N detected results. In other words, spatial diversity offers N independent replicas of transmitted signal. Third, the Array gain is also increased, which means SNR gain achieved by focusing energy in desired direction is increased. On the other hand, multi-carrier also cost more energy including both the transmission energy and the circuit energy consumption. Energy-efficiency analysis of multi-carrier system is important topic in multi-carrier research. To design a Multi carrier system for test evaluation a multi carrier system with four transmit and $j$ $(j \geq 1)$ receive antennas is developed.

At one time of forwarding, data blocks were generated defined as,

$\{b[i, n, k]: k = 01, \ldots, j\}$ for $i=1$ and 2, is transformed into two different signals,

$\{b_{i}[n, k, j]: k = 01, \ldots, j = 1, 2\}$ for $i=1$ and 2, respectively, through two space–time encoders. The signal for the $i_{th}$ transmit antenna is modulated by $\mathbf{q}[n, k]$ at the $k_{th}$ carrier of the $n^{th}$ data block. The received signal at each receive antenna is the superposition of four distorted transmitted Signals, which can be expressed as

$$r_{j}[n, k] = \sum_{i=1}^{2} H_{i, j}[n, k] b_{i}[n, k] + w_{j}[n, k]$$

(1)

for $j = 1, \ldots, j$.

Where $w_{j}[n, k]$ in (1) denotes the additive complex Gaussian noise at the $j_{th}$ receive antenna, and is assumed to be zero-mean with variance $\sigma^{2}$ and uncorrelated for different $n$’s, $k$’s, or $j$’s. $H_{i, j}[n, k]$ in (1) denotes the channel frequency response for the $k$th tone at time $n$, corresponding to the $i_{th}$ transmit and the $j_{th}$ receive antenna. The input–output relation for Multi-carrier system is represented in (1) can be also expressed in vector form as

$$r[n, k] = \sum_{j=1}^{j} H[n, k] b[n, k] + w[n, k]$$

(2)

Where

$\mathbf{r}[n, k] = \begin{pmatrix} r_{1}[n, k] \\ \vdots \\ r_{j}[n, k] \end{pmatrix}$, $\mathbf{b}[n, k] = \begin{pmatrix} b_{1}[n, k] \\ \vdots \\ b_{2}[n, k] \end{pmatrix}$ and

$\mathbf{w}[n, k] = \begin{pmatrix} w_{1}[n, k] \\ \vdots \\ w_{j}[n, k] \end{pmatrix}$

While the transmission process the signals are allocated with multiple power levels to transmit over the channel. It is required to utilize the transmitting power effectively to optimally usage of this resource. The method designed for the allocation of such resource is called ‘resource allocation’ approach. The approach of resource allocation is outlined in following section.

3. Resource Allocation

In a cellular system many cells with channels reused at spatially separate locations are used. Due to the fundamental nature of wireless propagation, transmissions in a cell are not limited to within that cell, and thus there is inter cell interference between users and base stations, that use the same channels. The majority of current systems are interference limited rather than noise limited. Interference is part of every mobile cellular communications system, and it constitutes a limitation to both radio network capacity and quality of service provided to users [3]. Inter
cell interference is managed via averaging of the effects of multiple interferers. It is more effective in the uplink than in the downlink. Interference averaging also allows statistical multiplexing of busy users, thus increasing system capacity. Resource allocation schemes in the uplink are of two categories, distributed and centralized. The objective of distributed allocation is to reduce the complexity to the Radio Network Controller (RNC). This scheme does not know the channel conditions of adjacent cells. Where as in case of centralized schemes, the network controller is responsible for allocating the resources in every cell. On the forward link, the data is split by the RNC to a number of base stations and the received data is combined by the mobile terminal. On the reverse link, the participating base stations forward the received data to the serving RNC to combine. In interference limited systems, the uplink capacity is limited by the total transmitted power at the base station and this power was limited by uplink capacity. Inter cell interference calculation is done by multiplying the number of users in a cell by the average interference offered in this cell, this kind of calculation, being suitable for real-time interference simulations based on the number of users, their path loss, slow fading, and the cell area. But in uplink using multi carrier system, inter cell interference density analysis is performed by assuming perfect power control. The number of users is taken into account, as well as the received signal power and the activity factor according to the user’s service calculates the average inter cell interference per cell. [7] Usually, in radio network planning, a fixed value is taken for the inter-to-intra cell interference ratio (i factor) 0.65, as well as for the interference margin in the power budget is 3 dB. The inter cell interference will be particularly significant when inter cell users are near the cell boundary and when the frequency reuse factor is equal to one, hence it is a crucial factor and cannot be ignored in the scheduling for multi-carrier system. A power allocation approach in cellular system based on system SINR is proposed in [1]. A optimal resource allocation based on RoT for cell is developed in this paper. The approach of resource allocation is named as Load matrix. The conventional approach for such resource allocation under a single carrier system is outlined below.

4. Load Matrix Approach[1]

The Load Matrix (LM) concept has the facility to joint management of interference within a cell while allocating radio resources to users and this concept proposed intakes the intercell interference information into account in order to avoid RoT outage. In a multicell system one of the main challenge in resource allocation is the control of intercell interference. LM is a centralized scheduler, uses a database containing the load contribution of all active users in the network and it assigns radio resources to all active users in the network.

The basic problem in the uplink scheduler is to assign appropriate transmission rate and time to all active users, result maximum radio resource utilization across the network while satisfying the QoS requirements of all the users. [13]

The important factor in the resource allocation is the users transmit power. The constraints to be satisfied for a network of M users and N cells are

Constraint1: This constraint states that the maximum user power $P_{\text{max}}$. For each active user $i$ in the network, its transmit power $P_i$ must be maintained in an acceptable region defined as

$$0 \leq P_i \leq P_{\text{max}}, i \in \{1, \ldots, M\}$$

Constraint2: The total received power at base station should be kept below a certain threshold for all N base stations in the network it uses Rise over Thermal noise (RoT) to represent the interference constraints.

$$RoT_j \leq RoT_{\text{target}} j \in \{1, \ldots, N\}$$

$RoT_j$ is the total in band received power fixed target value to maintain uplink interference level at the base station $j$ (BSj) over thermal noise. The $RoT_j$ for M active users in the network given below is used to estimate RoT of cells, can be written as

$$RoT_j = (N' + \sum_{i=1}^{M} P_i G_{ij})/N'$$

Constraint3: The signal to noise plus interference ratio required at the serving base station $j$ if rate $k$ is being assign to the user to achieve a given frame error rate is $\text{SINR}_{\text{target},k}$. For each user, depending on its channel type and speed, each rate $k$ has a minimum required SINR called $\text{SINR}_{\text{target},k}$. This constraint satisfies only by considering $\text{SINR}_{\text{target},k}$ as SINR.

$$\text{SINR}_{ij} \geq \text{SINR}_{\text{target},k} \in \{1, \ldots, N\}, k \in \{1, \ldots, K\}$$

LM nothing but a centralized scheduler assigns radio resources to all the M users and N cells in the network, $LM_{ij}$ is the load factor contribution by user $i$ at BS$j$ defined as

$$LM_{ij} = \frac{P_i G_{ij}}{N' + \sum_{i=1}^{M} P_i G_{ij}}$$

Where $G_{ij}$ is the channel gain from user $i$ to BS$j$ averaged over scheduling period, $N'$ is the thermal noise and $P_i$ is the transmitted power. The $LM_{ij}$ values stored in column $j$ of LM database, RoT of cell $j$ can be written

$$RoT_j = \frac{1}{N' + \sum_{i=1}^{M} P_i G_{ij}}$$

$\text{SINR}_{ij}$ can be written as

$$\text{SINR}_{ij} = \frac{P_i G_{ij}}{N' + \sum_{i=1}^{M} P_i G_{ij}}$$

The required transmitted power for user $i$ at rate $k$ is,

$$P_{i,k} = \frac{N' \text{RoT}_j \text{SINR}_{\text{target},k}}{G_{ij} \text{SINR}_{\text{target},k}}$$
If above all constraints are satisfied then only power $P_{ck}$ is acceptable and user $i$ will be scheduled for transmission. After that LM elements are updated and RoT is calculated for each cell using [10]. The performance of the LM scheduling has the best RoT over other algorithms because this scheduler significantly reduces the probability of the RoT exceeding its target. The RoT is computed over a single carrier system. For the modeling of this approach in Multi-carrier system a modified model of RA is proposed which is outlined in next section.

5. Multi Cell Power Coding

The Load matrix approach considered in the previous section is able to allocate the power efficiently for a single cell users based on SINR and RoT concepts. It considered only signal to noise ratio for power allocation for single user communication. While for the modeling in Multi-carrier communication system the Signal to interference ratio is affected distinctly in each carrier hence a single SINR for allocation is not optimal. To obtain the optimization of power allocation in Multi carrier system in this paper a diverse approach of SINR based on bifurcated SNR and SIR is proposed. In this approach the signal to interference noise ratio is considered as a combination of original signal to noise ratio (SNR) and signal to interference ratio (SIR) defined by the following equation;

$$\text{SINR} = \left( \frac{\delta_{SNR}}{2\text{SNR}} + \frac{\delta_{SIR}}{2\text{SIR}} \right)^{-1} \quad (11)$$

Where $\frac{\delta_{SNR}}{2\text{SNR}}$ denotes the background signal-to-noise ratio, while $\frac{\delta_{SIR}}{2\text{SIR}}$ is the signal-to-interference ratio.

By considering the above equation in to the SINR for the conventional LM approach, the proposed SINR is defined as

$$\text{SINR}_{ij} = \frac{P_k\delta_{SIR}}{\delta_{SNR} + \frac{\delta_{SIR}}{2\text{SIR}}} \quad (12)$$

The required transmitted power for user $i$ at $k^{th}$ carrier is then defined as,

$$P_{R,i} = \frac{\text{SINR}_{prop,i} \times 10^{\delta_{SIR}}}{1 + \text{SINR}_{regen,i}} \quad (13)$$

carrier is then defined as;

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$$P_{abc} = \begin{cases} P_{R,i} & \text{if } \text{SINR} \leq P_{th} \text{abc} \\ \text{else} & \end{cases} \quad (14)$$

Where ‘k’ is number of carriers allocated in a multi carrier system. For the evaluation of the developed system a comparative analysis of the proposed approach is carried out.

6. Simulation Observation

For the evaluation of the proposed approach a communication system with a Rayleigh fading channel is designed. A channel count of 1, 3, and 5 are used with varying the user density for 3 and 8 simultaneous users. The system is validated for the SNR variation from -10dB to 10dB for an AWGN channel. The user information’s of 1200 bits are considered for each user and a carrier frequency of 2GHz is considered in compliance with 3GPP, LTE model. The sampling frequency is taken as 15MHz. The simulation observation under different channel effect and user density is evaluated. The obtained observations are as given below.

![Fig.1 BER v/s SNR plot at user density=3 and f_d=.001](image)

Fig.1 represents the Bit error rate versus Signal to noise ratio plot for a user density of three and at fading factor .001. From the Fig.1 it is clear that the performance of the proposed method for various channel cases is efficient. It also denotes that with an increase in SNR value at user density=3 and at a fading factor of $f_d=.001$ there is a nominal decrease in the BER of the proposed method is decreasing due to the availability of multiple channels, thus the total SINR is going to be decreased. Thus this decreased value provides the optimum power allocation for users.

Fig.2 represents the Bit error rate versus Signal to noise ratio plot for a user density of six and at fading factor .001. From the above Fig.2 it is clear that the performance of the proposed method for various channel cases is efficient. It also denotes that with an increase in SNR value at user density=6 and at a fading factor $f_d=.001$ there is a nominal decrease in the BER of the proposed method is decreasing due to the availability of multiple channels, thus the total
SINR is going to be decreased. Thus this decreased value provides the optimum power allocation for users.

Fig. 2. BER v/s SNR plot at user density=6 and \( f_d = 0.001 \)

Fig. 3. BER v/s SNR plot at user density=3 and \( f_d = 0.01 \)

7. Conclusion

For the optimize allocation of power resource, in this paper a enhanced approach to power allocation based on load matrix approach outlined in [1] is proposed. The diverse estimation of SINR based on multi carrier communication is proposed. The allocable power is derived by the computation of SNR and SIR for multiple carriers and a decision approach is developed. With the obtained simulation observations it is observed an improvement in error estimation hence lower in bit error rate is observed for variant noise level. Under different channel conditions and channel fade effect the estimation accuracy us observed to be higher than the conventional approach.

References


