PB/MC-CDMA 시스템에서 처리량 향상을 위한 효율적인 자원 할당 기법

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Efficient Resource Allocation Scheme for Improving the Throughput in the PB/MC-CDMA System

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요 약 PB/MC-CDMA는 기존 MC-CDMA 시스템과는 달리 여러 개의 블록으로 전체 주파수 대역을 분할하는 효율적인 시스템이다. 다중 블록 PB/MC-CDMA에서 효율적인 자원 할당 방식을 제안한다. 이 시스템은 주파수 효율을 향상시키고 다양한 채널 조건을 통해 사전에 정의 된 임계값을 만족시키면서 전체 처리량을 극대화 하는 것을 목표로 하고 있다. 또한, 컴퓨터 시뮬레이션을 통해 제안하는 시스템의 성능 처리량 측면에서 더 효과적인 것을 확인한다.

키워드 : 적합한 자원 할당, 부분 블록 멀티 케리어 코드 분할 기법, 처리량, 사전에 정의 된 임계값

Abstract PB/MC-CDMA is an efficient system which divides the whole frequency band into several blocks, unlike a conventional MC-CDMA system. We propose an efficient resource allocation scheme in Multi-Block PB/MC-CDMA (Partial Block Multi-Carrier Code Division Multiple Access). This system aims to improve frequency efficiency and maximize the total throughput while satisfying predefined threshold over various channel conditions. Through computer simulations, we confirm that the performance of the proposed system is more effective in terms of throughput.

Key Words : Adaptive resource allocation, PB/MC-CDMA system, Throughput, Predefined threshold

1. Introduction

The wireless systems currently in development provide a variety of multimedia services that have different quality-of-service (QoS) requirements. Multi-Carrier code division multiple access (MC-CDMA) has been regarded as a next-generation communication system that can realize a high-speed and large capacity cellular system over multipath fading environment [1]. The MC-CDMA scheme is the combination of OFDM and CDMA, using the whole frequency band divided into several subcarriers, and multiple user access is achieved using different

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spreading codes. However, as the number of users increases, system performance decreases rapidly, because multiple access causes severe Inter Code Interference (ICI). The PB/MC-CDMA system is one solution for reducing the ICI and other problems of the MC-CDMA system [2]. However, the wireless channel state varies quickly. The unpredictability of the propagation channel becomes a significant obstacle to offering high quality services. To satisfy the QoS requirements for all users with limited radio resources, the resource allocation method must adjust to channel state information. If we know the channel state information, the PB/MC-CDMA system may support the QoS requirements for various channel environments.

There has been considerable research regarding resource allocation schemes. In [3], an adaptive resource allocation method for the PB/MC-CDMA system was proposed. However, the author considers the average SIR instead of the instantaneous channel conditions. Jinri HUANG and Zhisheng NIU [4] proposed an adaptive user grouping and subcarrier allocation algorithm. However, they don't consider the various subcarrier allocations or the channel coding scheme when the channel environment changes.

We propose a system called Resource Allocation and Channel Coding (RACC) in Multi Block PB/MC-CDMA (Partial Block Multi Carrier Code Division Multiple Access). It considers not only the average SIR but also the current channel state for improving the throughput of the system. We also consider the dependence of the channel coding and resource allocation scheme on various channel fading conditions. The system users obtain channel state information through feedback from the receiver. We then decide the channel coding rate and the number of subcarriers for resource allocation. The resource allocation scheme is designed to maximize the total throughput by satisfying the various service requirements such as audio, video, multimedia etc., while it is performed to minimize the ICI under the constraints of total resources. The proposed system is very effective and is more flexible and reliable than the conventional PB/MC-CDMA system for providing high throughput.

This paper is organized as follows: The PB/MC-CDMA system is introduced and the system structure of the Efficient Resource Allocation Scheme for the PB/MC-CDMA system is discussed in Section 2. Simulation parameters and results are given in Section 3. Finally, Section 4 summarizes the major findings of this paper.

2. System Model

2.1 PB/MC-CDMA system

The Partial Block MC-CDMA system consists of several blocks, and each block contains a certain number of subcarriers which can be adjusted according to the requirements. PB/MC-CDMA is an effective scheme, especially to combat ICI.

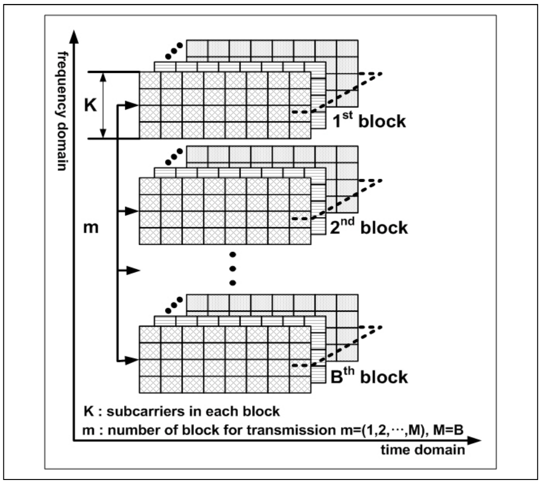

Fig. 1. Schematic diagram of a PB/MC-CDMA system [3]

Figure 1 shows the schematic diagram of a PB/MC-CDMA system. There are U users, K orthogonal spreading codes and N sub-carriers in the proposed system. The total number of blocks B is given by N/K; every block is indexed by b, where b=(0,1,⋯,B-1), and each sub-block consists of K sub-carriers. The notation M represents the number of used blocks for each user and depends on CSI. By assigning a proper integer to M (M≠1), the user's throughput and frequency efficiency can increase by sending m symbols.

The users employ block-unit bandwidth rather than the whole bandwidth, which is composed of the length of the orthogonal spreading code, K, in the PB/MC-CDMA system. It reduces the MAI by using the block-unit and increases user capacity by reusing the orthogonal spreading code [3]. Furthermore, the user's throughput is adapted by using the number of blocks, m, which depends on the channel condition. If $M=B$, the throughput is the same as that of the conventional MC-CDMA.

2.2 Efficient Resource Allocation Scheme in the PB/MC-CDMA

Adaptive transmission in the PB/MC-CDMA system requires resource allocation. Figure 2 is a schematic diagram of the proposed system. The user's coded QPSK symbol data are assigned to a block according to the user's CSI. We assume that the CSI is completely known because of feedback from receiver. The objective of resource allocation is to maximize throughput while satisfying the QoS requirement. The throughput function of the system, $f(\bullet)$, is defined by

$$d_{u,b}=f(\eta, M, r_{u,b}, \eta_{th}) \tag{1}$$

where $d_{u,b}$ denotes the number of bits per symbol allocated to the u^{th} user at the b^{th} block. $r_{u,b}$ is the code-rate of the u^{th} user at the b^{th} block. η and η_{th} are the instantaneous channel state information and predefined threshold for satisfying the system QoS. In this paper, the predefined threshold, η_{th} is defined as the ratio of the number of data symbols in the successfully received packet to the total number of received symbols.

The system throughput, Q, is represented as

$$\text{Maximize Q} = \sum_{u=0}^{U-1}\sum_{b=0}^{B-1} c_{u,b} \bullet d_{u,b} \tag{2}$$

where $c_{u,b}(t)\in\{0,1\},\ \forall b$, is the indicator of the sub-block allocation of the u^{th} user at the b^{th} block. We should allocate the resource and code rate carefully to maximize the throughput. After resource allocation and channel coding, each block is copied and spread over the frequency domain using the user's orthogonal spreading code.

These signals are fed into the IFFT (Inverse Fast Fourier Transform) and converted to time-domain signals, which are written as

$$s(t)=\sum_{u=0}^{U-1}\sum_{m=0}^{M_u-1}\sum_{i=0}^{I-1}\sum_{k=0}^{K-1} d_\beta^u(i)\, C^u(k)\times e^{j2\pi(K\beta+k)\triangle f(t-iT_s)} \tag{3}$$

where d_β^u is the u^{th} user's i^{th} complex QPSK data symbol denoted by $d^u(i)$ where $d\in\pm(1\pm j)/\sqrt{2}$, I is the number of symbols, K is the number of sub-carriers, M^u is the number of blocks of each other, and β is the block index function for the user defined by $\beta=\mathrm{mod}((u+m), B)$. The notation $\mathrm{mod}(x,y)$ indicates the remainder of x divided by y. Also, T_s is the symbol length and $\triangle f$ is the sub-carrier spacing. After the IFFT function, an orthogonal multi-carrier signal is generated, and a guard interval is inserted between PB/MC-CDMA symbols to avoid ISI and ICI caused by multi-path fading.

The PB/MC-CDMA signals pass through the frequency selective fading channel and have an addition to AWGN (Additive White Gaussian Noise).

At the receiver side, the guard interval is removed from the received signal, and it is converted to a sub-carrier component using a FFT. After this process, the u^{th} user's signal is assigned to the b^{th} block, and it is despread by the respective orthogonal spreading code to extract a desired signal. The signals restored by despreading are combined at the combiner, and then measured by the QPSK demodulation.

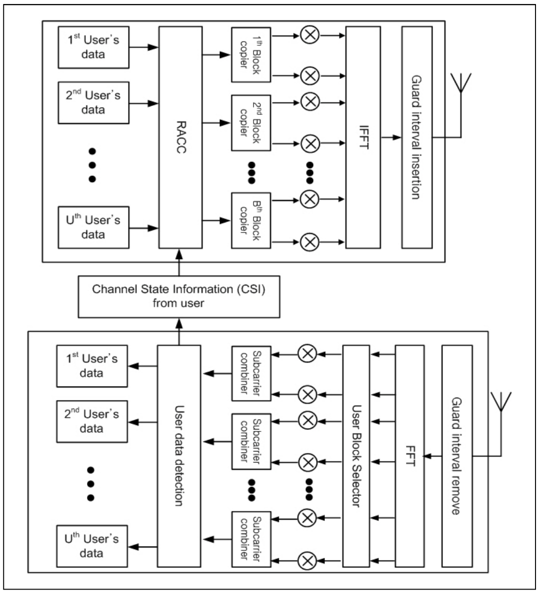

Fig. 2. The schematic diagram of the proposed system

3. Simulation Parameters and Results

In this simulation, we assumed a two-cell environment in a downlink that employed an 18-path exponential Rayleigh fading channel model with a 1-sample delay interval between paths. The attenuation between adjacent paths is 1dB. The multi-path propagation delay profile is shown in Figure 3. For channel simulation modeling, we considered the modified Jake's uncorrelated Rayleigh fading channel model described in [5].

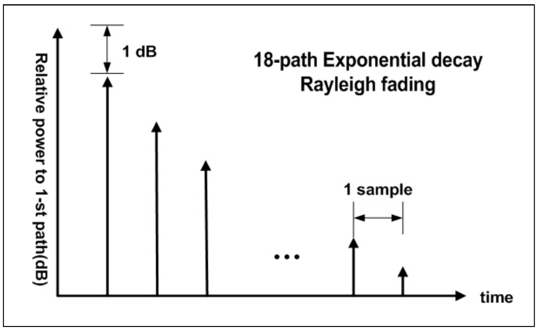

Fig. 3. Exponential Decay Model of Multi-path Rayleigh fading channel

Table 1 shows the simulation conditions in detail. We use 128 subcarriers, and the spreading factor is 16 with 16 users. The length of the GI is 25% of the symbol duration. We use convolution code of FEC with a 1/2 or 1/3 coding rate and a constraint length of seven. We change the SIR values from 0 dB to 10dB when the SNR value is 15dB. In this paper, SIR is defined as the power of the desired cell to the interference power of the different cell ratio.

Table 1. Simulation parameters

Number of sub-carriers	128
FFT/IFFT Point	128
Symbol rate	156.25 KHz
Short spreading code	Walsh-Hadamard code
Scramble spreading code	Random sequence
Data Modulation type	QPSK
Number of data symbols	64
Number of pilot symbols	4
Guard interval	25%
FEC	Convolution coding (R=1/2 or 1/3, K=7)
User	16
SNR	15dB
SIR	0dB ~ 10dB

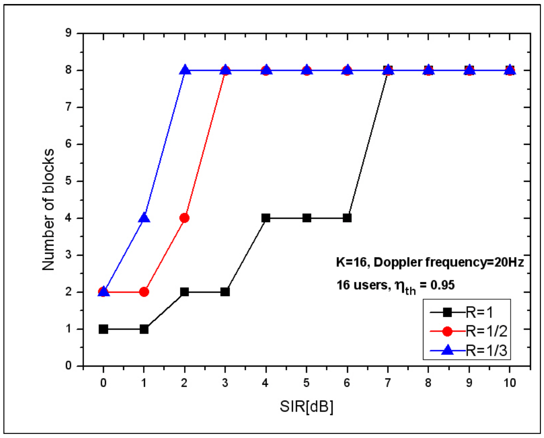

Fig. 4. The number of blocks according to the coding rate in the proposed system

Figure 4 shows the number of blocks of the proposed system when the channel condition varies, such as the average SIR and the instantaneous channel condition at different coding rates. In the simulation, the data rate of the system changes depending on the number of blocks and the channel coding rate. The notation 'η_{th}' denotes an arbitrary predefined threshold level specified by the user in order to support system performance.

Using this result, we confirm that the number of blocks increases with system SIR, because higher SIR values represent better channel conditions. In particular, when we use a channel coding scheme with a coding rate of 1/2 or 1/3, the number of blocks increases drastically. However, we know that the data rate of the proposed system is lower than that of the uncoded system with the same number of blocks from Equations (1) and (2).

For example, if the data rate of the system is N bps with one block, it becomes NMR bps with M blocks and code rate R, where $M = (0, 1, \cdots, B-1)$ and R=1, 1/2 or 1/3.

Therefore, if we use the proper channel coding rate and resource allocation scheme depending on the SIR and the instantaneous channel conditions, we can improve the performance of the proposed system.

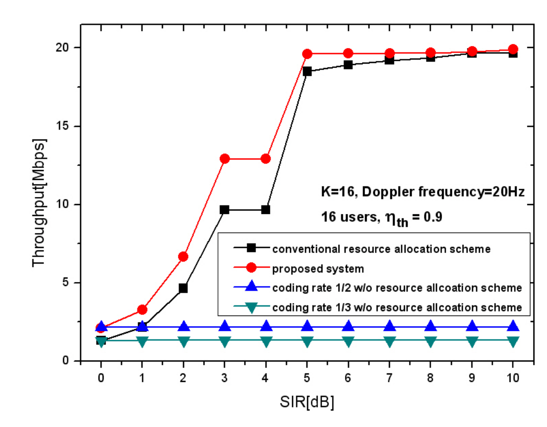

Fig. 5. Throughput performance when the SIR of the system changes from 0dB to 10 dB

Figure 5 shows the throughput performance when the SIR of the system changes from 0dB to 10dB. In this paper, the throughput is defined as the average rate of successful data delivery. From this result, the throughput of the proposed system is higher than that of a conventional system because we consider the actual adaptive resource allocation scheme depending not only on the average SIR but also on the instantaneous channel conditions. Therefore, the proposed system adaptively changes the number of blocks and coding rates, and as a result, throughput performance and frequency efficiency are improved in our proposed system.

4. Conclusions

In this paper, we proposed an efficient resource allocation scheme depending not only on the average SIR but also on the instantaneous channel conditions. This scheme can achieve improved throughput performance and frequency efficiency by satisfying the threshold value it uses the proper channel coding rate and resource allocation scheme depending on the average SIR and the instantaneous channel conditions. The proposed system exhibits much better performance than the conventional resource allocation system, which only considers average SIR. Therefore, the proposed system can achieve high-quality services required in wireless communication channels.

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