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Resource Allocation and Scheduling for Real-Time Traffic in OFDMA

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Abstract: OFDMA is an attractive multiple access technique for packet-based mobile broadband wireless access for beyond 3G and 4G systems. Radio resource allocation in OFDMA can exploit multiuser diversity to increase system capacity by implementing opportunistic scheduling techniques. This study presents a new opportunistic scheduling scheme for OFDMA-based wireless multimedia networks. We focus the scheduling algorithm on the class of delay-sensitive packets that belong to interactive applications such as telephony and video streaming. I divided the scheduling decision into 2 sub-problems: The OFDMA subcarrier allocation and subsequently the subcarrier assignment. Both the subcarrier allocation and assignment algorithms exploit multiuser diversity and are designed to provide fairness with respect to the realizable throughput per user, packet dropping ratios and packet delay distributions. We investigate various performance aspects of the proposed scheduling algorithm using actual MPEG-4 traffic traces under different system loading and requested deadline values. The results show the superiority of the proposed scheduling scheme and its excellent performance with respect to throughput, packet droppingand delay distributions.

Key words: Resource allocation, scheduling, real time, traffic, OFDMA

INTRODUCTION

Providing QoS (Quality of Service) guarantees to high-speed real-time traffic with stringent packet delay constraints and high throughout requirement is one of the most challenges on the design of future wireless networks.

Orthogonal Frequency Division Multiplexing Access (OFDMA) with high spectrum efficiency, flexible resource allocation features is an ideal multi-access method for next generation wireless networks. OFDMA is more suitable for high-speed real-time traffic transmission compared to other multiplexing access such as TDMA.

Modified-Largest Weighted Delay First (M-LWDF) is designed to support real-time data service in single channel TDMA system (Ramanan *et al*., 2001; Kim *et al*., 2004; Parag *et al*., 2005) extend the M-LWDF idea to OFDMA system using M-LWDF-liked rule to schedule user on each subcarrier in every time slot. These algorithms only simply extend the M-LWDF idea from single channel system to muti-channel system. They do not fully consider the unique characteristic of OFDMA system, such as possessing of muti-parallel channel and supporting muti-user at the same time.

In this study we discard above resource allocation fashion where the resource allocation and scheduling are processing on each subcarrier independently. We propose an iterative resource allocation and scheduling algorithms where the packet scheduling and subcarrier allocation is running in an alternate manner. This algorithm jointly considers all users and all the subcarriers information.

SYSTEM MODEL

This study investigates the OFDMA downlink transmission of a packet-switched network (Fig. 1). The packet in user queue must be delivered to the destinations before certain delay upper bounds. ARQ (Automatic Return request) is applied to recover the packet errorsand a packet is retransmitted until it is received successfully or is dropped due to the expiration of the deadline. Assume the base station can received the channel state information from all users and the user queue length at base station is infinite.

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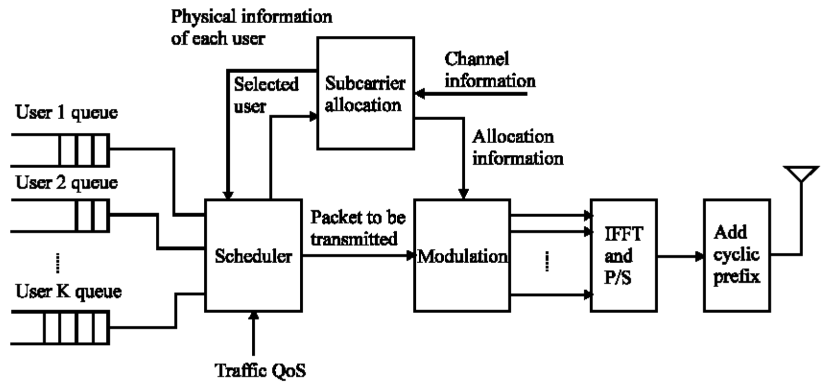

Fig. 1: Downlink transmitter structure at base station

THE PROPOSED ALGORITHM

In this study, we propose an iterative resource allocation and scheduling algorithm. The proposal algorithm is composed of 2 mutually cooperative parts: Packet scheduling and subcarriers allocation.

Subcarriers allocation: Because of the subcarriers allocation, each subcarrier is assigned to a user whose channel gain is good for it. Equal power allocation would hardly reduce the system throughput (Rhee and Cioffi, 2000). So we assume that every subcarrier adopts adaptive bits allocation but equal power distribution.

The user k rate in subcarrier n is denoted by $r_{k,n}$. In the subcarriers allocation, whether the subcarrier n is allocated to user k is decided by the relative rate $r'_{k,n}$, not the $r_{k,n}$, $r'_{k,n}$ is calculated as:

$$r'_{k,n} = \left(\frac{r_{k,n}}{\sum_{i \in \hat{K}} \left(r_{i,n} \right)} \right) r_{k,n} \tag{1}$$

Where, $\hat{k}$ is the set of active users. Using $r'_{k,n}$ as a subcarrier allocation factor can prevent one user occupy too many good subcarriers. Subcarrier m is allocated to User k such that:

$$m = \arg\max_{n} r'_{k,n}, n \in A$$

Where, A is the set of unallocated subcarriers.

Packet scheduling: In this study, there are three factors in scheduling strategy. The first one is the waiting time $W_k(t)$ of the Hol (Head of Line) packets. This factor is used to represent the packet urgency level. The second one is the ratio ($r_k(t)/\overline{r}_k(t)$) of the current physical user rate $r_k(t)$ and the average physical rate $\overline{r}_k(t)$. This factor is used to represent the user rate information in time domain. $r_k(t)$ and $\overline{r}_k(t)$ is given by:

$$\begin{aligned} r_k(t) &= \sum_{n \in A} r_{k,n}(t) \\ \overline{r}_k(t) &= (1 - 1/P_w)\overline{r}_k(t-1) + (1/P_w) r_k(t) \end{aligned} \tag{3}$$

Where, P_w is the sliding window length. The third one is the variance var_k of the user rate in each unallocated subcarriers. This factor is used to represent the user rate information in frequency domain.

In order to control the weighted value of each factor in scheduling strategy, we transform the factor value (f) to the corresponding priority value (P) using a linear-type priority function P = af+b. The total priority of user k is expressed as:

$$P_k(t) = P_{rate}(k,t) P_{delay}(k,t) P_{var}(k,t) \tag{4}$$

Where, $P_{rate}(k,t)$, $P_{delay}(k,t)$ and $P_{var}(k,t)$ are the priority function value derived from $W_k(t), r_k(t)/\overline{r}_k(t)$ and var_k. Scheduler selects the user with the highest priority value.

In linear-type priority function (P = af+b), the coefficient a and b are calculated by the following equations,

$$\begin{cases} P_{min} = af_{min} + b \\ P_{max} = af_{max} + b \end{cases} \tag{5}$$

Where, f_{max} and f_{min} is maximal and minimal factor value, P_{max} and P_{min} is maximal and minimal presetting priority value.

The proposal algorithm: The proposal resource allocation and scheduling algorithm can be described as following:
Step 0: Initialization

A = {all subcarrier}, $\hat{K}$ = {the usre whose queue is not empty}. For all $k \in \hat{K}$, calculate $r_k(t)$, $\bar{r}_k(t)$ and var_k in A

Step 1: Packet scheduling:

$I = \arg\max_k P_{rate}(k,t)\, P_{delay}(k,t)\, P_{var}(k,t),\ k \in \hat{K}$

Step 2: Subcarriers allocation:

Allocation subcarrier to the Hol packet of user i base on the relative rate $r'_{i,n}$ in each subcarrier. Updata the unallocated subcarrier set A.

Step 3: Update:

If there are packets in user queue and there are still unallocated subcarriers. Update $r_k(t)$ and var_k in A, then go to step 1. Otherwise the resource allocation is over.

RESULTS

An OFDMA system with 1024 subcarrier and 10 users is considered. The entire system bandwidth is 10 MHz. The frame consists of 20 OFDM symbol. The channel model is COST 207 TU. The Doppler frequency is 20 Hz. Fixed length packets of 2000 bits arrive at base station according to a Poisson process. The delay upper bound requirement is set to 40 ms.

In the Fig. 2, it is demonstrated that the system performance is significantly improved at the low packet loss rate. A 2 dB power gain over algorithm in (Parag *et al.*, 2005) is observed at packet loss rate 10^{-3}. The advantage of the proposed algorithm is further illustrated in Fig. 3, where the packet delay in proposal is lower than (Parag *et al.*, 2005) even at the same packet loss rate.

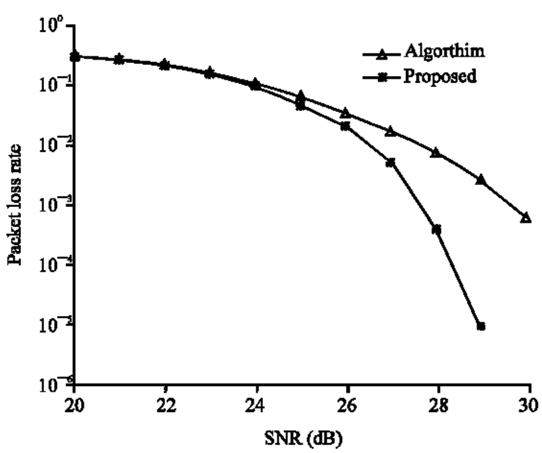

Fig. 2: Packet loss rate when each user traffic rate = 5.17Mbsp

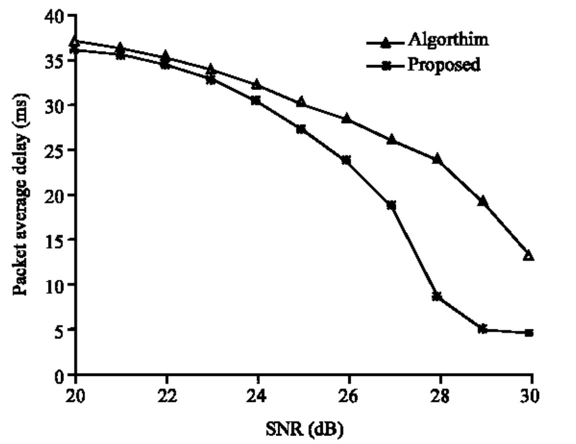

Fig. 3: Average packet delay when each user traffic rate = 5.17 Mbsp

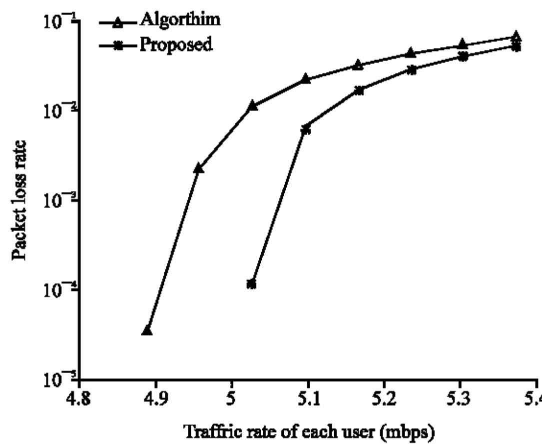

Fig. 4: Packet loss rate when SNR = 26 dB

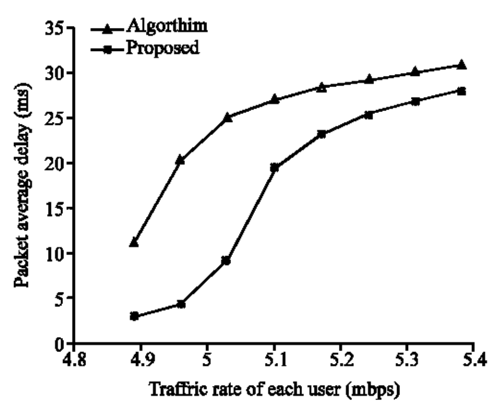

Fig. 5: Average packet delay when SNR = 26 dB

Figure 4 and 5 demonstrated that at the same packet delay or packet loss rate requirement, the proposal algorithm can support a higher traffic rate than (Parag *et al.*, 2005).

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