Improving Mobile Satisfaction in Multiuser OFDM Wireless Networks

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***Abstract*—This paper proposes a new MAC scheduling scheme for efficient support of multimedia services in multiuser OFDM wireless networks, both in the uplink and in the downlink. This scheme is based on an extended higher layers/MAC/PHY cross layer design. Performance evaluation shows that the proposed scheduling outperforms existing wireless OFDM based scheduling schemes providing the greatest Quality of Servics (QoS).**

***Index Terms*—Orthogonal Frequency Division Multiplexing, opportunistic scheduling, cross-layer design, multipath fading.**

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) efficiently reduces the disastrous effects of multipath fading in wireless transmissions. This modulation technique is now acknowledged as the reference for next generation broadband wireless networks (4G systems) and is already widely implemented in most recent wireless systems like 802.11a/g or 802.16. Recently, much research effort has focused on multiple access schemes that operate on top of an OFDM based physical layer. At the MAC level, making an efficient use of the scarce bandwidth is challenging in order to guarantee the respect of the QoS constraints.

The most evolved schemes take advantage of multiuser diversity for optimizing the network capacity based on opportunistic scheduling. Mainly two classes of schemes emerge in the literature: MaxSNR based schemes [1] and Proportional Fair (PF) based schemes [2]. In MaxSNR, priority is given to the mobiles which currently have the greatest signal-to-noise ratio (SNR) value. This allocation strategy maximizes the system capacity. However, a negative side effect is that mobiles close to the access point have an absolute priority over mobiles more distant since their path loss attenuation is much smaller. In PF based schemes, the bandwidth is allocated to the mobile which currently have the better channel state with respect to its time average. Since all mobiles experience the same channel state variations around their mean, all mobiles obtain an equal number of radio resource units across time. This results in an equal sharing of the total available bandwidth. However, since the farther mobiles have a lower spectral efficiency than the closer ones, the mobiles do not all benefit of an equal average throughput which induces unequal delays. Consequently, it appears that, in spite of their high performances in terms of system throughput maximization, both MaxSNR and PF suffer of fairness deficiencies due to unequal spatial positioning of the mobiles which often inducing unequal QoS satisfaction.

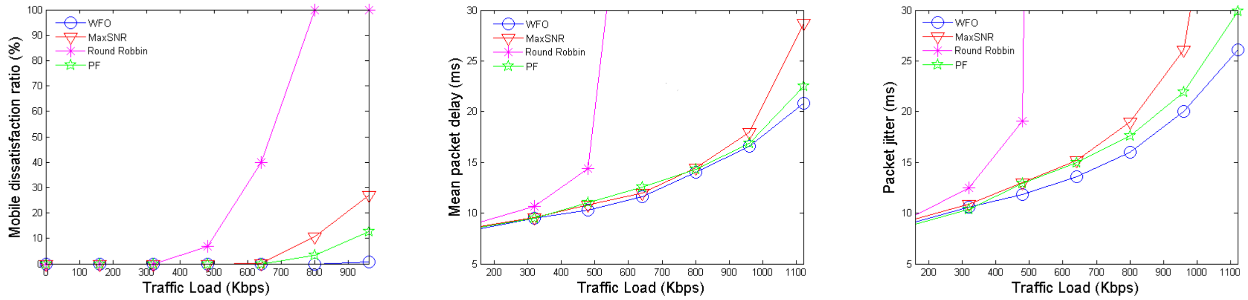
In this paper we propose the "Weighted Fair Opportunistic" (WFO) scheduling scheme. It jointly takes into account both the transmission conditions and the QoS targets in a higher layers/MAC/PHY cross layer approach. Physical layer informations are exploited in order to take advantage of the time, frequency and multiuser diversity and maximize the system capacity. Higher layer informations are exploited in a weighted system that introduces dynamic priorities between flows for ensuring the same QoS level to all mobiles whatever their respective position. This results in an efficient bandwidth allocation ensuring high QoS.

The paper is organized as follows. Section II provides a description of the system under study and introduces the QoS management principle embodied in the proposed scheduling. Section III describes the scheduling algorithm. In Section IV, we present a detailed performance evaluation through a simulation study. Section V concludes the paper.

II. System Description and QoS criteria

The physical layer operates using a structure which ensures a good compatibility with the OFDM based transmission mode of the IEEE 802.16-2004 [3]. The resource allocation is considered in a centralized approach and performed on a frame by frame basis for the set of mobiles located in the coverage zone of an access point.

A crucial objective for modern multiple access schemes is to fully support multimedia transmission services. Regarding delay requirements, the meaningful constraint is a limitation of the occurrences of large delay values. We define the concept of *delay outage* by analogy with the concept of outage used in system coverage planning. A mobile transmission is in delay outage when its packets experienced a delay greater than a given threshold. The Packet Delay Outage Ratio (PDOR) target is defined as the maximum ratio of packets that may be delivered after this fixed delay threshold. In the following, T_k represents the delay threshold of the mobile k. The PDOR experienced by each transmission is tracked all along their lifetime. At each transmission of a packet of mobile k, the total number of packets whose delay exceeded the threshold divided by the total number of packets transmitted since the beginning of the connection is computed. The result is denoted $PDOR_k$. The objective of the WFO scheduling is to regulate the experienced PDOR across the time such as theses values stays below the PDOR target. This ensures the satisfaction of the delay requirements at a short-term time



(a) Mobile dissatisfaction ratio. (b) Mean packet delay. (c) Packet jitter.

Fig. 1. Observed mobile dissatisfaction, mean delay and jitter.

scale. Additionnaly, in the following a mobile is considered as satisfy when, at the end of its connexion, its delay constraint is met (experienced PDOR $\geq PDOR_{target}$).

III. The WFO Scheduling Algorithm

At each scheduling epoch, the scheduler (located in the access point) computes the maximum number of bits $m_{k,n}$ that can be transmitted in a time slot of subcarrier n if assigned to mobile k, for all k and all n. MaxSNR based schemes allocate the resources to the mobile which have the greatest $m_{k,n}$ values. We introduce a new parameter which modulates these pure opportunistic resource allocation in order to provide fairness while preserving the system throughput maximization. This parameter called "Weighted Fair" (WF) parameter is based on the current estimation of the PDOR of mobile k and defined by:

$$WF_k = f(PDOR_k), \quad (1)$$

where f is a strictly positive and monotonically increasing function. The WFO scheduling principle is then to allocate a time slot of subcarrier n to the mobile k which has the greatest WFO parameter value $WFO_{k,n}$ with:

$$WFO_{k,n} = WF_k \times m_{k,n}. \quad (2)$$

Based on the PDOR, the WF parameters directly account for the level of satisfaction of the delay constraints for an efficient QoS management. The WFO parameters introduce dynamic priorities that delay the flows which currently easily respect their delay threshold to the benefit of others which go through a critical period. The WFO algorithm operates function of the specific channel conditions and currently experienced QoS of each mobile in a cross-layer higher layers/MAC/PHY approach. This results in a well-balanced resource allocation which keeps a maximum number of mobiles active across time but with continuously low traffic backlogs. Preserving this multiuser diversity allows to continuously take a maximal benefit of opportunistic scheduling. Thus, the bandwidth usage efficiency and the global mobile satisfaction are improved.

IV. Performance Evaluation

We assume all mobiles run the same videoconference application. This demanding type of application generates a high volume of data with high sporadicity and requires tight delay constraints which substantially complicates the task of the scheduler. The $PDOR_{target}$ is set to 5 %. The threshold time T_k is fixed to the value 80 ms compatible with real time constraints. In order to study the influence of the distance on the scheduling performances, a first half of mobiles is situated close to the access point and a second half twice over farther. The total number of mobiles sets the traffic load.

Fig. 1(a) shows that the WFO brings the largest level of satisfaction. Even with a high traffic load of 960 Kbps, the dissatisfaction ratio is only 0,8 % with the WFO versus 12,8 % with the best of the other scheduling schemes. With its system of weights, the WFO dynamically adjusts the relative priority of the flows according to their experienced delay. With this approach, the WFO takes advantage of the breathing space offered by the easy respect of the delay constraints of the closer mobiles (with better spectral efficiency). It sparingly delays the closer mobiles in order to help the farther ones. This interesting performance result is corroborated in Fig. 1(b) and 1(c) where the overall values of the mean packet delay and jitter obtained using the WFO are inferior.

V. Conclusion

In this paper, we propose a new scheduling scheme for wireless multimedia networks, called "Weighted Fair Opportunistic (WFO)". This scheme operates on top of an OFDM-based physical layer and shows a good compatibility with the existing 802.16 standard. Based on a system of weights, the WFO scheduling introduces dynamic priorities between the mobiles according to their transmission conditions and the delay they currently experience in a higher layers/MAC/PHY cross-layer approach. With its well-balanced resource allocation, WFO preserves this multiuser diversity and takes a maximal benefit of the opportunistic scheduling technique for maximizing the system capacity. Simulation results show that the WFO scheduling outperforms other wireless OFDM based scheduling schemes providing efficient QoS management.

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