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An integrated cross-layer framework of adaptive FEedback REsource allocation and Prediction for OFDMA systems

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ABSTRACT

Orthogonal frequency division multiple access (OFDMA) technology has been adopted by 4th generation (a.k.a. 4G) telecommunication systems to achieve high system spectral efficiency. A crucial research issue is how to design adaptive feedback mechanisms so that the base station can use adaptive modulation and coding (AMC) techniques to adjust its data rate based on the channel condition. This problem is even more challenging in resource-limited and heterogeneous multiuser environments such as Mobile WiMAX and long-term evolution (LTE) networks. In this paper, we develop an integrated cross-layer framework of adaptive FEedback REsource allocation and Prediction (FEREP) for OFDMA systems. The proposed framework, implemented at the base station side, is composed of three modules. The feedback window adaptation (FWA) module dynamically tunes the feedback window size for each user based on the received automatic repeat request (ARQ) messages that reflect the current channel condition. The priority-based feedback scheduling (PBFS) module then performs feedback resource allocation by taking into account the feedback window size, the user profile and the total system feedback budget. To choose adapted modulation and coding schemes (MCS), the channel quality indicator prediction (CQIP) module performs channel prediction by using recursive least square (RLS) algorithm for the users whose channel feedback has not been granted for schedule in current frame. Through extensive simulations, the proposed framework shows significant performance gain especially under stringent feedback budget constraints.

1. Introduction

Users today expect the same wireline broadband access and multimedia Internet experience from the new generation of wireless networks. Recent 3G operators' statistics have shown a significant increase in mobile data usage with a rapid growth of traffic volume [1]. Many reasons are driving this trend: the proliferation of powerful smart phone devices, the increasing audio/video streaming and IPTV demand and the diversified operators offers for price cutting flat-rate tariffs. To face this rapid growth in broadband data usage, most operators are preparing 4G solutions, among which Mobile WiMAX (IEEE 802.16 m) [2] and 3GPP LTE-Advanced are the most promising candidates.

The high bandwidth and flexibility offered by 4G systems are mainly due to the orthogonal frequency division multiple access (OFDMA) technology which has been adopted in almost all wireless broadband access standards. As shown in Fig. 1, in OFDMA systems, the base station (BS) uses adaptive modulation and coding (AMC) to change its transmission data rate based on the channel condition (characterized by channel quality indicator (CQI)), which is returned periodically by each user. Fig. 2 shows the frame structure of an OFDMA system (IEEE 802.16e [3]) in which the field channel quality feedback, consisting of a number of slots, is dedicated for the users to report their channel conditions to the BS in order to apply the AMC

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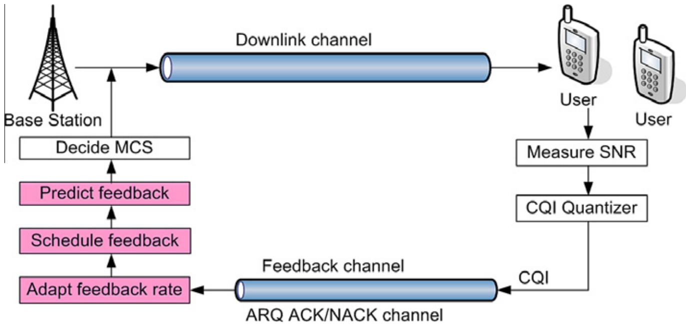

Fig. 1. OFDMA system.

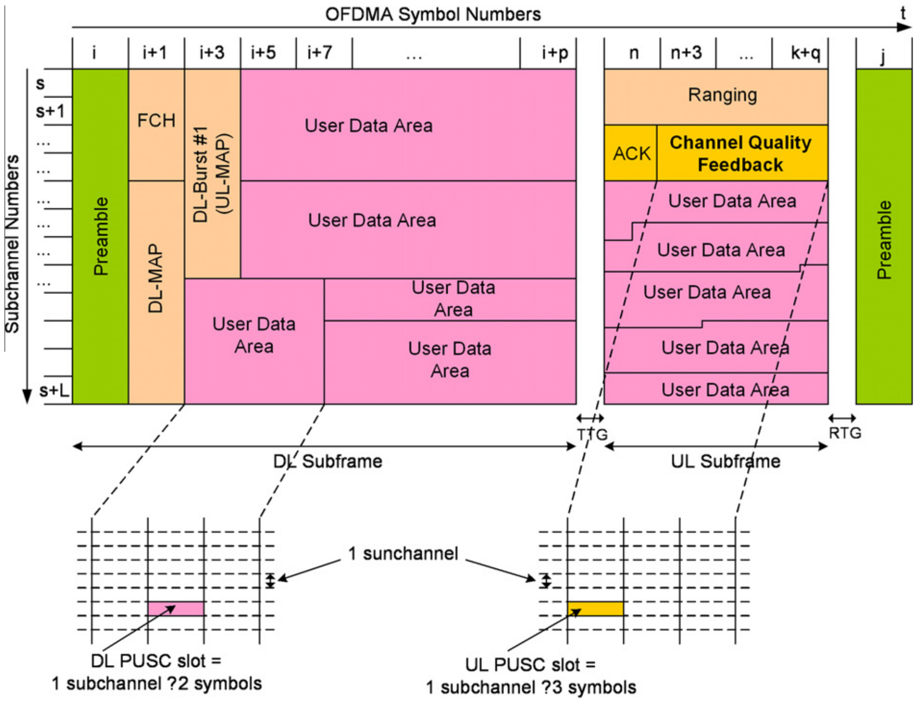

Fig. 2. Frame structure of an OFDMA system (IEEE 802.16e).

technique. As the number of slots reserved for channel feedback is limited, optimized techniques for feedback reduction are mandatory. In practical systems such as Mobile WiMAX, for example, users are allowed to send channel feedback periodically once in every w frame (w is referred to as feedback window), or aperiodically using allocation/deallocation messages.

4G networks are designed to support heterogeneous environments. On one hand, heterogeneity concerns the channel conditions experienced by users. On the other hand, the system is aimed at supporting different applications, each of which has its specific requirement in terms of quality of service (QoS) [4]. Consequently, applying the same feedback strategy for all users is definitely not adapted in these heterogeneous environments [5]. In such context, natural but crucial questions are raised: (i) how to reduce the feedback overhead for a better resource utilization without degrading the system performance, (ii) how to allocate the available feedback slots in the OFDMA frames among the active heterogeneous users to send their channel condition, given the total budget constraint, and (iii) how to design adapted feedback mechanism for heterogeneous users?

In this paper, we tackle this feedback reduction problem by proposing an integrated cross-layer framework named FEedback REsource allocation and Prediction (FEREP). The proposed framework, implemented at the BS side, is composed of three modules: the feedback window adaptation (FWA), the priority-based feedback scheduling (PBFS) and the CQI prediction (CQIP). In the FWA module, the feedback window size of each user is tuned based on the received ack/nack from automatic repeat request (ARQ) protocol that implicitly reflects the current channel condition. The PBFS module then performs feedback scheduling by taking