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QoS-aware bandwidth allocation and admission control in IEEE 802.16 broadband wireless access networks: A non-cooperative game theoretic approach

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Abstract

In this paper, we propose an adaptive bandwidth allocation and admission control mechanism based on game theory for IEEE 802.16 broadband wireless networks. A non-cooperative two-person non-zero-sum game is formulated where the base station and a new connection are the players of this game. The solution of the game formulation provides not only the decision on accepting or rejecting a connection, but also the amount of bandwidth allocated to a new connection (if admitted). A queueing model considering adaptive modulation and coding in the physical layer is used to analyze quality of service (QoS) performances, namely, the delay performance for real-time and the throughput performance for non-real-time polling services and best effort service. This queueing model is used by the proposed bandwidth allocation and admission control mechanism to ensure that the utilities for both the base station and the new connection are maximized. The performance of the proposed scheme is evaluated by simulation and compared with that of each of the traditional admission control with static and adaptive bandwidth allocation schemes.

Keywords: Bandwidth allocation; Admission control; Broadband wireless access; Game theory

1. Introduction

Broadband wireless access (BWA) based on the IEEE 802.16 technology [1] is a promising technique for last-mile access. IEEE 802.16 standard has been proposed to provide high-speed broadband wireless connectivity through a pre-defined quality of service (QoS) framework for multimedia traffic. Even though the physical layer specifications and the medium access control (MAC) protocol signaling are well defined in the standard, the resource allocation and admission control policies for the IEEE 802.16 air-interface remain as open-issues.

There are three different service classes, namely, real-time, non-real-time polling services, and

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best-effort services defined in the IEEE 802.16 standard. Real-time and non-real-time polling services support QoS guarantee in terms of delay and throughput, respectively. Therefore, the bandwidth allocation and admission control schemes are required to consider the user satisfaction on delay and throughput performances explicitly. Also, the physical layer aspects such as adaptive modulation and coding need to be taken into consideration for optimizing system performance while satisfying users' QoS performances.

In this paper, we propose a QoS-aware bandwidth allocation and admission control method based on queueing analysis and a game theoretic formulation. The queueing model is used to calculate the throughput and the delay performances to be used by the game theoretic model to decide whether a new connection can be accepted or not. The queueing analysis considers adaptive modulation and coding in the physical layer as defined in the IEEE 802.16 standard. Also, a realistic traffic arrival process which captures burstiness is considered through a Markov modulated Poisson process (MMPP).

From the proposed game theoretic model, an equilibrium point between the base station and a new connection can be obtained to achieve the target level of satisfaction on the QoS performances (e.g., delay and throughput). The conflict in this game arises due to the fact that constrained by limited radio resources (i.e., bandwidth), the base station wants to maximize utility (e.g., revenue) from the ongoing connections by providing higher level of QoS to these connections, while a new connection wants to achieve the highest possible QoS performance as well. We represent the payoff in this game by user utility calculated as a function of the perceived delay and throughput performances for the connection. Among the available strategies of both the base station and a new connection, the Nash equilibrium is determined by using the best response and the decision on admission control is made based on the strategy that maximizes the utility of the base station. The connection-level and the packet-level performances for the proposed bandwidth allocation and admission control scheme are investigated. Also, the performances are compared with those of the traditional schemes (i.e., static and adaptive bandwidth allocation).

Note that, the queueing model presented in this paper is a simplified version of that in [2]. The game formulation in this paper is an extension of that in [3]. In particular, in addition to the polling service, the best-effort service, in which user satisfaction is a function of QoS performance (i.e., throughput), is also considered in this paper.

The rest of this paper is organized as follows. Section 2 provides an overview of related work on radio resource management in wireless networks using game theory and queueing analysis for wireless transmission. Section 3 presents a general overview on the IEEE 802.16 air-interface standard and describes the system model considered in this paper. The queueing formulation is presented in Section 4. Section 5 presents the game theoretic formulation of the bandwidth allocation and the admission control problem. The numerical and the simulation results are presented in Section 6. Section 7 states the conclusions.

2. Related work

Bandwidth allocation and connection admission control are classical problems in wireless systems. While bandwidth allocation is responsible for allocating scarce radio resource (e.g., bandwidth) to ongoing and incoming connections such that their QoS requirements are satisfied, admission control is applied to avoid overwhelming limited radio resource due to accepting too many connections. The resource allocation and admission control problems for the cellular wireless networks such as TDMA and FDMA-based [4] and CDMA-based [5] cellular wireless systems were studied in the literature.

Game theoretic models were used for admission control in wireless systems. In [6], a game theoretic framework for reservation of guard bandwidth in a cellular wireless network was proposed. In [7], an integrated admission control and rate control method using non-cooperative game was proposed for CDMA wireless networks in which user churning among the different service providers was considered. In [8], the admission control problem in a IEEE 802.11 wireless LAN was posed as a non-cooperative game. The game is played by the access point and an arriving mobile station. The objective is to maximize service provider's revenue while maintaining the QoS of the ongoing flows at the desired level. In [9], the problem of joint multiuser detection and power control was investigated using game theory. The users in the network choose their strategies in terms of uplink receive and transmit powers to maximize their own utilities. This utility