

Chapter XIV

Scheduling and Access Control for Wireless Connections with Throughput Guarantees

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ABSTRACT

Emerging wideband code division multiple access (WCDMA) data services will likely require resource allocation to ensure that throughput targets are met. Scheduling and access control can both be key components in this task. In this chapter, we introduce a two-layer scheduler and connection access controller that attempts to balance efficiency with fairness. We first propose a scheduler that takes advantage of variations in the wireless channel—both channel fluctuations in time for each user, and channel variations among multiple users at a particular time. By mixing a max-min policy with a policy of serving users with relatively good channels, the scheduler can achieve individual average throughput targets in a manner that encourages system efficiency. We then propose a two-layer algorithm that offers targeted throughput for interactive nomadic data streams, such as video or music streaming. The design purpose is to provide users with service differentiation, which lays the groundwork for network optimization in terms of capacity or utility, and can be easily extended to revenue maximization. Upon the request of a data stream connection, a target throughput is negotiated between the user and the network/base station. The network attempts to achieve the throughput targets over the duration of each individual connection by maximizing a system objective based on users' satisfaction that is represented by a utility function. We assume that a users' utility function depends not only on the throughput target but also on final achieved throughput. The algorithm integrates connection access control and resource allocation per connection request with rate scheduling on a per frame basis adaptive to slow fading. Through numerical analysis, the proposed joint scheduler and connection access controller is shown to achieve the design goals.

INTRODUCTION

In recent years, wireless networks have been evolving rapidly, driven by emerging multimedia applications and supported by advanced technologies. Code division multiple access (CDMA), one of the most widely applied technologies for cellular wireless networks, is undergoing a fundamental transition from providing voice only service to wideband CDMA (WCDMA) that accommodates convergence between data, audio and video (Holma & Toskala, 2004).

Much research has addressed the extremes of traffic that requires constant bit rate and traffic that can accept best effort service. However, there is an intermediate class of interactive traffic that does not require constant bit rate but requires more predictable throughput than that provided by best effort service. Relatively few papers have addressed connection access control (CAC) and rate scheduling (RS) for such interactive traffic. For such interactive traffic, we would hope that the network could support soft performance guarantees to match the limited tolerance of these applications to variations in performance, and enhance radio resource efficiency and aggregate network capacity as well.

An impediment so far to addressing CAC and RS for such traffic has been the lack of the ability to allow interactive connections to communicate a performance goal and to allow the network some flexibility in achieving these goals. In this chapter, we first focus on the scheduler, which allocates power and rate in real-time among competing data streams. Efficiency depends on how well the scheduler takes advantage of variations among users. Fairness depends on how well the scheduler achieves the throughput targets of individual data streams. The two are related, as higher efficiency makes throughput targets easier to achieve. We then consider joint CAC and RS for connections, which can specify a target throughput. The target is interpreted as an average to be achieved over the lifetime of the connection. A user's evaluation

of the throughput achieved over the connection is represented by a utility function that depends not only on the throughput target but also on the connection's achieved throughput, thus allowing satisfaction to depend on the degree to which the target was achieved. There is a balance to be achieved between the number of connections accepted into the network and the throughput achieved for each accepted connection. We therefore jointly consider CAC and RS, and propose a two-layer structure that separates these functions by time scale and that communicates vital information between these two layers.

Related Work

There is a vast literature on quality of service (QoS) provisioning in wireless networks, and we only survey a very limited portion that is throughput or rate oriented. In the scheduling literature, a number of proposals focus primarily upon system efficiency, and incorporate rate scheduling into power control of wireless CDMA networks. Typical approaches in this genre exploit channel variations among multiple users at a particular time (here called *multi-user diversity*) in such a way that users with better channels are assigned higher transmission rates (Berggren & Kim, 2004; Jafar & Goldsmith, 2000; Kim & Honig, 2000; Knopp & Humblet, 2000; Li & Ephremides, 2005). However, such approaches do not take fairness (e.g., throughput targets) into account, and consequently do not take full advantage of channel fluctuations in time for each user (here called *temporal diversity*). Fairness is often implemented through schedulers that explicitly consider the cumulative throughput achieved by each connection (e.g., max-min policies) (Bertsekas & Gallager, 1987; Kelly, 1997). However, such policies typically do not strongly consider efficiency.

A relatively small portion of the literature does consider both efficiency and fairness. The well known and widely deployed algorithm in this

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