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Cross-layer QoS support framework and holistic opportunistic scheduling for QoS in single carrier WiMAX system

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A B S T R A C T

Providing Quality of Service (QoS) to different service classes with real-time and non-real-time traffic integration is an important issue in WiMAX systems. Opportunistic MAC (OMAC) is a novel view of communication over spatiotemporally varying wireless links. It combines the features of a cross-layer design and an opportunistic scheduling scheme to achieve high utilization while providing QoS to various applications. Channel characteristics, traffic characteristics and queue characteristics are essential factors in the design of opportunistic scheduling algorithms. In this paper, we propose a cross-layer QoS support scheduling framework and a corresponding opportunistic scheduling algorithm to provide QoS support to the heterogeneous traffic in single carrier WiMAX point-to-multipoint (PMP) systems. We model the uplink transmission in the single carrier WiMAX system as a multi-class priority TDMA queueing system to analyze the average packet delays of different service classes. Extensive simulation experiments have been carried out to evaluate the performance of our proposal. The simulation results show that our proposed solution can improve the performance of the WiMAX PMP system in terms of packet loss rate, packet delay and system throughput.

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1. Introduction

The WiMAX (IEEE Std 802.16d, 2004) system has received a lot of attention from the academic and industry sectors in the past few years as it comes with the ability to provide broadband wireless access and potential ability to compete with existing wired and wireless networks. One important issue in the design of WiMAX systems is to provide QoS to different service classes by using an efficient scheduling scheme.

Wireless access networks have unique characteristics, which are the time-varying channel conditions and the multi-user diversity. The Medium Access Control (MAC) protocol and scheduling algorithms have to be developed specially for this environment (Liu et al., 2003). It requires a cross-layer MAC protocol design approach, whereby Channel Specification (Cspec) carrying the estimated instantaneous channel information can be fed to the MAC layer from the physical (PHY) layer and Traffic Specification (Tspec) carrying traffic QoS related information can be fed to the MAC layer from higher layers such as the network or application layer. The Cspec feedback includes information on the estimated instantaneous Signal-to-Interference and Noise Ratio (SINR), supportable data rate $R(t)$, Received Signal Strength Indications (RSSI) or Bit Error Rate (BER) of a link. The Tspec feedback includes information on the traffic Maximum Latency (ML) constraint, Maximum Sustained Traffic Rate (MSTR) and the instantaneous length of queues at a station. The cross-layer nature of OMAC (Amoakoh et al., 2006) with an opportunistic scheduling scheme has the potential to revolutionize the design of broadband wireless access networks from the physical to the networking layer.

Recently, various opportunistic scheduling schemes have been proposed for wireless communication systems. They can exploit the time-varying nature of the radio environment to improve the spectrum efficiency while maintaining a certain level of QoS satisfaction for each connection or user in various wireless networks. The proposed opportunistic scheduling schemes can be classified into channel-aware only and channel-aware and queue-aware algorithms based on their functionality of scheduling algorithms (Hassel, 2006). Max Carrier-to-Noise Ratio Scheduling (MCS) (Bonald, 2005) is a typical channel-aware opportunistic scheduling scheme. The MCS scheme is to allocate resources to users with the best channel condition to achieve high system throughput. On top of channel characteristics, traffic characteristics also play an important role in the design of an opportunistic scheduling algorithm. The Proportional Fair Scheduling (PFS) schemes (Jalali et al., 2000; Jinri and Niu, 2007; Bang et al., 2008) attempt to trade-off among the throughput, efficiency and fairness among users by taking packet length into account (Jinri and Niu, 2007), or estimating future channel quality (Bang et al., 2008). Modified Largest Weighted Delay First (M-LWDF) (Andrews et al., 2000) is a modified version of the PFS scheduler that tries to meet the QoS requirement in terms of head-of-line packet delay. Traffic-Aided

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