ABSTRACT

With the exploding increase of mobile users and the release of new wireless applications, the requirement for bandwidth becomes a predominant issue. High bandwidth and Quality of Service (QoS) provisioning are the critical goals in the development of communication techniques. Also, achieving service differentiation and QoS satisfaction for heterogeneous applications is often a very complicated issue. This issue refers to many fields, such as connection admission control (CAC), congestion control, routing algorithm, MAC protocol, and scheduling scheme. Among these fields, packet scheduling plays the most important roles in fulfilling service differentiation and QoS provisioning. It decides the order of packet transmissions, and provides mechanisms for the resource allocation and multiplexing at the packet level to ensure that different types of applications meet their service requirements and the network maintains high resource utilization.

In the current dominate layered networking architecture, each layer is designed and operated independently to support transparency between layers. Among these layers, the physical layer is responsible for raw-bit transmission, and the Medium Access Control (MAC) layer deals with the multiuser access to the shared physical medium. However, wireless channels suffer from time-varying multipath fading and the statistical channel characteristics of different users are different. Hence, the sub-optimality and inflexibility of this architecture result in inefficient resource use in wireless

networks. So, we need an integrated adaptive design across different layers. Thus, cross-layered design and optimization across the physical and MAC layers are highly desired for wireless resource allocation and packet scheduling.

The basic objectives considered in this thesis are effective resource allocation on single carrier and multicarrier Orthogonal Frequency Division Multiplexing (OFDM) networks by exploiting knowledge of Channel State Information (CSI) and the characteristics of traffic and enhancing the spectral efficiency / throughput and guarantee QoS. This research focuses on establishing a theoretical framework and to develop efficient algorithms to support diverse QoS and statistical QoS with bounded delay requirements in single carrier networks and algorithms for resource allocation in wireless multicarrier networks based on cross-layer optimization. The simulation results show that the proposed Cross-layer design based scheduling and resource allocation algorithms can provide an efficient and stable mechanism for spectral efficiency improvement and QoS differentiation.

There are four major contributions presented in this thesis. First an adaptive cross-layer packet scheduling algorithm is presented and it is shown to achieve good user and system throughput while satisfying the varying delay requirements of any wireless system. Since increased system throughput reduces the load (i.e. interference) on the system, it increases channel bit rates and consequently reduces overall delays. A cost function is defined to include the current channel qualities and delay states of the packets in the queue that negotiates between minimizing delay and maximizing throughput. Thus, improving system throughput / channel bit rates can have a positive effect on average normalized packet delay and the total number of missed packet deadlines. However, due to the heterogeneity of packet delay requirements, it is not enough to simply increase system throughput. The scheduling algorithm must adapt its system throughput improvement policies to the varying delay requirements of the packets in queue, so that it can take advantage of high bit rate channels and while doing so does not threaten packet deadlines or degrade average normalized delay.

Secondly, an effective capacity concept is applied for cross-layer scheduling to allocate resources adaptively to support the real-time multimedia QoS for downlink heterogeneous mobile wireless networks. Different mobile users are expected to tolerate different levels of delay for their service satisfactions depending on their distinct QoS requirements. For instance, non-real-time services such as data dissemination aim at maximizing the throughput with a loose delay constraint. In contrast, for real-time services like multimedia video conference, the key QoS metric is to ensure a stringent delay-bound, rather than to achieve high spectral efficiency. There also exist some services falling in between, e.g., paging and interactive web surfing, which are delay-sensitive but whose delay requirements are not as stringent as those of real-time applications. The diverse mobile users impose totally different and sometimes even conflicting delay-QoS constraints, which impose great challenges to the design of mobile wireless networks. Therefore, to support the real-time wireless multimedia QoS, link adaptation techniques is considered in this work not only at the physical layer, but also at the upper-protocol-layers such as data-link layer when designing the wireless networks. The system resources are allocated according to the heterogeneous fading channel statistics, the diverse QoS requirements, and different traffic characteristics. Analytically the admission-control and power / time slot allocation conditions to guarantee the statistical delay-bound for real-time mobile users is derived to evaluate the proposed scheduling algorithm.

A jointly rate based optimal delay-sensitive subcarrier and rate allocation policy is studied as third part of thesis for Orthogonal Frequency Division Multiplexed systems to maximize the total successfully deliverable data rate from the system in terms of throughput while satisfying the heterogeneous user delay requirements. This optimization framework involves both information theory (to model the multi-user OFDM physical layer) as well as queuing theory (to model the delay dynamics) and employs obsolete channel state information and does not take traffic burstiness into account. By transforming the average delay constraints into the average rate constraints, the delay-sensitive cross-layer scheduling problem is formulated into a mixed convex and combinatorial optimization problem. Further, it is shown to have robust system performance as well as guaranteeing delay constraints.

Finally, two rate-based scheduling schemes viz. QoS Proportional Fair and Adaptive Cross-layer Packet scheduling, which take traffic burstiness also into account are presented. Utility functions with respect to average delays is used for designing channel and queue-aware scheduling, which is highly advantageous to data transmission with a low latency requirement. Orthogonal Frequency Division Multiplexing (OFDM) provide fine granularity for resource allocation since they are capable of dynamically assigning sub-carriers to multiple users and adaptively allocating transmit power.