Channel Feedback Scheduling For Wireless Communications

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Abstract

Opportunistic scheduling can significantly improve wireless network performance by exploiting the underlying channel condition. There has been a lot of work on opportunistic scheduling, but the problem of finding the right feedback mechanism to convey channel information has largely been untouched. In emerging multichannel systems, the per-channel feedback induces a substantial amount of feedback overhead and requires high computational complexity. To reduce the feedback overhead, we consider an opportunistic feedback strategy that activates the channel feedback opportunistically according to the channel condition. Then, we combine the opportunistic feedback with the best-n channel feedback scheme where a mobile user chooses the best n channels and transfers this information to the base station. We analyze the throughput and the amount of channel feedback information for proportionally fair opportunistic scheduling under Rayleigh fading channels. The numerical results confirm that our partial feedback schemes achieve a remarkable reduction in the amount of feedback information without significant throughput degradation, thereby saving the scarce wireless bandwidth and limited battery power.

Keyword: feedback, wireless network.

1. INTRODUCTION

The last few years have witnessed a remarkable proliferation of wireless services, and an exponential growth in the number of users. The main challenge in the next generation of wireless systems is to accommodate the increasing demand for wireless services as well as new high-rate applications that require high performances. A lot of work has focused on increasing the cell capacity by using new techniques like orthogonal frequency division multiplexing (OFDM), orthogonal frequency division multiple access (OFDMA), and multiple-input-multiple output (MIMO) antennas.

Meanwhile, some work has paid attention to downlink scheduling to exploit the cell throughput enhanced by multiuser diversity. The notion that the base station (BS) uses the feedback information about the channel state to improve wireless spectrum efficiency has of late become very popular. This is primarily due to the ability of third generation wireless systems that use adaptive modulation and coding (AMC) techniques to change their sending rates based on the estimated channel quality. This has led to the development of opportunistic scheduling schemes where a BS chooses users for transmission according to their channel conditions, fairness, or other performance constraints. Among these schemes, proportionally fair (PF) scheduling is widely used in real systems such as high data- rate (HDR, also called cdma2000 1x EV-DO) systems and high speed downlink packet

access (HSDPA) systems. While there has been much work on opportunistic scheduling that relies on channel feedback, there does not have been much work on finding the appropriate channel feedback mechanism. It seems reasonable to assume that channel feedback should occur more often if the channel experiences fast fading. In HDR systems, a mobile terminal (MT) sends channel feedback twice in a slot of 1.667msec. Moreover, in such CDMA systems, uplink control channels for the feedback generate interference to other channels. In HSDPA systems, the basic feedback interval is 2msec, and can be extended to 10msec, 20msec, 40msec, and 80msec in order to reduce the uplink network traffic and interference under static channel environments. Although, the feedback information consists of one

bit of hybrid-automatic-repeat-request (HARQ) and five bits of channel-quality indicator (CQI), the total transmission bits per feedback correspond to 30bits because of channel coding. The feedback overhead1 becomes a more serious problem in multichannel systems like OFDMA

Systems that have tens of shared channels. If every active user sends feedback data for all channels, it consumes a lot of uplink bandwidth. For example, an emerging system in Korea, the IEEE 802.16e-based WiBro system is expected to encounter this problem in the AMC mode. If each user sends the feedback on the states of its 24 channels, the total amount of CQI becomes very large. This problem will also appear in all OFDMA systems including the IEEE 802.16 system considered in the Wi MAX forum. Therefore we develop partial feedback strategies. First, we consider an opportunistic channel feedback scheme. This scheme activates the feedback opportunistically only when the channel condition is better than a given threshold that is set adaptively according to the number of users. Second, we analyze a best-n channel feedback scheme for multichannel systems where each MT sends the feedback for its best n channels instead of all channels. Combining this with the opportunistic feedback scheme, we propose an opportunistic best-n channel feedback scheme. Recently, there has been some research on reducing the channel feedback information; the concept of opportunistic channel feedback is introduced. Especially the approach is similar to our opportunistic algorithm in this paper, while the works and investigate probabilistic transmission for random access.

However, channel feedback mechanisms for multichannel systems are not investigated thoroughly in the previous literature. Our work considers various partial channel feedback strategies with comprehensive analysis. In addition, we calculate the cell throughput under PF scheduling that is more realistic in cellular environments, while the previous work deals with ideal Shannon capacity.

2. OPPORTUNISTIC SCHEDULING

2.1 Single-channel scheduling

Wireless channels change over time in unpredictable ways due to location environments, user movement, or other interference. Considering various factors, they are generally characterized by large-scale and small-scale propagation effects. The large-scale effect is modeled by path loss and shadowing, and it can be handled easily in the average sense. In contrast, the small-scale effect (or short-term or fast fading), caused by multipath, causes short-term fluctuation of wireless channels and deteriorates the instantaneous performance. To overcome this problem as well as the near-far effect, CDMA systems have adopted a method of Fast power control, where the receiver sends the transmitter a short signal to increase or decrease its transmit power according to the estimated signal-to-interference-plus-noise ratio (SINR). The transmitter reduces the power level at high SINR, and raises it at low SINR. The update rates for IS-95 and WCDMA systems are 800Hz and 1500Hz, respectively. Meanwhile, data-only networks such as HDR and HSDPA have begun exploiting the

channel fluctuation over the downlink, rather than overcoming it. If an MT estimates the current SINR and sends its quantized value to the BS, the BS decides a suitable data rate
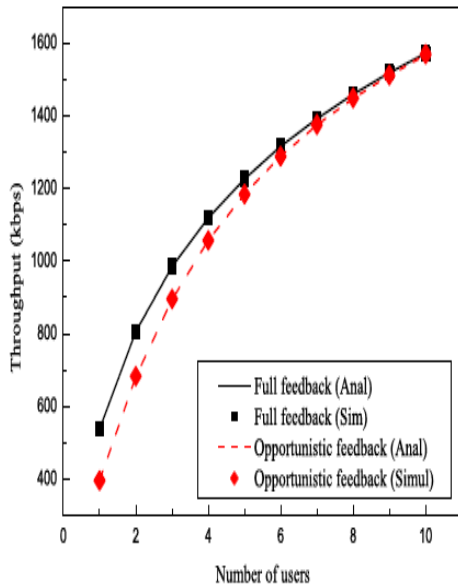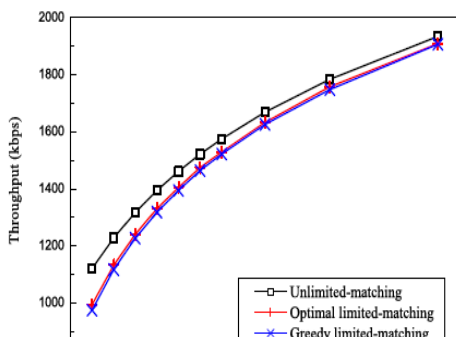
2.2 Performance of PF scheduling

We refer to the throughput analysis of PF scheduling Let Gk be the scheduling metric given by the feedback of user k, which becomes $D_k = D_{-k}$ in the PF scheduler. If we denote Gk_i as max $\{G_1,\ldots G_{k-1}, G_{k+1}, \ldots G_k\}$ for the given K users, the opportunistic scheduler chooses user k if Gk is larger than Gk_i. Hence, we can express the cumulative density function (CDF)

$$F_{k-}(t) = \Pr\{G_{k-} \leq t\} = \prod_{m \neq k} F_m(t),$$

Where Fm(t) is the CDF of Gm and assumed to be mutually independent. For simplicity, we also assume Gm is mutually independent in the sense that D_k converges on a long-term average.

2.3 Multichannel scheduling

Extending the opportunistic PF scheduling to the multichannel case, we develop two types of multichannel scheduler: unlimited-matching scheduler and limited-matching scheduler. The unlimited matching scheduler can assign a user to multiple channels, whereas the limited-matching scheduler limits a user to a single channel. The second type of allocation may be used when the resource management policy wants to restrict users from monopolizing channel resources, or it needs to
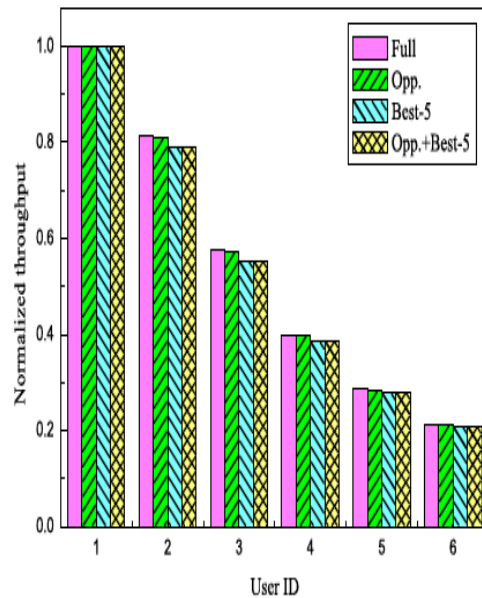
work

under a
highly
limited

terminal capability in terms of channel assignment.

3. NUMERICAL RESULTS

We now evaluate the performance when the number of shared channels is large. Instead of Calculating the cell throughput over the entire cell area, we consider users with the same channel conditions (average data rate of 2Mbps) in order to focus on the effect of multiuser diversity. The data rates are assumed to be continuous. To generate inter cell interference, a cell has six hexagonal neighboring cells, and each cell has a BS at its center with a radius of 1Km. Our system model has 24 virtual channels as in WiBro systems. We assume that the downlink queues for active users always have packets to transmit. Finally, to investigate the fairness performance of partial feedback schemes, we compare the throughputs of uniformly distributed users. For the selected six among ten

users. The each user's throughput normalized by that of user 1. The user index is sorted according to the average channel condition such that user 1 has the best condition. The throughput is proportional to the average channel condition by the nature of proportional fairness. Hence, we can conclude That the partial feedback schemes do not affect the fairness performance.

4. CONCLUSION

In this paper, we have developed new channel feedback strategies for opportunistic scheduling in wireless networks. The opportunistic feedback scheme reduces the feedback overhead significantly by activating the feedback only when the channel condition is good enough. Such a scheme works adaptively with the number of users without a noticeable degradation in throughput. For multichannel systems, it is combined with the best-n feedback scheme that works for a partial number of channels instead of all channels. Through numerical results, we show that the combined

opportunistic best-n scheme performs best in reducing the feedback overhead with comparable throughput. Although our analysis is based on a simple channel model and PF scheduling, we believe that our work can be applied to more general partial feedback mechanisms that have the advantage of saving bandwidth and transmit power. We expect that our work can be applied for designing next-generation communication systems that deal with multichannel resources such as in CDMA, OFDMA, and multi-antenna systems.

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