

Multi User MIMO Scheduling Fourth Generation Cellular System

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Abstract: *In this article an overview of the scheduling algorithms proposed for fourth-generation multiuser wireless networks based on multiple-input multiple-output technology is presented in the system. In MIMO systems a multi-user diversity gain can be extracted by tracking the channel fluctuations between each user and the base station, and scheduling transmission for the “best” user. Based on this idea, several opportunistic scheduling schemes that attempt to improve global capacity or satisfy users with different QoS requirements have been proposed for better result. Transmit beamforming procedures aimed at increasing the channel fluctuations have been proposed. The simultaneous exploitation of both spatial and multi-user diversity is not straightforward; however, it may be achieved by a refined selection of the “best” user. In addition, a multiple access gain can be obtained from a simple SDMA/TDMA system. Finally, several resource allocation schemes are discussed for this hybrid multiple access system.*

Keywords: MIMO, cellular system, single antenna system

1. Introduction

Multiple-input multiple-output (MIMO) technology utilizes multiple antennas at the transmitter and/or receiver with the aim of improving transmission reliability and providing high raw data rates. The antennas array in MIMO systems can be used to either improve the transmission reliability for a given data rate (i.e., providing diversity gain) or increase the data rate for a given transmission reliability. The system consists of K users communicating to a common entity (e.g., a base station, BS). The nature of independent time varying channels across different users in a multi-user wireless system provides multi-user diversity. This particular form of diversity could be exploited by tracking the channel fluctuations between each user and the BS, and scheduling transmissions to users when their instantaneous channel quality is near maximum.

When a set of users wants to transmit simultaneously, the medium access control (MAC) layer allocates the radio resources to these users according to their QoS needs. When users have the same QoS requirements, the MAC resource allocation strategy attempts to optimize global system performances.

This article provides an overview of the multiplexing and scheduling techniques proposed in the context of multi-user MIMO-based wireless networks

To improve global system performance for delay-tolerant applications, the presence of strict QoS requirements leads to Numerous interesting challenges.

2. Background and Problem Definition

For point-to-point MIMO systems, the theoretical capacity is linearly proportional to $\min(N_T, N_R)$ where N_T is the number of transmit antennas and N_R is the number of receive antennas. This capacity increase requires a rich scattering

environment as well as perfect knowledge of the channel state information (CSI) by both the transmitter and receiver.

The single-user scenario, the capacity of MIMO multi-user channels is quite difficult to obtain. An excellent overview of the results on the Shannon capacity for single-user and multi-user MIMO channels is provided. In MIMO systems that exploit spatial diversity, the use of multi-user diversity is not straightforward, especially when the number of antennas is large. However, exploiting both diversities at the same time is possible with a refined selection of the “best” users

3. Channel Aware Scheduling

3.1. Single antenna system:

Extensive work has been done in this field. In their pioneering work, Knopp and Humblet have investigated multi-user diversity for uplink transmissions in cellular single-cell single-antenna user models. They proposed a power control scheme based on the idea that only one user transmits over the entire bandwidth at any moment, and that user has the “best” channel at that particular moment.

It is worthwhile to note that this particular power control scheme is somewhat opposite to conventional schemes since it allocates more resources (i.e., power) to a user when his/her channel state is “good” and less resources when it is bad.

3.2 Multi antenna system:

The utilization of spatial diversity in MIMO systems decreases channel fluctuations and, as a result, reduces the multi-user diversity gain. When users are homogenous, assigning the transmission slot to the user with the currently maximum feasible rate equalizes the long-term average throughput among all users and the long-term fraction of time slots allocated.

The curves correspond to no channel-dependent scheduling and opportunistic scheduling, the impact of using multiple antennas at both the transmitter and receiver significantly improves the capacity over using only receive diversity

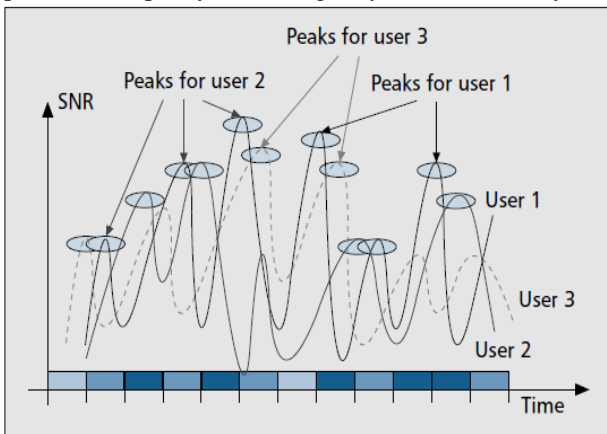


Figure 1: MIMO System

4. Multi-user Diversity Spatial Diversity

Theoretical results indicate that the capacity improvement from spatial diversity in $NR \times NT$ point-to-point communication scheduling.

1. Saturates to some limit when only NT increases
2. Grows logarithmically when only NR increases
3. Grows linearly when both NT and NR increase in the same Proportions

The capacity gain provided by spatial diversity is harder to evaluate, because the overall throughput depends strongly on the relative data rate sharing among users

It can be stated that if a channel-aware scheduling algorithm is applied straightforwardly in a spatial diversity MIMO system, when the number of antennas increases, the multi-user diversity gain should decrease. This is due to the fact that the fluctuations of channel fading, which is the source of this gain, is reduced. The optimal power allocation strategy would then be to focus transmit power on a single transmit antenna only or selecting the best transmit antennas. Selection transmit diversity, which selects the best among N_u transmit antennas per user based on CSI, presents a good trade-off.

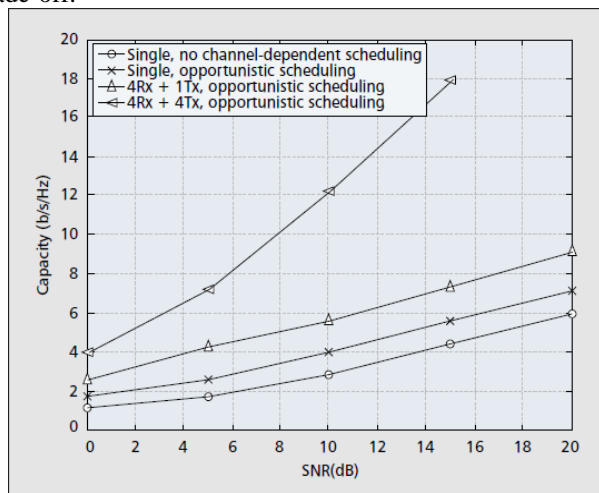


Figure 2: No channel dependent scheduling and opportunistic scheduling

5. SDMA/TDMA System

The results on allocating power to the best set of users instead of a single user lead to the design of a scheduling scheme able to exploit both the multi-user diversity and multiple access gain provided by SDMA. In any case the multi-user gains in MIMO systems depend on the multiple access technique (e.g., TDMA, code-division multiple access [CDMA], or orthogonal frequency division multiple access [OFDMA]). SDMA/TDMA systems have attracted considerable attention due to the relative simplicity of both receiver structures and feedback requirements.

In order to jointly design the transmit beam forming and time slots assignment scheme in SDMA/TDMA systems, Zhang presents a general information-theoretic framework. The scheduling is modelled as the distribution of a given set of users into disjoint groups; users belonging to the same group share the same slot. The MAC protocol is assumed to have knowledge of the relationship between the spatial signatures of users, and hence be able to make a selection among different combinations of co-slot users. The optimal scheduling maximizes the channel capacity in the sense of maximizing mutual information.

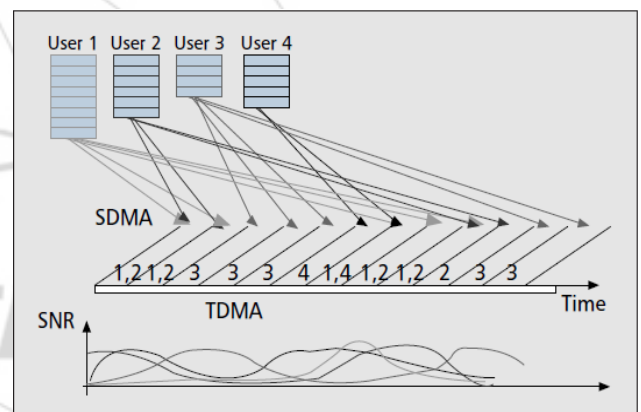


Figure 3: SDMA/TDMA system

6. Conclusion

In this article we have presented an overview of several proposed scheduling algorithms for multi-user multiple-antenna wireless networks. The opportunistic transmission scheme was first proposed for single-antenna systems to make use of multiuser diversity. The main idea is to track the channel fluctuations and schedule transmission for the user with the “best” channel. This transmission scheme was extended for multiple-antenna multi-user wireless systems. The opportunistic beam forming idea is to induce large and fast channel fluctuations and thus improve the multi-user diversity gain. We have highlighted the difficulties of exploiting both the spatial and multi-user diversity gains in a MIMO multi-user system. We have presented some solutions that allow exploiting both diversities at the same time, leading to increasing the multi-user diversity gain with the number of antennas. We have also discussed exploitation of multiuser diversity in a spatial multiplexing MIMO system with the goal of satisfying high-data-rate applications.

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