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On the Achievable Throughput of Per Chunk User Scheduling for MIMO-OFDM Downlink Using Opportunistic Feedback

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Abstract:
Future mobile communication systems will adopt the multiple antennas at both transmitter and receiver to improve system capacity and spectral efficiency. In our proposed system a Per-chunk user scheduling with opportunistic feedback for multiple-input–multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) is considered. In this system we provide a solution for achievable throughput by grouping adjacent subcarriers into chunks, the amount of required feedback information is reduced. Based on the net throughput criterion, which accounts for the reduction in sum rate due to the feedback overhead, it is shown that there exists an optimal chunk size that maximizes the net throughput. In which, for each chunk, only users with achievable rates higher than a predetermined threshold report back their rates. Analytical expressions for the net throughput are derived, which enable finding the optimum threshold that maximizes the average net throughput. The results show that increasing the total number of users in the system results in the net throughput of most existing MIMO-OFDM downlink schemes decreasing to zero for moderate-size user pools, whereas the net throughput of per-chunk user scheduling with opportunistic feedback increases with the total number of users even that number is very large.

1. Introduction

MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) and/or to achieve a diversity gain that improves the link reliability (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication Standards such as IEEE802.11n (Wi-Fi),4G, 3Gpp long Term Evolution, WiMAX and HSPA+. Increasing demand for broadband wireless services calls for much higher throughputs in future wireless communication systems. It has been shown that, with the use of multiple antennas at the transmitter (Tx) and the receiver (Rx), the capacity of a point-to-point communication link increases linearly with min$\{M,N\}$, where M is the number of Tx antennas, and N is the number of Rx antennas [1], [2]. More recently, there has been great interest in multiuser multiple-input–multiple-output orthogonal frequency division multiplexing. In this paper, we consider per-chunk user scheduling for a MIMO-OFDM downlink and optimize the chunk size using a very close approximation for the sum rate of the system. We also show the net throughput advantage of per-chunk user scheduling with optimized chunk size over a number of limited feedback multiuser MIMO-OFDM downlink schemes.

1.1. Our main Contributions are given as Follows

- A very close approximation for the average sum rate of MU MIMO-OFDM with spatial multiplexing and per-chunk user scheduling is found and used to determine the system average net throughput.
- It is shown that there exists a chunk size that maximizes the average net throughput, and also for a fixed chunk size, there exist a specific number of users that maximizes the average net throughput.
- To further reduce the amount of feedback and increase the average net throughput, opportunistic feedback is considered, in which, for each chunk, only users with achievable rates higher than a predetermined threshold report back their rates. Analytical expressions for the net throughput are derived, which enable finding the optimum threshold that maximizes the average net throughput.

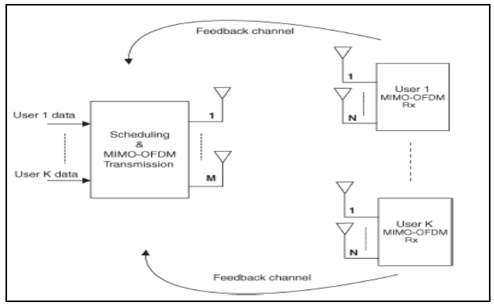


Fig.ure 1: Multiuser MIMO-OFDM system model

This paper is organized as follows: In Section II, the system model for multiuser MIMO downlink and the net throughput definition are introduced in Section III. Per chunk user scheduling with opportunistic feedback is outlined and simulation results are given in Section IV, and Section V concludes the paper.

1.2. Literature Survey

Literature survey is the most important step in As all MU-MIMO schemes that use partial CSIT can be applied to individual subcarriers of MIMO-OFDM, in the following, three low-complexity high-throughput schemes are selected from existing limited-feedback MIMO downlink techniques, and they are briefly described. Each of these schemes represents a class of limited-feedback MIMO downlink transmission methods, and in this section, these schemes are compared with MIMO-OFDM per-chunk user scheduling. These schemes are briefly described here.

- In [3], a limited-feedback MIMO downlink scheme based on eigenvector pre coding and ZF receiver processing is proposed, in which system parameters determine the number of data streams to be assigned to one user and delivered to it through eigen-mode transmission, whereas the remaining data streams are assigned to other users with ZF receiver (Rx) processors.
- In [4], a multiuser MIMO downlink scheme called transmit beam matching (TBM) is introduced, which extends to multiple antenna users the per-user unitary rate control (PU2RC) scheme, which is Samsung's proposal to 3GPP. This scheme has the relatively low complexity structure of PU2RC, and it uses the channel matrix pseudo inverse operation to minimize inter stream interference at each user terminal.
- In [5], a multiuser MIMO downlink scheme employing spatial multiplexing is proposed, in which users use linear processors and send back the SINR of each spatial channel to the BS, and the BS selects the user with the highest SINR for each data stream. Another scheme that we will consider later in this section is time division multiplexing (TDM), in which all spatial and frequency resources are assigned to one user at each time instant. In TDM and at the beginning of each scheduling time slot, each user evaluates the rate that it can achieve if all subcarriers are assigned to it and sends back this rate value to the BS. Next, the BS selects the user with the highest reported rate for that scheduling time slot and serves that user.

2. Per-Chunk User Scheduling

2.1. Channel and System Model

We consider multiuser MIMO-OFDM downlink in a single cell, in which the BS is equipped with M transmit antennas and there are K homogeneous users, each equipped with N receive antennas. We assume that, at the beginning of each frame, the user scheduler at the BS assigns a number of adjacent subcarriers (a chunk) to a single user (FDM). Then, point-to point MIMO spatial multiplexing with ordered successive interference cancellation (SIC) detection is used on each subcarrier of the assigned chunk. For a mobile user's receiver to be able to recover the data sent to it by employing point-to-point MIMO spatial multiplexing, it is required that N be equal to or greater than M. Here, $N = M$ is considered, which, from a practical point of view, is reasonable for small values of M. The system block diagram is shown in Fig. 1.

2.2. Net Throughput

In the case of frequency-division duplex (FDD) MU-MIMO downlink transmission, the users estimate their respective channels using pilots sent by the BS and feed back the CSI to the BS. The BS must hold its transmission until it receives the required CSI of all users and that causes a delay in data transmission on the downlink. The increase in the number of users in the system results in a larger delay, and this leads to a smaller fraction of the coherence time interval remaining for data transmission. The CSIT collected by the BS is only useful for transmission within one coherence time interval. In the case of time-division duplex (TDD) MU-MIMO downlink-uplink radio channel reciprocity can be exploited to obtain CSIT. In this case, the

CSIT of all users is obtained either through embedded pilot in the uplink transmission or by specially scheduled uplink transmissions known as channel sounding. The sounding signals are orthogonal across simultaneously scheduled users. Since data transmission cannot begin before CSI of all users becomes available, transmission time is effectively reduced to only the portion of the frame duration that is left after CSI has been estimated. Therefore, in both TDD and FDD systems and to obtain CSIT, a delay exists, and its length depends on the number of users in the system. This delay reduces the time available for downlink transmission and results in a lower average sum rate. Net throughput accounts for this loss in the average sum rate. The FDD mode of transmission will be assumed for the rest of this paper, but the analysis and its results will also be applicable to TDD. Consider an FDD MIMO-OFDM downlink with finite coherence time, which is denoted here as T. The feedback overhead reduces the average system throughput

$$R_{\text{net}} = R\left(1 - \frac{(N_f + N_I)T_f}{T}\right)$$

Where Nf is the average number of feedback values per subcarrier sent back by all users during one coherence time interval. Tf is the time required to send back one quantized feedback term value with b bits to the BS. NI is an additional overhead required per subcarrier for user identification and depends on the chunk size Lc, the number of users K, and the number of bits b being sent during each Tf seconds. To be able to identify each of the K users in the system, NI is found to be the smallest integer multiple of 1/Lc that satisfies NI ≥ log2 (K)/bLc. The term (Nf + NI) Tf/T is the portion of the coherence time needed to send the feedback information in an FDD system.

3. Chunk-Size Optimization of Per-Chunk User Scheduling

As it was mentioned in Section I, the chunks are 2-D tiles, each consisting of a number of adjacent subcarriers in the frequency domain and a number of consecutive OFDM symbols in the time domain. Assuming that the number of subcarriers in each chunk is Lc (for simplicity, we assume that all chunks have the same number of subcarriers, L is an integer multiple of Lc, and 1 < Lc < L), the highest instantaneous reliable rate on the qth chunk in bits per second per Hertz (in bits per second per hertz) for user k is given By

$$r_{\text{chk},q}^{(k)} = \frac{1}{L_c} \sum_{l_c=(q-1)L_c}^{qL_c-1} r_{l_c}^{(k)}, \quad 1 \le q \le Q$$

Where Q = L/Lc denotes the number of chunks in the system. $r_{l_c}^{(k)}$ Is defined as

$$r_{l_c}^{(k)} = \log_2 \det\left(\mathbf{I} + \rho \mathbf{H}_{l_c}^{(k)} \mathbf{H}_{l_c}^{(k)^H}\right), \quad 0 \le l_c \le L-1$$

4. Further Feedback Reduction in Opportunistic Feedback

Consider limited-feedback MIMO-OFDM downlink with per-chunk user scheduling, in which users report back the achievable rates for only those chunks on which they can achieve rates greater than a predetermined threshold r(k) chk,q > rth. The chunks not indicated by any user in its report are assigned randomly to users. Following equation is the average net throughput for this case is obtained. The net throughput maximizing chunk size L(max) c and rate threshold r(max) th are found using numerical search methods.

$$\bar{R} = \mathrm{E}\left[\frac{1}{Q} \sum_{q=1}^{Q} \max_{1 \le k \le K} r_{\text{chk},q}^{(k)}\right]$$

4.1. Net Throughput Comparison

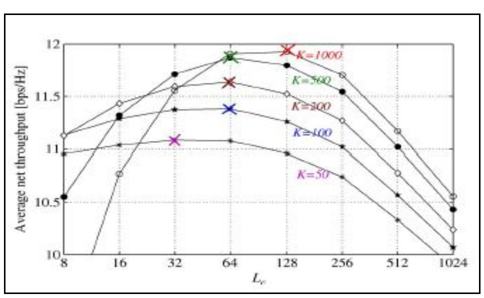
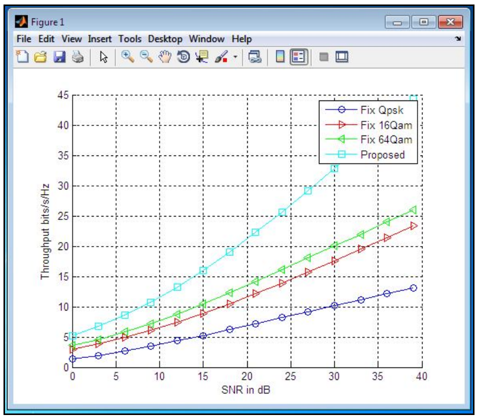


Figure 2: Net Throughput Comparison

In Fig. 2, the average net throughput of per-chunk user scheduling is plotted versus the chunk size Lc. The system considered has L = 2048 subcarriers with M = N = 3 as the number of antennas at the BS and each user terminal. It is also assumed that Tf/T =0.003. Furthermore, the frame size is assumed to be equal to the channel's coherence time and long enough to allow transmission rates close to each links capacity; since the average net throughput only depends on Tf/T and not T itself, the actual value of T is irrelevant to the results presented here. In this figure, the effect of varying the number of users in the system K and the chunk size Lc on the average net throughput is examined. As seen in the figure, for any K value, there exists a chunk size that maximizes the average net throughput. In addition, by increasing K from 50 to 1000, the optimum chunk size varies from L(max) c = 32 to 128.

In Fig.3 the average net throughput of various schemes (Fix QPSK, 14QAM, 64QAM)with opportunistic feedback is plotted versus the number of users for a system with L = 2048 subcarriers, for the same parameter values. The optimum chunk size L (max) c is used for each K value to obtain the net throughput of the per-chunk user scheduling with opportunistic feedback scheme.



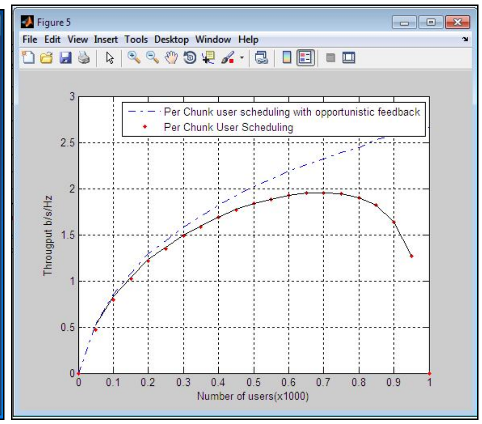


Figure 3: the average net throughput of various schemes with opportunistic feed back

Figure 4: Average net throughput of per-chunk-user scheduling with opportunistic feedback

In Fig. 4 shows that, as the number of user's increases, the net throughputs of per-chunk user scheduling increases steadily with the increase in the number of users before starting to decrease at very large values of K (> 1000). For per chunk user scheduling with opportunistic feedback, even for very large numbers of users, the net throughput increases with increasing the number of users. From the fig.4 it is concluded that over time-varying channels, the advantage of per-chunk user scheduling with opportunistic scheduling over other MIMO-OFDM downlink schemes increases as channel varies faster in time. Faster channel variations mean that CSIT needs to be updated more often and that increases the feedback overhead.

Furthermore, it is known that the sum rate of DPC, as well as spatial multiplexing with ZF Rx processing, has asymptotically optimum increase with the number of users, when the number of users approaches infinity , whereas this is not true for per-chunk user scheduling with opportunistic scheduling. Therefore, as we can see with a more realistic throughput definition, the throughput superiority of these schemes, particularly for large user pools, no longer exists.

5. Conclusion

We have considered the net throughput maximization of per chunk user scheduling with opportunist feedback for multiuser MIMO-OFDM downlink and have compared its average net throughput with that of a per-chunk user scheduling MIMO-OFDM downlink schemes. The results show that, while other schemes' net throughput drops down to zero as the number of users increases, the net throughput of per-chunk user scheduling with optimized chunk size experiences an increase with the number of users. This increase is present, even for very large user pools, e.g., K = 1000. We have also shown that the net throughput maximizing chunk size depends on the number of users awaiting service in the system. Numerical results show that, as the channel coherence time decreases for a fixed feedback rate, the per-chunk user scheduling net throughput superiority over other schemes increases. The net throughput of per-chunk user scheduling has been further increased by adopting an opportunistic feedback strategy.

6. References

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