Adaptive proportionality - Opportunistic Scheduling for High Speed Packet Access MIMO Systems

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***Abstract* — In MIMO system, it is known that Multi-user diversity can be used to increase the sum system throughput. The maximization of the throughput under quality of service (QoS) constraints is a still open field for research. In this paper, a scheduling algorithm that uses fairness among users as a QoS constraint is considered. This algorithm, called Adaptive Proportionality - Opportunistic Scheduling (APOS), can meet a trade-off between throughput and fairness. To achieve this goal the APOS scheme allocates each spatial channel by sorting users in a descending order of their channel signal to interference plus noise ratios (SINR), and selects the user owning the worst case performance among the L users owning the first sorted SINRs. Accordingly, each space channel is allocated to the user owning the L best SINRs and a min of average rate to proportionality coefficient rate r_k(t)/ α_k . To show the performance of the proposed scheme a selection of simulation results is used. These results show that APOS outperforms some well-known scheduling algorithms.**

***Keywords* — MIMO system, Multi-user diversity, Adaptive Proportionality - Opportunistic Scheduling (APOS),Qos.**

I. INTRODUCTION

THE research of low complexity scheduling algorithms in the downlink of a packet access multiple input and multiple output (MIMO) wireless systems has widely studied in the literature [1]. MIMO systems have a good potential to provide high speed packet access and the scheduler has to maximize the system throughput under some QoS constraints by exploiting the available diversity gain [2].

The allocation of transmit antennas to users is considered in spatial multiplexing (SM) [3]-[4]-[5] and time division multiplexing (TDM). The transmit antennas are allocated independently to users, hence, each user can be selected to receive packets from one or more antennas per time slot. In MIMO systems, resource allocation schemes and scheduling policies play important roles in providing service performance guarantees, such as throughput, delay, fairness, and throughput. Several published papers showed a compromise between throughput and fairness [9]-[10]. Among proposed algorithms, some of them can increase the sum average throughput in MIMO systems as Opportunistic Scheduling (OS) and others enhance the fairness constraint and pay high cost in throughput. The OS allocates each antenna to the user that experiences the largest SINR at each time slot [6]. Switched Opportunistic scheduling algorithm (SOSA) [2] and the Proportional Fairness Scheduler (PFS) [7] are proposed to provide a tradeoff between throughput and fairness among users. According to the SOSA algorithm, the selected user would combine a good channel condition and a low user performance.

The main goal of this paper is to provide an algorithm for transmit antenna assignment that maximizes the system throughput while satisfying the QoS requirements. Therefore, we provide an alternative solution that adds proportional fairness among users while increasing the system sum rate. The proportionality is defined by a set of coefficients, where each user has to receive data and r_k(t)/ α_k of the system sum rate. To achieve this goal the best L users are selected to compete for the available antennas. Each antenna is allocated to the user that experiences min average capacity to proportionality coefficient rate r_k(t)/ α_k. Accordingly this algorithm while system sum throughput is adaptively maximized fairness proportional fairness among users is satisfied.

The remainder of this paper is organized as follows: in section II the system model is introduced, section III presents the proposed scheduling algorithm. In section IV, the system throughput according to the proposed scheduling algorithm is analyzed by presenting a selection of numerical results and we conclude in section V.

II. SYSTEM MODEL

The considered scheme is a multi-user MIMO wireless packet transmission system as presented in Fig.1. The downlink between the transmit antennas of the base station and user terminal receive antennas is considered. The BS serves N active users in a time division multiplex. It is assumed that a power control is employed to equally share the total transmit power P_t on the transmit antennas. User data packets are loaded on transmit antennas using a spatial multiplexing (SM) technique. The receiver in the mobile station (MS) is assumed to use a ZF detector. Each MS has to estimate the post detection SINR on the M_r

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receive antenna and feeds them back to the BS through a dedicated uplink feedback channel assumed to be error free.

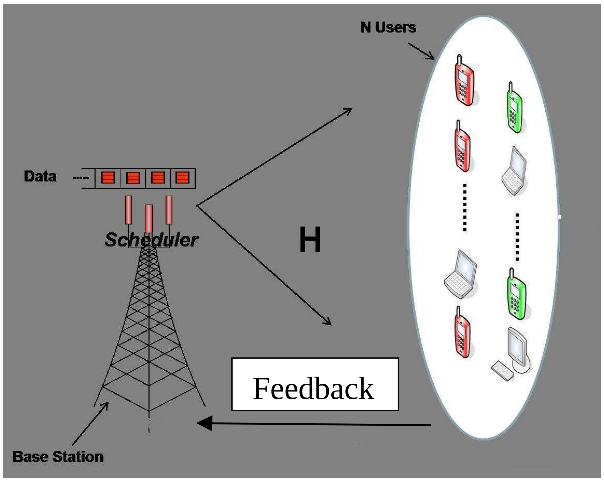

Fig. 1. System Model

Transmitted signals are assumed to experience path loss, log-normal shadow fading, and multi-path fading. The CSI is measured by matrix $H_n(t)$ which represents the short term fading on all the branches from the BS to the n^{th} user during a time slot. According to the assumptions, (i) each entry of the matrix H_n is an independent distributed complex Gaussian random variable CN (0; 1) representing short term fading; (ii) each spatial channel experiences flat fading during each time slot, and varies independently over slots. We denote by $H_n(t)$ the $M_r \times M_t$ matrix, s(t) $M_t \times 1$ the transmitted signal, $b_n(t)$ $M_r \times 1$ the additive white Gaussian noise (AWGN) vector with distribution CN $(0;N_0/2\ IM_r)$ for each element, and y(t) the $M_r \times 1$ received signal. Where, IM_r is the identity matrix with dimension M_r. Then, the received signal for the considered multi user MIMO system in the slot t is represented as follows,

$$y_n(t) = \sqrt{\frac{P_t}{M_t}} H_n(t) s(t) + b_n(t) \quad n = 1......N \qquad (1)$$

According to the assumptions specified below, we consider that each data stream is divided into sub-streams which would be transmitted through the M_t transmit antenna at different time slots. On each transmit antenna we assume that adaptive modulation and coding (AMC) is applied. The statistical characteristics of the post ZF detection (SINR) are used for theoretical analysis.

III. Theoretical Analysis

A. The post detection SINR

The received signal for the considered multi user MIMO system is given by (1). The zero forcing detector output conditioned by the knowledge of the channel state matrix H and the detection matrix W_{ZF} is,

$$\hat{s} = W_{ZF}\ y \qquad (2)$$

The error vector between the transmitted signal *s* and the received signal $\hat{s}$, is then

$$e = \hat{s} - s \qquad (3)$$

According to the ZF detection procedure, the detected symbol is obtained according to,

$$E\left[es^H\right] = 0 \qquad (4)$$

$(.)^H$ is the transpose conjugate of (.). According to equations (4), we have obtained:

$$W_{ZF} = \sqrt{\frac{M_t}{P_t}} H^{\dagger} = \sqrt{\frac{M_t}{P_t}} \left(H^H H\right)^{-1} H^H \qquad (5)$$

Where $H^{\dagger}$ denotes the Moore-Penrose inverse of the channel matrix H.

From (2) , we deduce:

$$\sigma^2 = E\{\hat{s}\hat{s}^H\} = E\left\{\left(\sqrt{\frac{P_t}{M_t}} W_{ZF} Hs + W_{ZF} b\right)_{n,n} \left(\sqrt{\frac{P_t}{M_t}} W_{ZF} Hs + W_{ZF} b\right)^H_{n,n}\right\} \qquad (6)$$

(.)n,n denotes the (n, n)th element of matrix (.), then the SINR associated with the nth symbol is:

$$\gamma_k = \frac{1}{\frac{M_t \sigma_b^2}{P_t}\left[\left(H^H H\right)^{-1}\right]_{n,n}} = \frac{1}{\frac{M_t}{\gamma_0}\left[\left(H^H H\right)^{-1}\right]_{n,n}} \qquad (7)$$

Where γ_0 is the average SINR at each of the receive antennas and σ_b^2 is the variance of the Gaussian noise.

B. SINR Probability distribution function

According to the assumptions, H is a matrix iid complex white Gaussian random variable. As demonstrated in [11], the post detection SINR using a ZF detector on each of the Mt streams, is distributed as a Chi-squared random variable with $2(M_r\text{-}M_t\text{+}1)$ degrees of freedom. The probability distributed function (pdf) of γ_n is then,

$$f_\gamma(x) = \frac{M_t}{\bar{\gamma}(M_r - M_t)!} e^{-\frac{M_t}{\bar{\gamma}}x} \left(\frac{M_t}{\bar{\gamma}}x\right)^{M_r - M_t} \qquad (8)$$

The corresponding cumulative distribution function (cdf) of γ_k is,

$$F_\gamma(x) = \int_0^x f_\gamma(t)dt \qquad (9)$$

$$F_\gamma(x) = 1 - e^{-\frac{M_t}{\bar{\gamma}}x} \sum_{k=0}^{M - M_t} \frac{1}{k!}\left(\frac{M_t}{\bar{\gamma}}x\right)^k \qquad (1◊)$$

C. The proposed scheduler

The group S defines users who have been chosen by the scheduler to receive data on the considered antenna and the group U describes the set of users. For each spatial channel and at each time slot, the (APOS) scheme would sorts users in descending order by their SINR. G is the group of users having the L best SINR on the considered antenna (spatial channel). The considered antenna is allocated to a user of G that experiences min average capacity to proportionality coefficient rate r_k(t)/ α_k , where α_k is the proportionality coefficient can be defined by the ratio of throughput required for a relative user to the sum system throughput. This procedure is repeated until allocating the available spatial channels. The proposed scheduling algorithm will be as follows,

Initialization

-S={scheduled users} ={Id_{u1*}, Id_{u2*},….. Idu_{Mt*}}
-Define the set of users U={U_1, U_2,……U_k}
-Define the SINR in each antenna
- Define the proportionality coefficients that verifies:

$$\sum_{i=1}^{k} \alpha_k = 1$$

$$\gamma_{ch} = \gamma_{ch1}, \gamma_{ch2}, \ldots\ldots\ \gamma_{chk} = \{0,0,\ldots\ldots\ldots\ldots\ldots\ldots\ldots 0\}$$

-Define the instantaneous throughput an antenna ch

$$c_{ch} = \{ c_{ch1}, c_{ch2}, \ldots\ldots\ldots\ldots c_{chk} \} = \log(1+\gamma_{ch})$$

-Define G the set of the best L users

Begin

-Ch=1

Step 1: Read the k users SINR on the channel ch $\gamma_{ch} = \{ \gamma_{ch1}, \gamma_{ch2}, \ldots\ldots\ldots\ldots \gamma_{chk} \}$

Step 2:Sort SINR in descending order

$$\gamma_{ch}^{S} = \{ \gamma_{ch}^{S1}, \gamma_{ch}^{S2}, \ldots\ldots\ldots\ldots \gamma_{ch}^{Sk} \}$$

G= {k Є I_{ch} / k≤L} with I_{ch}= S_1,S_2……S_k index of sorted users

Step 3: Select for antenna ch the user with index k*

$$k^* = \arg\min_{I_{ch(k)} \in G} \frac{\gamma_k}{\alpha_k}$$

S(ch)= S ∪ {k*},
ch=ch+1
while ch ≤ M_t go to step 1.

End

IV. Numerical Results

In this subsection, the performance of different scheduling algorithms is evaluated in terms of system throughput when the ZF detectors are used. Simulations have been carried out to compare simulation results of our scheduling schemes to a selection of known scheduling algorithms. Each policy dynamically decides which user should be scheduled to receive packets in a time-slot based on users' current transmissible throughputs and proportionality coefficients depending on the QoS constraints. The OS, PFS scheduling schemes serve as a benchmark of performance comparison. The considered system for simulation is a single cell with N active users. The time window used for simulation is T_c = 100 time slots.

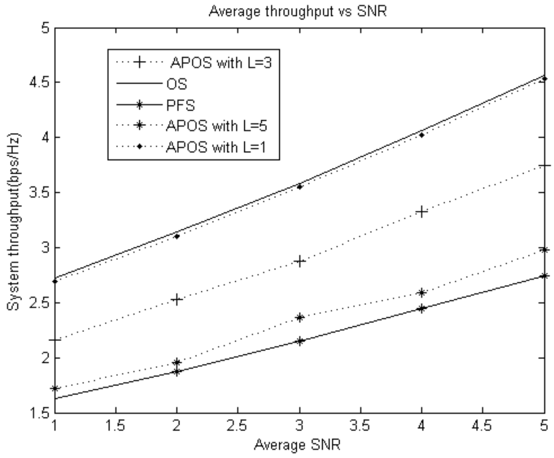

Fig. 2. Comparison between APOS, OS, PFS when M_t=2, M_r=2, T_c =100 slots, N=8.

Figure 2 illustrates the impact of the operating average SINR on the relative capacity gain and plots the spectral efficiency (throughputs in bps/Hz) of the proposed scheduler, where the value of L have to change. If L = 1 the algorithm APOS is the opportunistic scheduler known also as max SINR. As L increases the fairness among users increases as shown in figure 3 for the cost of a decrease in the system throughput. Thus, whenever L increases, we are approaching to PFS algorithm. We can conclude that APOS can adaptively offers a compromise between fairness among users and system throughput.

To measure the fairness degree as a QoS requirement, the Jain's fair index [8] is used as a metric for the fairness comparison of users' average throughputs (R_n). This index is given as follows,

$$JF(N) = \frac{\left(\sum_{n=1}^{N} \frac{R_n}{\alpha_n} \right)^2}{N \sum_{n=1}^{N} \left(\frac{R_n}{\alpha_n} \right)^2} \qquad (11)$$

Table1 shows the fairness degree of the throughput in the proposed schemes for different values of L. We can also see that the fairness index of APOS varies for that of the OS when L=1 to near for the PFS index when L=8. We conclude that APOS can provide near optimal fair degree as soon as the value of L increases to be the number of users.

TABLE 1:Jain's Index

APOS schemes	L=1	L=3	L=5	L=8
Jain's Index	0.8207	0.9980	0.9990	0.9995

Figure 3 shows that for L = 2, the user's throughput for the set of coefficients of proportionality {1, 1, 2, 2, 3, 3, 4, 4}/20. We can note that users of index 1 and 2 have half of the throughput of users 3 and 4 as given by this set of coefficients.

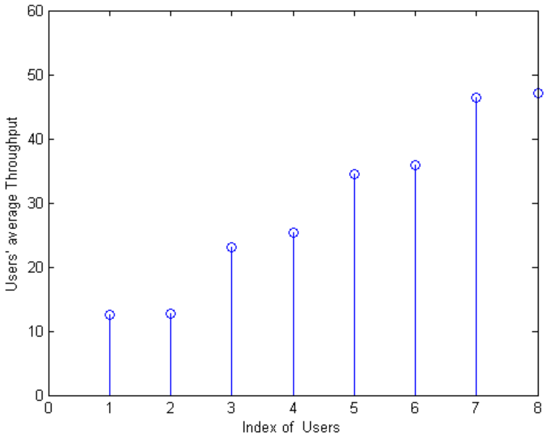

Fig. 3. Users average Throughput when M_t=2, M_r=2, T_c =100 slots, N=8.

V. CONCLUSION

In this paper, we proposed an algorithm for scheduling users in wireless MIMO systems. The scheduler in the base station defines a proportionality coefficient for each user that depends on the user transmissible rates and the user QoS criteria. According to the presented simulation results, we can conclude that the proposed algorithm can satisfy adaptively both constraints throughput and proportional fairness among users.

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