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Multi-Threshold based Scheduling for Multi-User Multiple-Input Multiple-Output Systems

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Abstract: Problem statement: Multi-User Multi-Input Multi-Output (MU-MIMO) system had eventually used in 4th generation wireless networks either to achieved diversity gain or multiplexing gain. Many recent scheduling addresses the threshold based resource allocation where in resource were not utilized properly. **Approach:** In this study a new Multi Threshold Based Channel Aware Scheduling (MTCAS) was proposed for performance improvement and proper resource utilization. This approach was projected for multiuser Multiple-Input Multiple-Output (MU-MIMO) system under Space-Time Block Coding (STBC) transmission. The goal of this scheduler was to offer improved performance in terms of a low Bit Error Rate (BER), high Packet Delivery Ratio (PDR), high average capacity and service fairness among the users. This scheme allows the set of users to send data based on their channel quality. **Results:** Simulation compares this scheduler performance with other scheduling schemes such as Fair Scheduling (FS), Normalized Priority Scheduling (NPS) and Threshold based Fair Scheduling (TFS). **Conclusion:** The obtained results prove that MTCAS has significant improvement in average bit error rate performance as compared to the other scheduling schemes.

Key words: Multiple-Input Multiple-Output (MIMO), Packet Delivery Ratio (PDR), Bit Error Rate (BER), Multi-Threshold based Channel Aware Scheduling (MTCAS)

INTRODUCTION

Without additional bandwidth multiuser Multiple-Input Multiple-Output (MU-MIMO) technology can send message to multiple user in cellular base stations and in Wireless Local Area Network (WLAN) access points. In rich multipath environments downlink data rate are linearly maximized with the number of the transmitter antenna (Vishwanath *et al*., 2003 and Jindal and Goldsmith, 2005). Proper scheduling in such system extracts multiuser diversity (Chen *et al*., 2008). Mostly, multi user scheduling schemes (Torabi *et al*., 2008) used to schedule the users with the best channel quality. The scheduler of Generalized Selection Combining (GSC) proposed in (Ma and Zhang, 2006) selects the Ns users with the largest SNRs from the N active users (where $Ns \leq N$) in each time-slot. A scheduler proposed in (Jiang *et al*., 2004 and Kang *et al*., 2010) interacts with the physical layer for sum rate improvement. Proportional Fair Scheduling (PFS) algorithm shown in (Berger *et al*., 2003) provides fairness among users instead of simply selecting best users. Open loops transmit diversity of a simple proportional fair scheduler exhibit poor performance as compared to closed loop transmit diversity scheme under a wide range of mobility conditions studied in (Berger *et al*., 2003). Multi-user diversity gain extracted by opportunistic scheduling proposed for single-antenna multi-user systems (Ma and Zhang, 2006) and then extended for multiple-antenna systems (Torabi and Haccoun, 2011). In the existing MAC layer scheduling, despite MIMO advantages, we see the performance gap among the proportional fair scheduling presented in (Berger *et al*., 2003) and threshold based fair scheduling shown in (Chanthirasekaran and Bhagyaveni, 2011a).

MATERIALS AND METHODS

This study proposes a new multi-threshold based channel aware scheduling to fill the gap between the existing thresholds based scheduling. This scheduler allocates resource based on user's channel quality (i.e., Signal to Noise Ratio (SNR)). First the scheduler schedules the users fairly who come under SNR_H region then it schedules the user fairly who come under SNR_M region Then its grant resources for a first L number of scheduled users. Here L is taken as a number of resources available at the base station.

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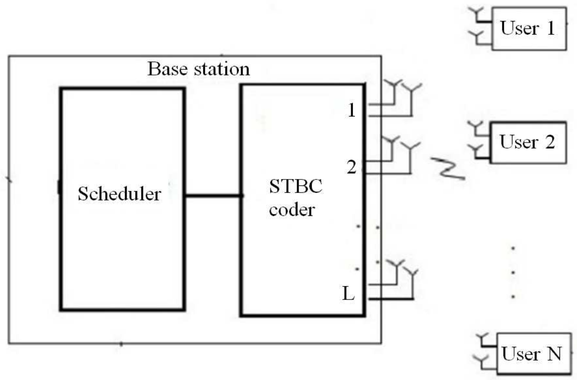

Fig. 1: Downlink MU-MIMO system

Then, we compare the proposed scheduler performance with other scheduler like Fair Scheduler (FS), Normalized Priority Scheduler (NPS) and Threshold based Fair Scheduler (TFS).

This study presents a system overview, describes various scheduling algorithms, discusses the simulation results of the new resource allocation scheme and offers concluding remarks.

System overview: In this study, the model of downlink multiuser MIMO system, where a single Base Station (BS) with 'L' pair of transmit antennas communicate with 'N' number of mobile users each with M_R receive antennas are shown in Fig. 1.

Here the BS sends request of all 'N' users in getting their channel state information. Then it schedules the user based on the multi threshold region value. The multi threshold value is aimed to meet resource utilization and performance improvement. The BS scheduler using proposed scheduling algorithm grants resource to the multiuser via Clear to Send (CTS) packet. Then these granted user send their message by using Alamouti-STBC coded 2×2 MIMO system.

Review of scheduling algorithms for mu-MIMO system: We assume that the base station knows the channel state information of all active users. It can select a group of users from all the active users to achieve the best performance with the help of various scheduling algorithms. Here the equal number of transmitting antennas (two for MIMO) is allotted per user in the time slot among active users by considering the number of resources available. The following scheduling algorithms are used in the scheduler at the base station for performance comparison.

Fair scheduling: Let 'N' be the total number of users who send their CSI to BS in a time slot t_k. Let 'L' be the total number of resources available at the base station.

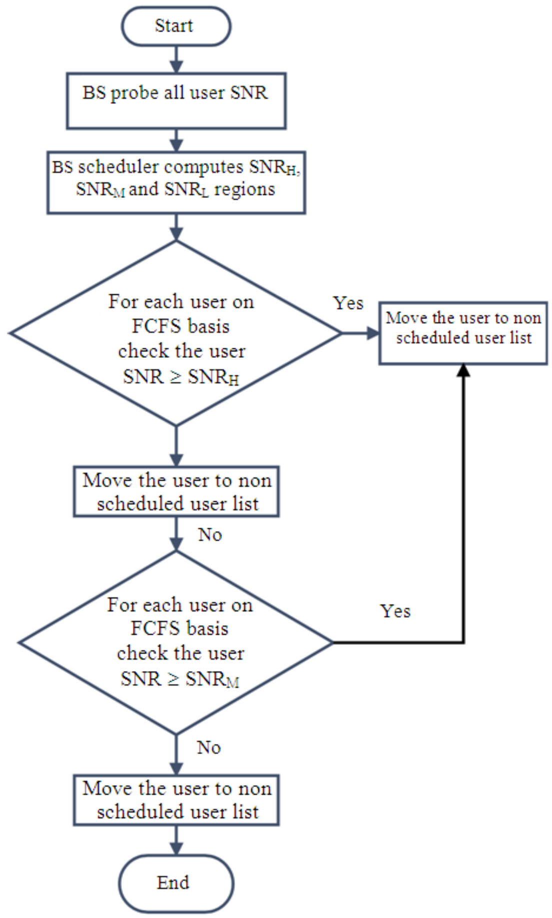

Fig. 2: Flow Diagram of MTCAS

This scheduler grants resource based on First Come First Serve (FCFS) basis. Let $\{x_1, x_2, x_3, \ldots x_N\}$ be the active users in the BS at time slot t_k. As a fair scheduler grant resource for the number of users based on first come first serve basis, the first L number of users are scheduled by this scheduler. This scheduler maintains the service fairness but the average BER performance of the system under this scheduling is poor. In order to improve the link level performance normalized priority scheduling is proposed in (Yang and Alouini, 2006).

Normalized priority scheduling: Normalized priority scheduler receives SNR information from all users at each time slot and it computes normalized SNR of each user which is based on user's previous SNR values. Then it assigns resources to an L number of best normalized user. The granted users transmit their data by Alamouti-STBC coded 2×2 MIMO system. This normalized priority scheduling achieves BER performance but at the cost of fairness. To achieve better fairness among users threshold based fair scheduling was described in (Chanthirasekaran and Bhagyaveni, 2011b).

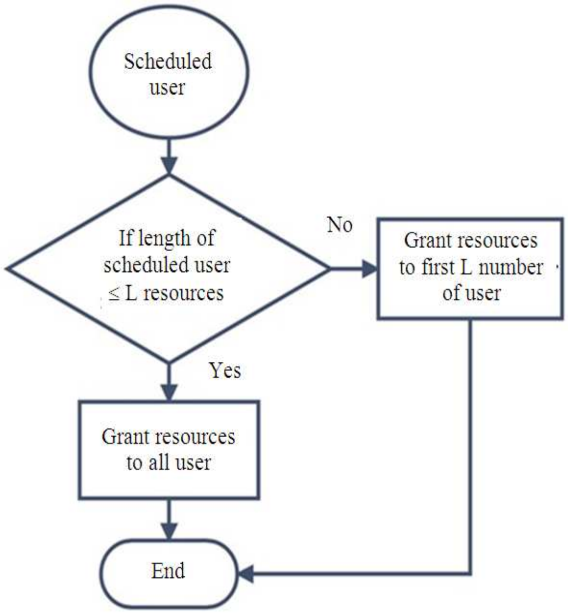

Fig. 3: MTCAS Resource allocation

Threshold based fair scheduling: Threshold based fair scheduler (Chanthirasekaran and Bhagyaveni, 2011b) computes offer-able SNR threshold 'Th' by using the average of minimum SNR and maximum SNR of active user as given in Eq. 1:

$$Th = AVG\ \{\min(SNR), \max(SNR)\} \quad (1)$$

Then 'L' resources are granted to the users in the time slot t_k based on first come first serve if their SNR ≥ 'Th'. Let $x = \{x_{1_1}, x_2, x_3, ...x_N\}$ be the users request received at time slot t_k and Let $x' = \{x_1^{'}, x_2^{'}, x_3^{'}........x_p^{'}\}$ be the users whose SNR's are greater than or equal to 'Th' $x' \subset x$ where and p≤ N. The granted users G_{t_k} in the time slot t_k are given as Eq. 2:

$$G_{t_k} = \{x_1^{'}, x_2^{'}, x_3^{'}........x_q^{'}\}\ q \le L \quad (2)$$

Thus the TFS achieves fairness and better BER performance than NPS but at the cost of resource utilization. Hence in this study a new Multi-Threshold based Channel Aware Scheduling (MTCAS) algorithm is proposed for improving the system resource utilization.

Multi-Threshold based Channel Aware Scheduling (MTCAS): Multi-Threshold based channel aware scheduler probe all active user SNR and computes multi threshold region value SNRH SNRM and SNRL which is based on best user channel strength as given in Eq. 3:

$$\begin{aligned} &SNR_L < \max(SNR)/3, \\ &\max(SNR)/3 \le SNR_M < 2 \times \max(SNR)/3, \\ &2 \times \max(SNR)/3 \le SNR_H \end{aligned} \quad (3)$$

Then it allocates resources to each user if user SNR is ≥ SNR_H till resource available. If any resource is remained then the scheduler allocates resources to the next threshold region user that is whose SNR is ≥ SNR_M.

This scheduler considers the second threshold regions to improve the resource utilization. Among this two threshold region this scheduler first schedule SNR_H region users to improve the performance and then its schedule the SNR_M region users to improve the resource utilization. The Scheduling flow diagram of MTCAS is shown in Fig. 2 and MTCAS resource allocation flow diagram is shown in Fig. 3.

Let $x = \{x_{1_1}, x_2, x_3, ...x_N\}$ be the active users at time slot t_k, $x' = \{x_1^{'}, x_2^{'}, x_3^{'}........x_p^{'}\}$ be the users whose SNR ≥ SNR_H and $x'' = \{x_1^{''}, x_2^{''}, x_3^{''}....x_s^{''}....x_q^{''}\}$ be the user those who come under SNR_M region. The granted user is given in Eq. 4:

$$G_{t_k} = \begin{cases} x_1^{'}, x_2^{'}, x_3^{'}........x_L^{'} \quad \text{if} \quad p \ge L \\ x_1^{'}, x_2^{'}, x_3^{'}........x_p^{'}, x_1^{''}, x_2^{''}, x_3^{''}........x_q^{''} \\ \quad \text{if } p < L \text{ and } (p+q) \le L \\ x_1^{'}, x_2^{'}, x_3^{'}........x_p^{'}, x_1^{''}, x_2^{''}.....x_s^{''} \\ \quad \text{if } p < L, (p+q) \ge L \ \&\ (p+s) = L \end{cases} \quad (4)$$

This scheduler considers the user who comes under two threshold regions for performance improvement and proper resource. If the resources are unutilized after resource allocation those remain unutilized during the particular time slot. But those chances are very less since MTCAS consider two threshold region.

RESULTS AND DISCUSSION

The system is modeled using one base station, 'N' number of active user and 'L number of resources (pair of antenna) available at the base station. The BS receives user's SNR. The performance of scheduling is simulated under each user has 2 antennas and demand 2 antenna resources from the base station. In 2×2 MU-MIMO systems the user data's are transmitted via Rayleigh channel after Alamouti-Space Time Block Coding (STBC). Simulation parameters are shown in Table 1. For this simulation the user's SNR value is preferred as random between 1 and 25.

The BER performance of 2×2 MU-MIMO system with MTCAS scheduler with a number of resource L = 4 is shown in Fig. 4. Figure 4 shows that the MTCAS performed well as compared to TFS when the number of users are greater than twice over the resource available.

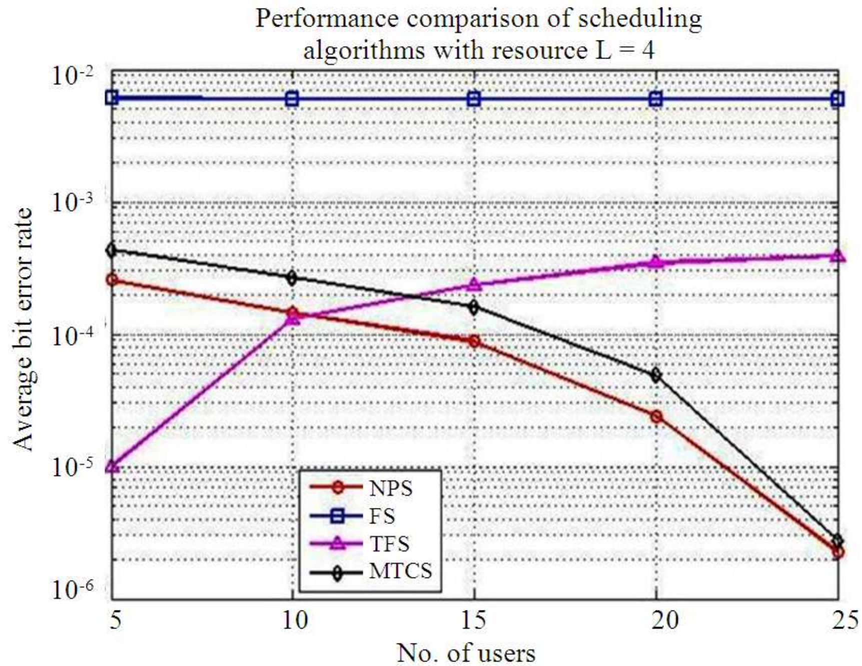

Fig. 4: BER performance comparison of 2×2 MTCAS with other scheduling with resource L = 4

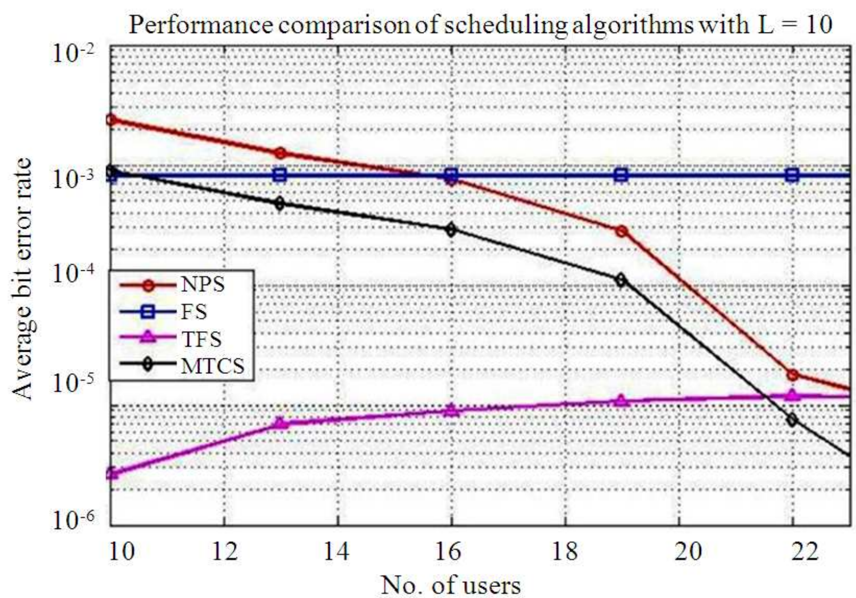

Fig. 5: BER performance comparison of 2×2 MTCAS with other scheduling with resource L = 10

This is because when the number of user increases there will be a change of scheduling better channel quality user. When the number of users is less than twice over the resource, MTCAS deem two threshold region user, hence it schedules further user even if the channel quality comes under second threshold region. Therefore resource utilization will be more as compare to TFS. Also it is observed that MTCAS almost gives similar performance as compared to normalized priority scheduling but MTCAS fairness is enhanced as compared to NPS due to MTCAS delight the users fairly who come under threshold regions.

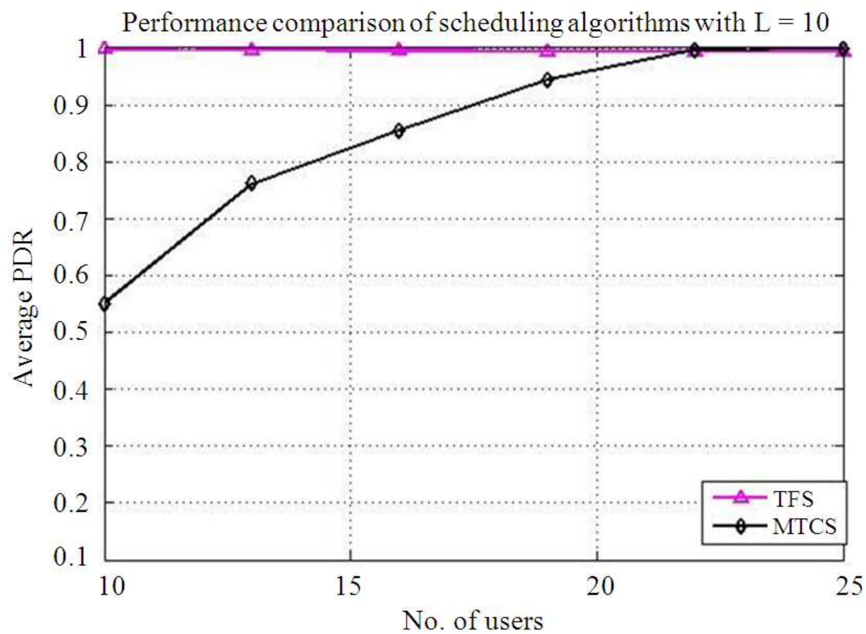

Fig. 6: PDR performance comparison of 2×2 MTCAS with TFS with resource L = 10

Table 1: Simulation parameters for MIMO-STBC system

System	MIMO-STBC
Number of transmit antenna	2 for each user
Number of receive antenna	2 (each user)
Channel	Rayleigh flat fading
Noise	AWGN
Modulation	BPSK
Total number of active user N	25
Number of resource L varied	4,6,10

The BER performance of MTCAS with other scheduling with L = 10 is shown in Fig. 5. MTCAS performance is superior to NPS but inferior as compared to TFS. When the available resource is more, TFS may schedule less number of users as compared to MTCAS. Hence TFS resource utilization is less as compared to MTCAS. Therefore MTCAS achieve better resource utilization at the cost of small degradation in BER performance when the number of users exceeds twice the number of users.

The Packet Delivery Ratio (PDR) of MTCAS is shown in Fig. 6. Simulation results are compared with TFS. The PDR performance of MTCAS scheme is found improved as compared to the TFS scheme when the number of users exceed twice over the number of resources available. Also it is observed that when the number of users are less than twice over the number of resources the PDR performance of TFS is good as compared to MTCAS but at the cost of less resource utilization.

CONCLUSION

This study proposes a MTCAS scheme for performance improvement and resource utilization in MU-MIMO system. The MTCAS perform based on user’s channel quality. BER performances of this scheme with BPSK modulations in the flat Rayleigh fading channel is compared with other scheduling schemes such as FS, NPS and TFS. From the simulation results it is found that MTCAS outperform other scheduling schemes in BER and PDR performance when the number of users greater than twice over the number of available resources. Also it is observed that the resource utilization of this scheduler found improved as compared to TFS. This scheme provides a network BER of about 3*10-5 and PDR of 96%.

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