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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 10 (7): 1452-1456, 2011
ISSN 1812-5638 / DOI: 10.3923/itj.2011.1452.1456

An Efficient Scheduling Scheme for Resource Utilization and Performance Enhancement of Multi User MIMO Wireless Systems

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Abstract: Efficient resource utilization and management is a key demand for improved capacity and quality of service in wireless communication networks. Resource utilization and bit rate requirements push the new challenging wireless communication standards for algorithm and signal theory implementation to their limits. One of the main strategies which are being used to achieve the required rates is the Multiple Input-Multiple Output (MIMO) technique which employs multiple antennas both at transmission and reception. In this study, a new technique for resource allocation through Efficient Scheduling (ES) for multi user multiple-input multiple-output (MU-MIMO) systems under Space-Time Block Coding (STBC) transmissions is described. The ES scheme is developed with the goal to provide improved performance in terms of a low Bit Error Rate (BER), high Packet Delivery Ratio (PDR), partial resource utilization and service fairness among the users. This scheme allocates resources adaptively to the multi users based on their received Signal to Noise Ratio (SNR) and available resources. The ES performance is analyzed and compared with other scheduling schemes such as Fair Scheduling (FS); Priority Scheduling (PS) and threshold based scheduling (TFS) using simulation. The obtained results prove that ES has significant improvement in PDR performance as compared to the other scheduling schemes.

Key words: Multiple-input multiple-output (MIMO), packet delivery ratio (PDR), bit error rate (BER), efficient scheduling (ES)

INTRODUCTION

Each antenna element on a MIMO system operates on the same frequency and therefore does not require extra bandwidth. Also, for fair comparison, the total power through all antenna elements is less than or equal to that of a single antenna system. Hence MIMO system consumes no extra power due to its multiple antenna elements (Tsoulos, 2006). As a consequence of their advantages, MIMO wireless systems have captured the attention of international standard organizations. The use of MIMO has been proposed multiple times for use in the high-speed packet data mode of third generation cellular systems (Molisch, 2005; Gesbert *et al*., 2003). Also, to increase the multiplexing gain, the system capacity has to be increased. This can be achieved by using multiple antennas for data signals transmission. Signal processing at the transmitter and at the receiver may result in the effect of coherent combining hence the Signal to Noise Ratio (SNR) of the system is increased (Foschini and Gans, 1998; Tse and Viswanath, 2005; Chanthirasekaran and Bhagyaveni, 2009). Spatial diversity using Space-time Block Coding (STBC) has been actively investigated by Zhang and Gulliver (2005), Dohler and Aghvami (2004) and Perez *et al.* (2005). Zhang and Gulliver (2005) derived a closed-form Symbol Error Rate (SER) of the STBC for various modulations and fading channels; the outage probability of the STBC over Nakagami fading channels was derived by Dohler and Aghvami (2004). Perez *et al.* (2005) presented a closed-form approximation of the STBC for capacity in various fading channels. For a reliable multimedia communication service, Spatial Multiplexing based MIMO technique plays a vital role. The spatial diversity is exploited if the same signal is transmitted on all antennas and can be used to increase the reliability of reception while the spatial multiplexing gain is achieved by transmitting different signals on each antenna to increase the throughput for a fixed reliability level (Tse *et al*., 2004). It has been shown that it is a trade-off between the spatial diversity gain and the spatial multiplexing gain of a MIMO-system (Tse *et al*., 2004). To jointly exploit the gain from Multi User Diversity (MUD) and multiple antennas in MIMO systems, several users have to be scheduled in each time-slot (Jagannathan *et al*., 2006). The spatial diversity in a MIMO system can be exploited by using e.g., Space-Time

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Block Coding (STBC) to obtain better error production (Alamouti, 1998). In MUD environment, combination of scheduler and antenna diversity schemes is analyzed (Jiang *et al.*, 2004; Chen and Wang, 2006). Chanthirasekaran and Bhagyaveni (2011) presented a scheduler with STBC for BER improvement. Combining the scheduler with STBC for the improvement of the multi user packet delivery, challenges of fairness and resource utilization was not addressed in those studies.

In this study, an efficient scheduling is proposed. This scheduler allocates resource adaptively based on Signal to Noise Ratio (SNR) of the multiple users for performance improvement and verify the resource utilization. The scheduler grants resource for the set of best users under poor performance region the threshold based fair scheduling (TFS) and grant resources for the multiple users whose SNR is above threshold under good performance region of TFS. The performance of the proposed scheduler is compared with other scheduler policies like Fairness Scheduling (FS), Priority Scheduling (PS) and threshold based fair scheduling (TFS). From the results it is observed that ES scheme produces better PDR.

SYSTEM OVERVIEW

Here, the model of downlink multi user MIMO system where a single Base Station (BS) with ‘r’ pair of transmit antennas communicates with ‘n’ number of mobile users each with M_R receive antennas are shown in Fig. 1.

Figure 2 shows functional blocks of the base station. Here, the n users place their request to the BS using request to send (RTS) packets. The scheduler using proposed scheduling algorithm grants resources to the multi users using Clear to Send (CTS) packets. Then these granted users transmit their message using STBC coder under MIMO system. In a SISO system they employ single antenna for transmission.

The proposed scheduling algorithm allocates resources effectively for multiuser. The various multiuser scheduling algorithms are compared with proposed scheduling algorithms.

SCHEDULING ALGORITHMS

We assume that the base station knows the channel state information. It can select a group of users from all the requested users to achieve the better performance with the help of various scheduling. Here the equal number of transmit antennas (one for SISO and two for MIMO) are allotted per user in the time instant t_k for n_{tk} number of requested users by considering the number of r_{tk} resources available. The following scheduling algorithms are used in the scheduler at the base station for performance comparison.

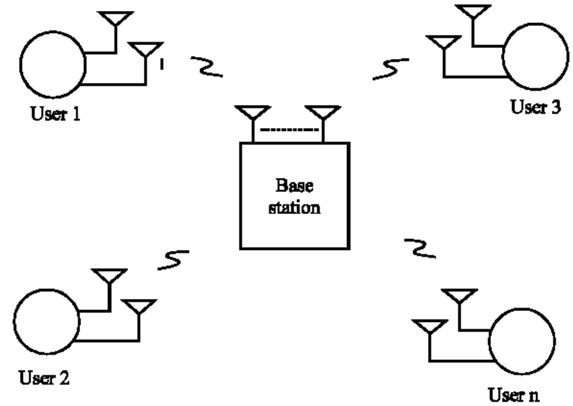

Fig. 1: Model of downlink multi user MIMO system

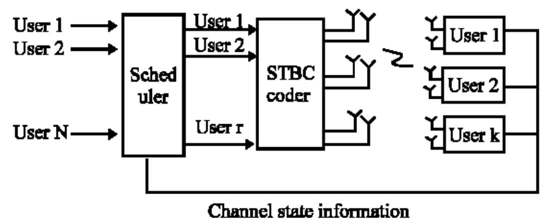

Fig. 2: Block diagram illustrating the internal blocks of base station of MU-MIMO system

Fair scheduling: Let n_{tk} be the total number of users who placed request in a time slot t_{tk}. This scheduler grants resources r_{tk} based on First Come First Serve (FCFS) basis. If the request received at BS in a time slot t_k is $\{x_{t1}, x_{t2}, x_{t3},..., x_{tk}\}$ where x_{t1} is the user whose request is received at time t_1, x_{t2} is the user whose request is received at time t_2 analogously x_{t3},... x_{tk} where $t_1<t_2<t_3<.....<t_k$ with $\Sigma\, x_{tk} = n_{tk}$. The granted users at time slot t_k as given in Eq. 1 receive CTS from the base station:

$$G_{tk} = \{x_{t1}, x_{t2}, x_{t3},..., x_{tP}\} \text{ till } \Sigma\, x_{tP} = r_{tk} \quad (1)$$

where, $t_1<t_2<t_3<.....<t_P<....<t_k$.

Algorithm for fair scheduling is as follows

- In time slot t_k let n_{tk} be the total number of request received
- Store the request with time stamp
- Start allocating r_{tk} resources based on min (time stamp) till $r_{tk} = 0$ or $n_{tk} = 0$

- The resource is allocated by acknowledging the request using CTS
- Those users who received CTS will start using their allocated pair of r_{tk} antennas
- The granted users transmit their data by Alamouti-STBC coded 2X2 MIMO system

As fair scheduler grant resource for the number of user based on first come first serve basis, it maintains the service fairness but the BER performance of the system is about 10^{-2} as shown in Fig. 3. In order to improve the BER performance PS is modeled.

Priority scheduling: The base station using its Channel State Information (CSI) computes SNR of each requested user. Priority scheduler sort the n_{tk} users based on their computed SNR strength. The scheduler grants resource to first r_{tk} sorted users. The granted users G_{tk} at time slot t_k is given as:

$$G_{t_k} = \{x_{SNR_{t1}}, x_{SNR_{t2}}, x_{SNR_{t3}}, ...x_{SNR_{tp}}\} \text{ till } \Sigma x_{SNR_{tp}} = r_{t_k} \quad (2)$$

Where:

$$x_{SNR_{t1}} > x_{SNR_{t2}} > ...... > x_{SNR_{tp}} \text{ and } t_p \leq t_k$$

Algorithm for priority scheduling is as follows:

- Receive n_{tk} user's request at time slot t_t
- Compute SNR
- Sort n_{tk} user's based on their SNR strength
- Grant resources for first r_{tk} number of sorted users
- The granted users transmit their data by Alamouti-STBC coded 2×2 MIMO system

As priority scheduler grants resources for 'r' number of best user, the performance of the system is good if r<<n. The performance decays when the number of resources is closely equal to number of users.

Threshold based Fai scheduling: Threshold based fair scheduler computes offer-able SNR threshold 'Th' by using average of minimum SNR and maximum SNR of requested user as given in Eq. 3:

$$Th = AVG \{\min (SNR), \max (SNR)\} \quad (3)$$

Then r_{tk} resources are granted to the users in the time slot t_k based on first come first serve and if their $SNR_i \geq$ 'Th' for I = 1, 2….n_{tk}. Let $x = \{x_{t1}, x_{t2}, x_{t3},..., x_{tk}\}$ be the

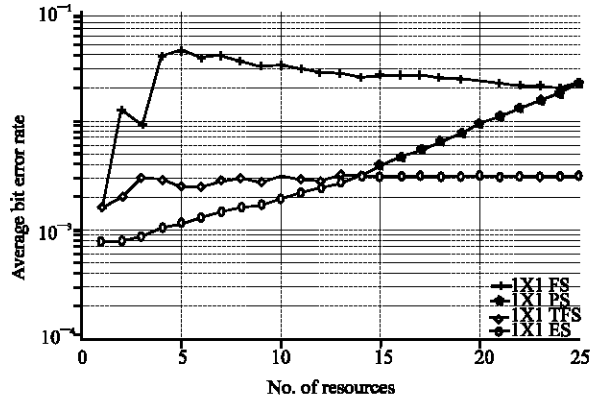

Fig. 3: BER performance comparison ES with TFS, PS and FS (1X1 System)

users request received at time slot t_k and Let $x' = \{x'_{t1}, x'_{t2}, x'_{t3},..., x'_{tk}\}$ be the users whose SNR's are greater than or equal to 'Th' where $x' \subset x$. The granted users in the time slot t_k is given as:

$$G_{tk} = \{x'_{t1}, x'_{t2}, x'_{t3},..., x'_{tk}\} \text{ whose SNR's above 'Th'} \quad (4)$$

Algorithm for Threshold based fair scheduling is as follows:

- Receive n_{tk} user's request at time slot t_k
- Compute SNR
- Compute the threshold based on average of minimum SNR and maximum SNR
- Grant resources for first r_{tk} number of users if their SNR is greater than or equal to the threshold
- The granted users transmit their data by Alamouti-STBC coded 2×2 MIMO system

TFS scheduling gives better performance when the number of resource exceeds about fifty percent of number of users. When the number of resource is less than or equal to fifty percent of number of users, the new Efficient Scheduling (ES) algorithm is developed for enhancing the system performance.

Efficient scheduling: Efficient scheduler works under two phase, the network learning phase and resource granting phase. In network learning phase the scheduler runs various scheduling algorithms and evaluates the performance of the network under various load condition. The results are maintained in performance table. During resource granting phase, as and when the request arise, the scheduler enables the Scheduling Algorithm Selection Process (SASP) which checks the performance table to identify the best algorithm for the present request condition and adapts the suitable scheduling algorithm. The granted users G_{tk} at time slot t_k is given as:

$$G_{t_k} = \begin{cases} \{x'_{t_1}, x'_{t_2}, x'_{t_3}, \ldots\ldots, x'_{t_p}\} \text{ whose SNR's above Th' if } \sum x'_{t_p} = r_{t_k} \\ \{x_{SNR_{t_1}}, x_{SNR_{t_2}}, x_{SNR_{t_3}}, \ldots, x_{SNR_{t_p}}\} \text{ till } \Sigma x_{SNR_{t_p}} = r_{t_k} \text{ otherwise} \end{cases} \quad (5)$$

Algorithm for this scheduling is as follows:

- Receive n_{tk} user's request at time slot t_k
- Compute the threshold based on average of minimum SNR and maximum SNR
- Compute the number of users whose SNR is more or equal to the threshold
- If the number of computed users is less than number of available resource r_{tk}, grant resource for users based on first come first serve and if their $SNR_i \geq$ 'Th' for i = 1, 2.... n_{tk} otherwise grant resource of best r_{tk} number of users
- The granted users transmit their data by Alamouti-STBC coded 2×2 MIMO system

SIMULATION AND RESULTS

The system is modeled using one base station receiving request from n_{tk} users. The users demand resources from the base station by using request packet. The performance of scheduling is simulated for two cases. In case 1 each user has one antenna and demands one antenna resource. In case 2 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 after Alamouti-Space Time Block Coding (STBC). Simulation parameters are shown in Table 1.

Figure 3 shows the BER performance of 1X1 antenna system with different scheduling. It has been observed that the ES outperforms well as compare to TFS and PS. From Fig. 3, it has been observed that this system is able to achieve the bit error rate in the order of 10^{-3}. To improve the BER performance 2X2 MU-MIMO system is derived and their performance is shown in Fig. 4 and 5.

The performance table during learning phase of efficient scheduler is illustrated in Table 2.

Figure 4 gives BER performance and it shows that the threshold based fair scheduling performes well as compared to priority scheduling when the number of resources exceeds fifty six percent of number of users otherwise PS gives better performance because it serves group of best users. When the available resources increases and become closer to the number of users, priority scheduling gives same performance as FS.

Also it is observed that the efficient scheduling is able to improve the BER performance as compare to

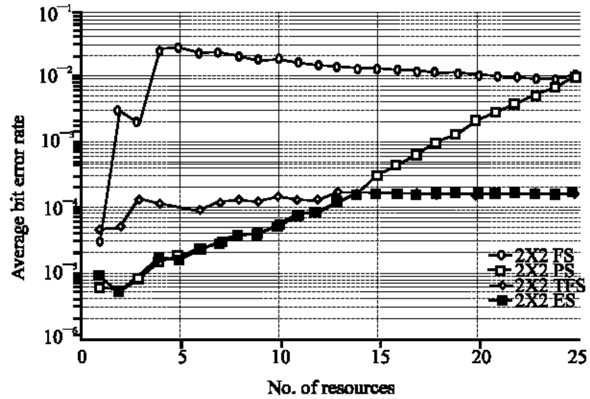

Fig. 4: BER performance comparison of 2X2 ES with other scheduling

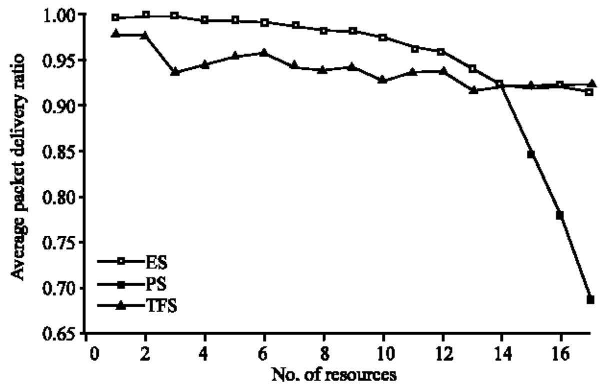

Fig. 5: PDR performance comparison of 2X2 ES with PS and TFS

Table 1: Simulation parameters for MIMO-STBC system

System	MIMO-STBC
Number of Transmit antenna	1or 2
Number of Receive antenna	1or 2
Channel	Rayleigh flat fading
Noise	AWGN
Modulation	BPSK

Table 2: Performance table of ES

Percentage of No. of resources available as compared to the No. of users	BER performance of	
	PS	TFS
8	5.5×10^{-6}	4.95×10^{-5}
16	1.475×10^{-5}	1.123×10^{-4}
24	2.183×10^{-5}	8.75×10^{-5}
32	3.725×10^{-5}	1.255×10^{-4}
40	5.29×10^{-5}	1.447×10^{-4}
48	8.49×10^{-5}	1.249×10^{-4}
56	1.622×10^{-4}	1.622×10^{-4}
64	4.402×10^{-4}	1.581×10^{-4}
72	9.239×10^{-4}	1.595×10^{-4}
80	2.073×10^{-3}	1.586×10^{-4}
88	3.761×10^{-3}	1.611×10^{-4}
96	6.651×10^{-3}	1.579×10^{-4}
100	1.016×10^{-2}	1.581×10^{-4}

threshold based fair scheduling when the number of resource is less than 56% of number of users. Also it gives better performance as compare PS when the number of resources exceeds fifty six percent of the number of users.

The Packet Delivery Ratio (PDR) of this scheme is shown in Fig. 5. The PDR performance of ES scheme is found improved by ten percent as compared to the TFS scheme and same as compare to PS till the number of resources are fifty six percent of the number of users. As it exceeds ES outperforms well and the PDR performance of PS rasticly decreases under this case. It is also observed that the ES is able to maintain the good PDR performance.

CONCLUSION

This study proposes ES scheme for resource utilization in MUMIMO system. The Efficient scheduler works under two phase, the network learning phase and resource granting phase. The performances of this scheme with BPSK modulations in flat Rayleigh fading channels is compared with other scheduling schemes such as FS, PS and TFS. From the simulation results it is found that ES outperform other scheduling schemes in BER and PDR performance. This scheme provides a network BER of about 5×10^{-5} and PDR of 92%. This study further can be extended by considering multiple network characteristic parameters.

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