Performance Improvement Using Opportunistic Scheduler in CDMA Systems

K.Jayanthi and P.Dananjayan
Department of Electronics and Communications Engineering
Pondicherry Engineering College
Pondicherry-605014, India

ABSTRACT

The unique characteristics of wireless networks, namely the time varying channel conditions and multi-user diversity necessitates new scheduling solutions to be developed. The wireless resource is scarce, and mobile users perceive time varying channel conditions. To effectively harness the precious resource and achieve higher network performance, good scheduling schemes opportunistically seeking to exploit channel conditions is absolutely essential. The prime objective of this work is to improve / maximize system performance (e.g. throughput, capacity) under various fairness and QoS constraints. Simulation analysis of the proposed scheme is carried out under CDMA environment. As expected, the obtained results prove to have higher throughput satisfying per user QoS constraints in both environments. In addition to this, system capacity and resource utilization considerably improved. Hence, this channel-based scheduler results in substantial system gain, which is the basic requirement in a multi-user wireless scenario. However, a trade off always occurs between system throughput and user fairness.

Key words: QoS provisioning, Scheduling, CDMA systems

1. INTRODUCTION

Wireless channels, in contrast to their wire-line counterparts have time varying location-dependent characteristics. Hence, the performance (e.g., throughput) of a user greatly relies on the channel conditions experienced by him. Consequently, one can expect for different performance even when the same resource is assigned to all active users. The goal of the scheduler is to serve active mobiles in a fair manner and also to take into account the time varying link effects. Thus resource allocation and scheduling policies are critical in wireless networks. In addition to channel effects, scheduling decision is also influenced by the state of the different queues, the flow or the nature of quality treatments a user looks for.

The conventionally used scheduling algorithms are round-robin and one step prediction. Round robin scheduling algorithm [1] does not take channel condition into account. It allocates equal amount of resource to each user irrespective of their channel conditions. In one-step prediction algorithm [2], the base station predicts the channel conditions of each user as either "good" or "bad". The base station allots more resource for the users who are having good channel states and neglects those are in bad channel. In summary, most of the previous work was mainly focusing on enhancing the system throughput blindly without much bothering for satisfying the required QoS guarantees of all the existing users. In this work, a novel scheme called ***"Opportunistic scheduling"*** is introduced [3,4]. The term opportunistic means 'the ability to exploit the variation of channel conditions'. Such schedulers take advantage of the changing channel conditions by serving a mobile station at times when the channel conditions to that mobile is good. It is important to note that utilization of good channel conditions will result in improved system capacity. At the same time some form of fairness needs to be provided to all users. Bearing this in mind, simulation analysis under two cases namely: with user fairness and without user fairness is carried out and its impact on performance is investigated.

2. SYSTEM MODEL

Consider a DS-CDMA system serving N active users sharing the power. Mobile users are assumed to move with random speed and random direction in the cell and are connected to the backbone network via the base stations. In this work, the downlink-scheduling is only focused. However the same can also be extended to uplink scheduling. The packets from the source are transmitted to the base station and they are buffered in queue as shown in figure 1. Separate queues are maintained for every user. The wireless channel for each user differs depending on the location, the surrounding environment, and mobility. It is assumed that the channel state information is known to the associated base station and this channel state do not vary within a timeslot. Based on the channel reports, different rate assignments are made to the mobiles. At the beginning of every time slot (frame duration), the power levels are assigned to the mobiles based on the data rates allotted in that specific timeslot.

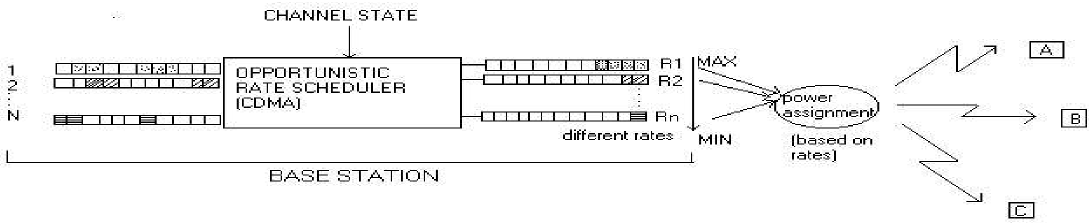

Fig. 1 System model

2.1 Scheduling Policy

The scheduling block of the base station keeps a record of the channel conditions of N users as $c_i(k) = [c_1(k),\ldots\ldots, c_N(k)]$ and control parameters for all those users as $V_i(k) = [V_1(k),\ldots..,V_N(k)]$ as shown in Fig. 2.. The output of the scheduling block is the scheduling decision $X(k) = [X_1(k),\ldots.,X_N(k)]$ for time slot k. That is, Xi(k) denotes the scheduler's selected transmission rate of user i in slot k. The control vector is updated by the control parameter updating block. In order to increase the system throughput using opportunistic scheduling in CDMA, a user with a high quality channel is usually assigned with a lower transmission power. Hence the power has to be opportunistically scheduled to select best set of users and rates subject to the following constraints:(i) Resource constraint and (ii) Fairness constraint. The opportunistic scheduling which satisfies the first constraint only is Opportunistic scheduling without fairness. The opportunistic scheduling which satisfies both the constraints is Opportunistic scheduling with fairness.

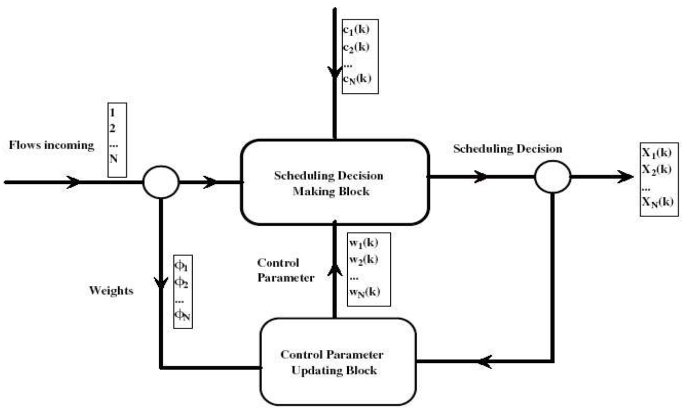

Fig. 2 Opportunistic Scheduling with control parameter

2.1.1 Resource Allocation without fairness

The total system resource limitation in a CDMA system is the maximum transmission power limit in each time slot. Let P_i be the transmission power allocated to user i, and assume that the base station has a constraint on its total transmission power such that

$$\sum P_i \leq P_{max} \tag{1}$$

Let gi represent the channel gain of user i, so that giPi is the received power at user i. Assume that the base station can send to user i with a rate, Xi is proportional to the received power and C_i is the channel condition of user i.

$$Xi = K.g_I P_i , \tag{2}$$

for some constant K, where Pi = Xi/ (K .gi) and Pi = Xi Ci . Based on the channel conditions the rate sets are assigned such that, the best channel user gets the highest data rate and all other users will get the relative data rates. The power level assigned for the user i is given by $P_I = C_i R_i$ such that the equation (1) is always satisfied.

2.1.2 Resource Allocation with fairness

The fairness constraint guarantees that there is none left without utilizing the resource and thus provides a certain amount of minimum resource for unfortunate users. To satisfy the fairness constraint, control vector is used which is updated based on the rated scheduled in the previous time slot. The control vector is updated using

$$V_i(k+1) = V_i(k) - a^k y_i^k \qquad (3)$$

$$y_i^k = \frac{\phi_i}{\sum_{j=1}^{N} \phi_j} - \frac{X_i(k)}{\sum_{j=1}^{N} X_j(k)}$$

$$a^k = 1/k$$

where V_i - control vector for user i, k is the time slot number and Φ - weight of user i . Thus the control parameter of user i is a function of its previous value, its weight and its data rate in that instant.

3. SIMULATION RESULTS

A CDMA system with 8 active users is considered for simulation analysis. At the beginning of a time slot, the channel condition and control vector for individual user is obtained. The obtained value has a minimum channel value of 0.0006 (good channel) and maximum of 1.0000 (bad channel). Opportunistic scheduling without fairness allocates data rate based on the channel value i.e., when the channel value is minimum, maximum data rate is assigned and vice-versa. The power is then allocated for each user starting from best channel to the worst using Pi = Ci*Ri.

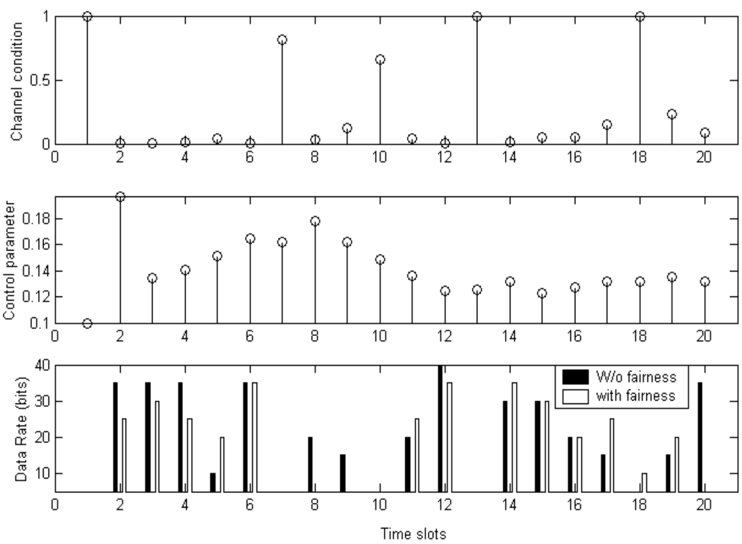

Fig. 3. Single user performance

For without fairness algorithm, the data rate is assigned purely based on channel conditions. Opportunistic scheduling with fairness takes C/W ratio (channel condition / control vector) and the data rates are assigned according to the sorted list of the ratio as shown in Fig.3. Figs. 4 and 5 shows the throughput comparison obtained for 8 users for a total of 30 time slots. Opportunistic scheduling without fairness has greater throughput as expected. The non-opportunistic schemes schedules requested minimum data rates until power constraint is satisfied. Hence the overall system throughput is lesser than opportunistic scheduling. Fig.6 reveals the throughput with increasing number of active users. A larger number of users provide an increased degree of freedom for the scheduler to exploit varying channel conditions and select the best subset of users for transmission. The total system throughput increases almost linearly with the number of users until saturation due to the system's total power constraint. Fig.7 is a plot of percentage of power utilized by a user in a group of [10,20,..150] users. When the numbers of users vary, channel ranking varies and hence the power utilized also varies.

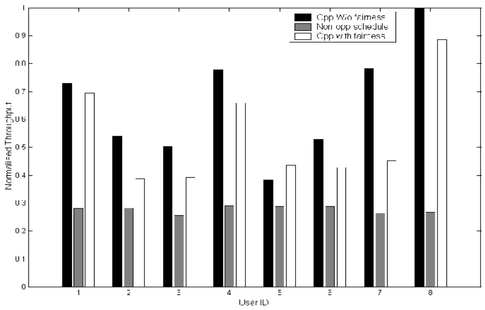

Fig .4 System throughput comparison as a function of user

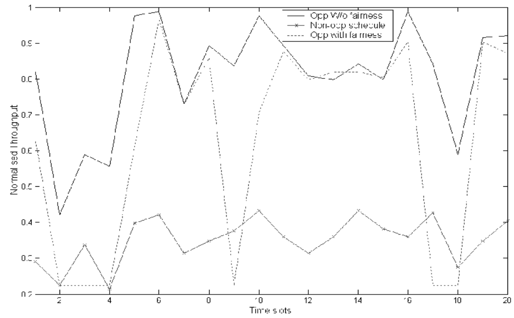

Fig .5 System throughput comparison as a function of time

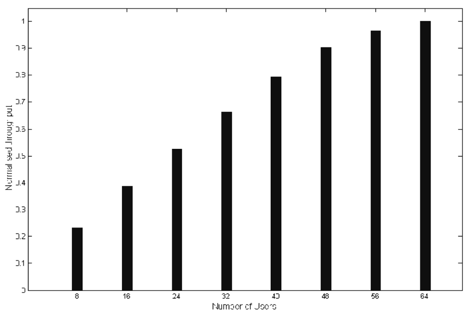

Fig.6 system performance

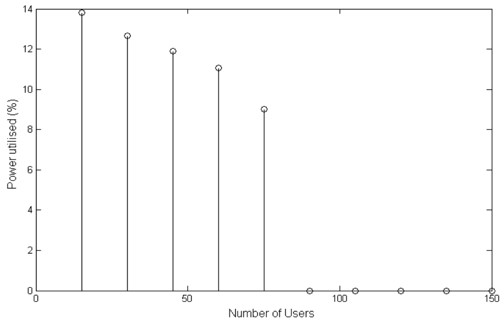

Fig.7 Power Utilisation

4. CONCLUSION

Opportunistic scheduling is a way to improve spectrum efficiency by exploiting the time-varying channel conditions. In this work, opportunistic scheduling in a multi-user environment is proposed to maximize the average system performance by exploiting variations of the channel conditions while satisfying certain QoS constrains in CDMA environments. By introducing the knowledge of the channel state in the scheduling algorithm, the system performance (BER, throughput, capacity, average transmitted power, and resource efficiency) improves. The performance of the proposed scheduler is extensively investigated under two cases: namely (i) with user fairness and (ii) without user fairness. From the analysis, it has been noticed that for system throughput maximization, scheduler without fairness is the best alternative resulting in improved capacity and resource efficiency. On the other hand, individual user requirements are being satisfied using the other alternative. Hence, the operators and the service providers can choose between the two in accordance to their specific requirements. Thus a tradeoff always exists between throughput maximization and user fairness.

Acknowledgement
The authors would like to express their sincere gratitude to the following: Mr.K.Varadharajan, Mr.A.Arunkumar, Mr.A. Aravazhi and Mr. M.Bharathidassan.

References

[1] Lars Wischhof, John W. Lockwood, “ Packet Scheduling for Link-Sharing and Quality of Service Support in Wireless Local Area Networks”, *Technical Report* WUCS-01-35, Applied Research Laboratory, Washington University in St. Louis, November 2001.

[2] Y. Cao and V. Li, “Scheduling algorithms in brand-band wireless networks”, *Proceedings of the IEEE,* vol. 89, pp. 76–87, January 2001.

[3] X. Liu, E. Chong, and N. Shroff, “Optimal Opportunistic Scheduling in Wireless Networks”, in *Proceedings of VTC Fall* 2003.

[4] Y. Liu and E. Knightly, “Opportunistic fair scheduling over multiple wireless channels”, in *Proceedings of the IEEE Infocom* 2003 , San Franscio, CA.