Comparative Analysis of Packet Scheduling Schemes for HSDPA Cellular Networks

Toni Janevski, *Senior Member, IEEE,* and Kire Jakimoski

Abstract — **In this paper we present comparison analysis for packet scheduling algorithms for HSDPA (High Speed Downlink Packet Networks). In particular, we analyze the round robin, max C/I and FCDS packet scheduling algorithms in HSDPA by comparing the average throughput, delay and fairness of the users, changing the number of the users in pedestrian and vehicular environment. The results have showed that the number of the users in a given coverage area is very important when choosing which packet scheduling algorithm for HSDPA networks. These results will be very useful for choosing the adequate scheduling algorithm in HSDPA network with aim to satisfy the desired quality of service for the mobile users.**

Keywords — **HSDPA, Mobile Networks, Scheduling.**

I. Introduction

THE High Speed Downlink Packet Access (HSDPA) was introduced in release 5 of Universal Mobile Telecommunications Systems (UMTS) in order to support the increasing demand for multimedia applications that require high data rates. In HSDPA [1], a high-speed downlink data channel is shared by multiple users within the same cell to offer peak rates exceeding 10 Mbps. HSDPA relies on new technologies that make it possible to achieve such high data rate. These new technologies include: Adaptive Modulation and Coding (AMC), Hybrid Automatic Repeat Request (ARQ), fast Packet Scheduling, and fast Physical Layer. One of the most important features of HSDPA is fast packet scheduling.

One of the basic principles for HSDPA is the use of channel-dependent scheduling [2]. The scheduler in the MAC controls what part of the shared code and power resource is assigned to which user in a certain TTI. It is a key component and to a large extent determines the overall HSDPA system performance, especially in a loaded network [3-8]. At lower loads, only one or a few users are available for scheduling and the differences between different scheduling strategies are less pronounced.

Although the scheduler is implementation specific and not specified by 3GPP, the overall goal of most schedulers is to take advantage of the channel variations between users and preferably schedule transmissions to a user when the channel conditions are advantageous. Several scheduling strategies are possible. However, efficient scheduling strategies require at least information about the instantaneous channel conditions at the UE, and information about the buffer status and priorities of the data flows.

The purpose of Packet Scheduling is to distribute resources among users in a fair and efficient way to maximize the system throughput. In order to achieve the highest possible throughput, another parameter has been added to the scheduling decision, which is the channel condition of the users, but this raises the issue of fairness. Different packet scheduling algorithms have different impacts on the performance of the system in terms of system throughput, packet delay, packet lose, fairness etc.

This fact is used as a motivation in this paper to simulate different scenarios in one cell changing the number of users, distance from the Node B (base station) and propagation environment for three scheduling algorithms (round robin, max C/I and FCDS). The results are given in instant throughput, average throughput and average delay. In this paper we provide analysis of throughput, fairness and packet delay for different scheduling schemes for HSDPA by using simulated scenarios in one cell. The main goal is to provide results that will help in the design process of HSDPA mobile networks, aiming to get better throughput and fairness for the users.

The paper is organized as follows. Section II describes the fast packet scheduling algorithms which are used in the simulations. Section III describes simulation conditions, scenario schemes and traffic model. Simulation results are presented in section IV. Finally, Section V concludes the paper.

II. Packet Scheduling Schemes

In this paper we perform analysis of three different packet scheduling algorithms for HSDPA: round robin, max C/I and FCDS.

Round Robin scheduler (RR): Users in round robin algorithm are served in a round robin (i.e. cyclic order) manner. The scheduler selects the user that has not been served for the longest time. Although this algorithm doesn't make any use if the instantaneous channel quality of the users and hence may suffer from low throughput, it is fair in the sense that each user gets the same amount of resources in terms of time slots.

Maximum C/I Scheduler (Max C/I): Probably the most straightforward and aggressive advanced packet scheduler is the maximum-throughput or maximum C/I packet

Dr. Toni Janevski is Professor at the Faculty of Electrical Engineering and Information Technologies, University "Sv. Kiril i Metodij", Karpos 2 bb, 1000 Skopje, Macedonia, (e-mail: tonij@feit.ukim.edu.mk).

Kire Jakimoski is Ph.D. student at the Faculty of Electrical Engineering and Information Technologies, University "Sv. Kiril i Metodij", Karpos 2 bb, 1000 Skopje, Macedonia, (e-mail: kire_jakimoski@yahoo.com).

scheduler, which always schedules the user with the best instantaneous channel quality. The main drawbacks of this scheduler are mainly its inherent unfairness and coverage limitations. This scheduler essentially ranks all the users according to their instantaneous carrier-to-interference (C/I) ratios. This scheduler is optimal in obtaining the maximum network throughput. In this case, the UE in favorable positions will have the highest throughput, but system services may be unavailable to the users in unfavorable positions. Max C/I is a kind of channel-dependent scheduler since the variations of radio channel condition are used for scheduling.

Fair Channel-Dependent Scheduler (FCDS): It is a more practical scheduler which has a strategy that incorporates the RR method and the Max C/I method, i.e. it uses variations of the radio channel conditions to improve system capacity while implementing a degree of fairness. Thus, it can be concerned as a trade-off between the two extreme scheduling methods.

III. Simulation Parameters

The performance evaluation of the RR, the Max C/I and FCDS was based on a discrete event simulations using Network Simulator 2 (NS2), version ns-2.30 [9]. However, NS2 by itself does not support UMTS and HSDPA. Therefore an extension to NS2 was used in the evaluation process called EURANE (Enhanced UMTS Radio Access Network Extension for NS2). The simulated environment consisted of one cell where Node B is located in the middle of that cell. The user is connected to Node B on the downlink by HS-PDSCH channel that is shared among all users and by HS-DPCCH on the uplink, which is dedicated for each user.

Two propagation environments have been used in these simulations, which are recommended by the International Telecommunication Union: Pedestrian-A and Vehicular-B environments. Table 1 gives the created simulation scenarios for this paper, i.e. changing the number of users and distance from the Node B for the two propagation environments. For the simulated scenario with 20 users on 500 m distance from the Node B, two users are placed on every 50 m distance from the Node B.

As a traffic source we have used FTP traffic generators. All cell users initiate traffic simultaneously. Additionally, all users are Category 5 users (we use 5 parallel codes per HS-DSCH) with achievable maximum data rate of 3.6 Mbps. Users are uniformly distributed in the cell. In Pedestrian-A environment users move with a speed of 3 km/h on their orbits in respect to Node B, and in Vehicular-B environment users move with a speed of 120 km/h. Simulations trace files were generated using Matlab pre-processing/generation of input trace files for the Eurane simulator of ns-2 tool.

IV. Simulation Results

A. Pedestrian-A propagation environment

In figure 1 are presented results for average throughput and average delay for 10 and 20 users uniformly distributed on every 50 meters till 500 meters distance from the Node B.

Table 1: Simulation scenarios

Propagation environment	Number of users	Distance from the Node B (meters)
Pedestrian-A	10	500
Pedestrian-A	10	1000
Pedestrian-A	20	500
Pedestrian-A	20	1000
Vehicular-B	10	500
Vehicular-B	10	1000
Vehicular-B	20	500
Vehicular-B	10	1000

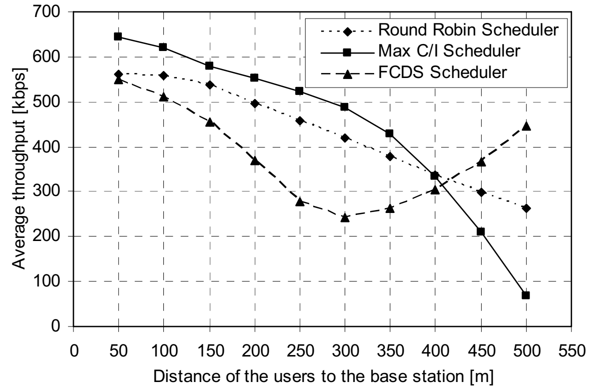
In Fig.1c and Fig.1d we show two plots for average throughputs and average delay because in the simulations every two users have been set on the same distance from the Node B, on every 50 meters.

We can conclude that the round robin scheduler is less sensitive when changing the number of the users. The fairness of the users is the best when this scheduler is used in scenarios with different number of users. Average throughput has very similar values for the users that are on the same distance from the Node B for the all three schedulers (Fig.1c). This is not the case if we compare the average delays. In fig.1d one can notice that the values for average delay are similar just for the round robin scheduler for the users that are on the same distance from the Node B, but they differ a lot if we look at the other two schedulers. With max C/I and FCDS scheduler, the delay is higher with adjacent users on every 50 meters. Round robin scheduler gives the best results for average delay.

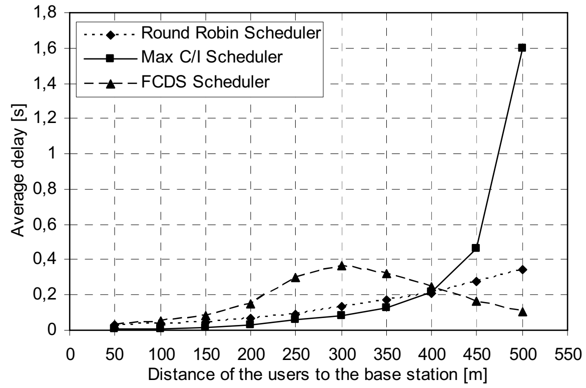
B. Vehicular propagation environment

The number of the users in Vehicular propagation environment is important factor when getting the results for average throughput and average delay for the three packet schedulers for HSDPA analyzed previously for Pedestrian environment.

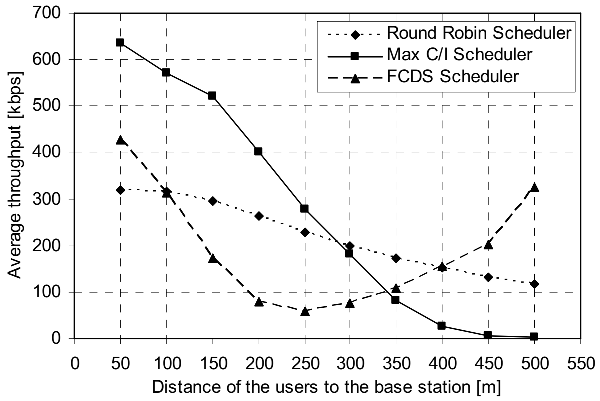
When the number of the users is lower we have better results for average throughput of the users when we use max C/I scheduler and FCDS scheduler. This is not the case when the number of the users gets higher. Then, only users that are very close to the Node B have high throughput and the others have not. The fairness is very bad when the number of the users is higher using max C/I scheduler. The same situation is with FCDS scheduler as well. The best scheduler for Vehicular environment for getting the best fairness of the users is round robin scheduler. However, the results with average delay are similar to Pedestrian environment. The best results for the average delay of users give the round robin scheduler. The results in Fig.2c and Fig.2d are very similar for average throughput and average delay. That was not the case for max C/I and FCDS schedulers when comparing average delay in Pedestrian environment. The average delay is less sensitive in Vehicular environment for max C/I and FCDS scheduler when there are more users on the same distance from the Node B.



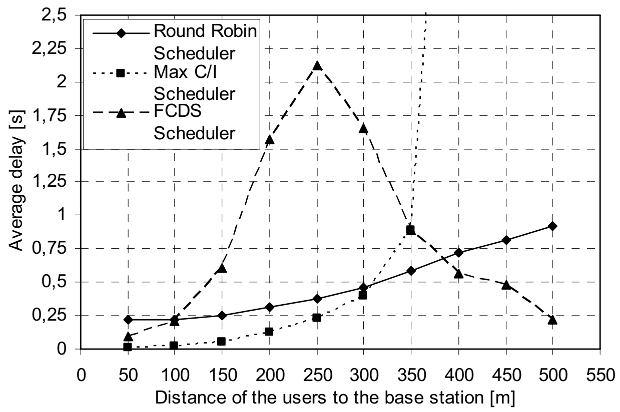
a) Average throughput for 10 users



b) Average delay for 10 users

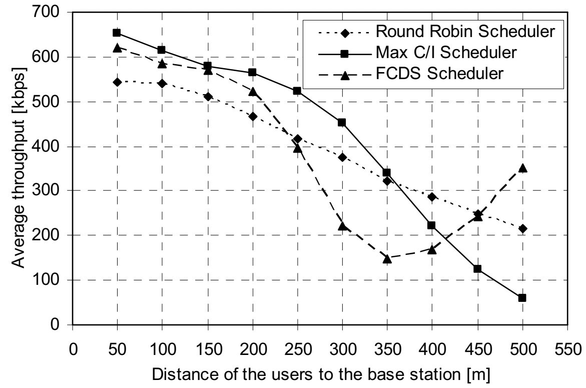


c) Average throughput for 20 users

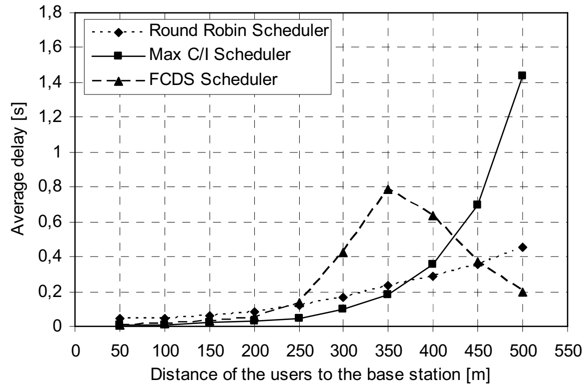


d) Average delay for 20 users

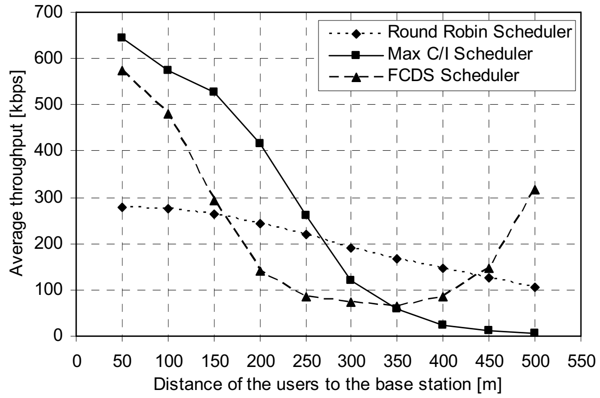
Fig.1. Simulation results for average throughput of 10 and 20 users on 500 m cell radius for RR, max C/I and FCDS scheduler in Pedestrian environment.



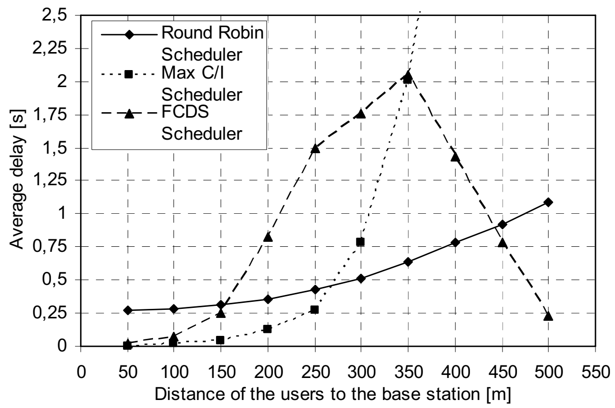
a) Average throughput for 10 users



b) Average delay for 10 users



c) Average throughput for 20 users



d) Average delay for 20 users

Fig.2. Simulation results for average throughput of 10 and 20 users on 500 m cell radius for RR, max C/I and FCDS scheduler in Vehicular environment.

Fig.3 shows similar behavior observed earlier in Pedestrian environment in Fig.2 for the RR, PF, and Max C/I algorithms in terms of cell average throughput. However, the overall cell throughput for all three algorithms is much less than Pedestrian environment because the path loss and multi-path fading effects are higher in Vehicular environment since the mobile speed is higher. According to the results Max C/I can offer much better system throughput than other scheduling schemes. Although Max C/I give much higher throughput to a few users, it fails to give any throughput to the majority of users whose channel qualities are not good.

The results from Fig.3 for different cell sizes and average of 20 active users (simultaneously downloading content from Internet) pointed out scheduling schemes that should be selected for different cell sizes. For smaller HSDPA cells, the priority should be given to Max C/I scheduling scheme since in smaller cells more users experience good radio channel conditions (i.e. good C/I ratio). However, our simulation results pointed that for macro cells, larger than several hundreds of meters, the best average results for users can be provided by using round-robin scheduling scheme for HSDPA mobile network, or combination of max C/I scheduling for users which are closer to the Node B, and round-robin scheduling for users that are distant from the base station.

V. Conclusion

In this paper we have analyzed the influence of number of users in Pedestrian and Vehicular environment in HSDPA networks regarding the average throughput, average delay and fairness for different packet scheduling algorithms i.e. round robin, max C/I and FCDS. The results showed that number of the users in a given HSDPA cell influences the performances of the packet schedulers in average throughput and average delay.

From the results we can conclude that round robin scheduler is the best when talking about the fairness of the users no matter how many users we have in the cell, but when we want to have better throughput for the users, max C/I scheduler and FCDS scheduler give better results for the users although not for all of them.

When the number of the users is higher, lower number of users get better throughput with each one of the three schedulers. When we are talking about fairness, the number of the users has impact in max C/I and FCDS scheduler which have worse fairness when the number of the users is higher, but it is not the case for round robin scheduler. This scheduler has the same fairness no matter how many users are scheduled in the cell.

Finally, regarding the distance between the user and the base station in HSDPA mobile network, the results outlined max C/I as better option for smaller cells and for users which are closer to the base station, while round-robin scheduling is better for distant users. However, a combination of these two may provide the best results in overall throughput in HSDPA cell.

References

[1] H. Holma and A. Toskala, “HSDPA/HSUPA for UMTS”, John Wiley & Sons, Ltd, Jun.2006.

[2] B. Al-Manthari, “Performance of Packet Scheduling Algorithms in High Speed Downlink Packet Access”, Telecommunication Research Lab School of Computing, Queen’s University, Winter 2005.

[3] Jose Luis Pradas Adan, “Effect of Multiple Simultaneous HSDPA Users on HSDPA End-User Performance for Non-Real Time Services in One Cell System”, Helsinki University of Technology, Department of Electrical and Communications Engineering, Espoo, 7 August 2006.

[4] R. Gluchowski, Dr A. Bak, “Packet Scheduling Algorithms in HSDPA”, Warsaw University of Technology, Information Technology and Electronics Department, Institute of Telecommunications, 30.05.2007.

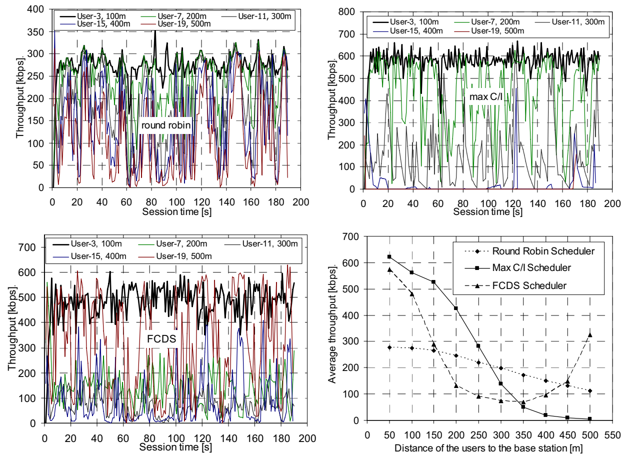
[5] E. Dahlman, S. Parkvall, J. Sköld and P. Beming, “3G evolution: HSPA and LTE for Mobile Broadband”, First edition 2007.

[6] H. Holma and A. Toskala, “WCDMA for UMTS – HSPA Evolution and LTE”, John Wiley & Sons, Ltd, 2007.

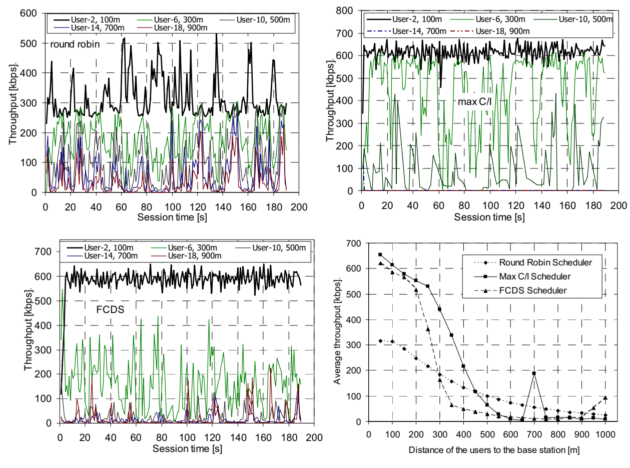
[7] H.vand den Berg, R. Litjens, J. Laverman, “HSDPA Flow Level Performance: The Impact of Key System and Traffic Aspects”, COST 290 Management Committee Meeting, Colmar, February 3-4, 2005.

[8] P. Jose, A Gutierrez, “Packet Scheduling and Quality of Service in HSDPA”, Department of Communication Tecnology, Institute of Electronic Systems, Aalborg University, Ph. D. Thesis, October 2003.

[9] Z. Haichuan, W. Jianqiu, “Implementation and Simulation of HSDPA Functionality with ns-2”, Linköping, March 21, 2005.



a) Case 1: 20 users in HSDPA cell with radius 500 m



b) Case 2: 20 users in HSDPA cell with radius 1000 m

Fig.3. Instant and average throughput in HSDPA cell for different cell sizes