CONTROLLING THE EFFECTS OF LINK ADAPTATION ERRORS AND USERS SPEEDS ON SCHEDULING SCHEMES IN HSDPA SYSTEMS

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ABSTRACT: *This paper focuses on evaluating effects of the link adaptation errors and user speeds on the performance of scheduling schemes in HSDPA system. The investigation focuses on three scheduling schemes such as Maximum Carrier to Interference (C/I), Proportional Fair, and Round Robin. The investigation is performed in terms of retransmissions and service throughput at various user speeds. A pre-emptive approach of applying scheduling scheme is also proposed to counter the link adaptation error effects on the performance of scheduling schemes.*

Key Words: HSDPA, Performance, Max C/I, Proportional Fair, Round Robin, Link Adaptation Errors.

1 INTRODUCTION

An evolution to the Universal Mobile Telecommunication System (UMTS) has been introduced known as "High Speed Downlink Packet Access (HSDPA)" in Release 5 specifications of 3GPP. HSDPA is introduced to provide multimedia services to the users with much high speed and to improve spectral efficiency as compared to UMTS. The theoretical maximum downlink data rate is achievable up to 14.4 Mbps [1, 2, 3]. However, in practical conditions, the achievable downlink data rate is limited up to 10 Mbps. These high data rates have become possible as a result of inclusion of new technologies such as Link Adaptation, Hybrid Automatic Repeat Request (HARQ) Retransmissions, and Fast Packet Scheduling. The introduction of these new features in UMTS is bundled as HSDPA in 3GPP specifications. In HSDPA, a new downlink transport channel "High Speed Downlink Shared Channel (HS-DSCH)" is also introduced for this purpose. The Transmission Time Interval (TTI) is shortened from 10ms to 2ms. This leads to better match of the transmission parameters with the user's channel conditions, thus resulting in improved spectral efficiency. Also, the packet scheduler is moved from Radio Network Controller (RNC) to Node B to minimize the delays introduced during retransmissions at Radio Link Control (RLC) layer. The relocation of packet scheduler from Radio Network Controller (RNC) to Node B opens new ways in defining scheduling strategies for scheduling packet data over the air interface [1, 2].

Any scheduling scheme would have to fulfil two goals when allocating resources to users in a cell. These include providing fairness among users in a cell during allocation of resources among them and achieving maximum cell throughput [1, 2]. To figure out which scheduling scheme achieves the above mentioned goals, various studies have been made in the past. Different scheduling schemes are compared with each other in HSDPA system [4-6], [17-19]. However, most of these studies only anticipate the performance of scheduling algorithms in a constrained environment. For instance, only single cell is considered in [4] and dynamic inter-cell interference is ignored in [5] which are not in compliance with the real world scenario. The mobility and traffic model is absent in [6] and comparison is performed in single cell. Moreover, the channel condition indicator values are self generated and only limited number of users are taken into account. In the above mentioned papers, the performance of scheduling schemes in HSDPA system has been studied over a single cell layout without taking into consideration the dynamic variation in the channel conditions and user's mobility in multi cellular scenario of Wideband Code Division Multiple Access (WCDMA) systems. Moreover, these studies have been made using a simple traffic model in which users have always data to be transmitted.

In this paper, we have conducted a comprehensive study of the performance of scheduling schemes in HSDPA system by using a dynamic system level simulator in multi-cellular environment by including all the essential features of HSDPA system which affect radio channel and link conditions in a dynamic fashion throughout the simulation run. The performance metrics taken into account include user average throughput, and retransmission percentage etc.

The rest of the paper is organized as follows. An overview of the scheduling schemes is presented in the next section. Then the effects of user speed on the scheduling are explained followed by the description of the proposed "Pre-emptive Approach". Having given a formal description of the problem and its proposed solution, we proceed to describe the simulation model followed by the results and discussion section. Finally the conclusion" and future directions are given.

2 OVERVIEW OF SCHEDULING SCHEMES

We have performed a study on the performance of scheduling schemes such as Maximum Carrier to Interference, Proportional Fair, and Round Robin in multi cellular environment in HSDPA system at different user speed levels.

Maximum Carrier to Interference (Max C/I) is also known as Maximum Throughput or Maximum SIR scheduling scheme. It is one of the most opportunistic scheduling schemes which exploits the user's channel condition by taking into account the radio channel conditions of the users during scheduling process. It selects the user having best channel conditions among all in the scheduling pool. Scheduling pool comprises of users whom are eligible for being scheduled in the subsequent TTI. The advantage of this scheduling scheme over others is that it increases system throughput. However, the cast of this advantage is paid in terms of fairness. It lacks fairness among users in terms of throughput and time [1, 2]. The Proportional Fair (PF) scheduling scheme was first described in [7] and was proposed for High Data Rate CDMA Systems. This scheme prioritizes users in a given cell based on the ratio of user's instantaneous supportable data rate and average throughput. The user having highest priority is selected for scheduling in the subsequent TTI. This scheme benefits those users in a cell which have good radio channel conditions relative to their average channel conditions or throughput observed. In this way, fairness is maintained in a proportional manner among users in terms of throughput [1, 2, 7, 8]. Round Robin (RR) is among one of the simplest scheduling schemes. It a channel independent scheduling scheme. It doesn't take into account the channel conditions of the users while making scheduling decision. It schedules users in a cyclic fashion [8].

3 EFFECTS OF USER SPEED

There are two major effects that can be viewed at high user speed such as faster change in channel conditions of the users and higher handover rates. With the increase in speed of the user, the variations in its channel condition increases and its transition from one cell to another cell also increases resulting in increased handover rates [7].

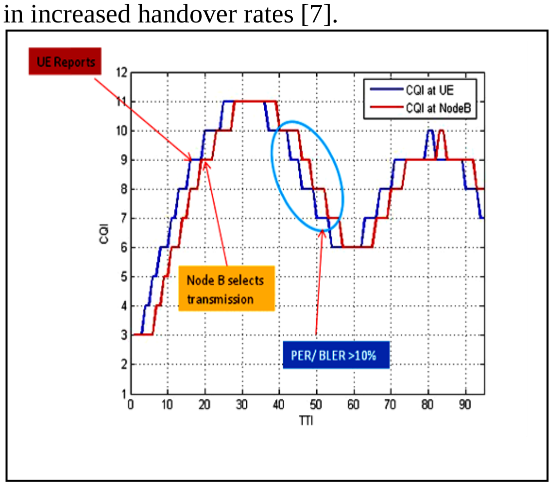

Figure1. CQI Processing Delay

The increased user speed results in faster variations in the channel condition of the users. The fading rate also increases with the increase in user speed. This causes changes in the instantaneous channel condition of the user within one TTI interval as shown in Figure 1. The difference between the reported channel conditions called Channel Quality Indicator (CQI) values and the instantaneous channel conditions during scheduling instant increases resulting in higher packet error rate. This degrades the performance of scheduling scheme or, in other words, the performance of HSDPA system.

Moreover, the increased user speed results in increased handover rates. In case of HSDPA, the increase in handover rate has some peculiar effects [6]. Such effects can be viewed in case of inter-Node B handover when user is handed over from one Node B to another Node B. The scheduling is performed at Node B. The Medium Access Control (MAC) entity, MAC-d Protocol Data Units (PDUs) are buffered at Node B. These MAC-d PDUs are transferred from RNC to Node B. In case of inter-Node B handover, the MAC-d PDUs buffered at Node B are discarded along with all the high speed Medium Access Control (MAC-hs) PDUs which have been sent to the user but are not yet acknowledged. In case of RLC working in acknowledgment mode, the RLC layer retransmits these MAC-d PDUs to the newly connected Node B after some time as it takes some time to detect a packet loss. This results in longer delays.

In this paper, this handover effect has not been simulated. Only the effect of fading rate over the performance of scheduling algorithm is analyzed.

4 PRE-EMPTIVE APPROACH

In HSDPA, no power control mechanism is present. The link adaptation mechanism is employed which tries to adapt the transmission parameters to the user's instantaneous channel conditions. With the increase in user speed, the rate of change in channel condition also increases with the increase in number of handovers. At higher speeds, the link adaptation mechanism doesn't accurately adapt the transmission parameters with the user's instantaneous channel conditions since the user's channel condition changes at a great pace. This results in link adaptation error causing increased number of packet retransmissions and losses. When the user speed increases, the reliability of the CQI report being sent by the user to Node B indicating its instantaneous channel condition degrades. In order to counter this degradation, several mechanisms have been proposed in literature such as outer-loop link adaptation mechanism [5]. It takes into account the number of acknowledgment and negative acknowledgments when selecting transmission parameters for the user.

We present a nouvel approach called "***Pre-emptive Approach***" which increased the probability of correct reception of packet at receiver by scheduling a user which is moving towards its positive fade in the subsequent TTI. The flow chart of the approach is shown in Figure 2. To our best knowledge, no publication regarding such approach exists.

In this approach, the users are classified into two categories. One category comprises of users whose channel conditions have improving trend, while other comprises of users whose channel conditions have deteriorating trend. This categorization is done at Node B scheduler and at each scheduling instant. Then based on the scheduling scheme employed, the user is selected for the transmission in the subsequent TTI. The priority is given to users whose channel conditions are improving.

From the obtained simulation results, it has been observed that the Proportional Fair and Max C/I scheme are those scheduling schemes that are more prone to the link adaptation error as compared to Round Robin. This is as both these schemes consider user channel condition while performing scheduling.

The above stated pre-emptive approach is also employed in the simulator to counter the link adaptation errors. The benefits obtained from this approach are discussed in the Results and Discussion Section in terms of network level performance and user level performance.

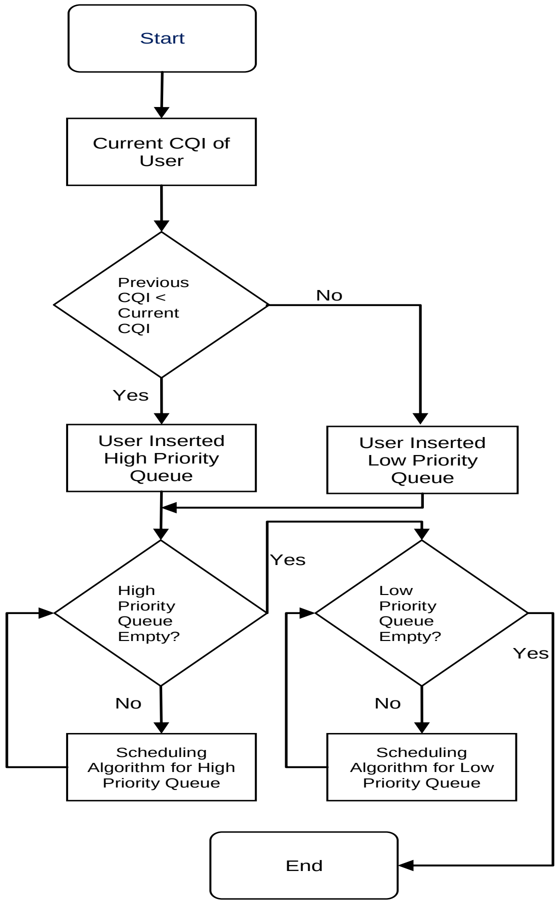

Figure 2. Pre-emptive Approach Flow Chart

Table 1. Simulation Parameters

Parameter	Value
BS Max Power	44 dBm
HS-DSCH Power	39 dBm
CPICH Power	33 dBm
Other Channels Power	33 dBm
Carrier Frequency	2000 MHz
Shadow Fading [12]	Mean 0 dB
Traffic Model	ETSI WWW Traffic
# HS-PDSCHs	5
# HS-SCCHs	1
HARQ Method	Chase Combining [2, 8]
Max Retransmissions	3
Flow Control	Credit based [i]
Reordering Mechanism	Sliding Window [14]
Terminal Speed	3 km/hr
Orthogonality Factor	0.6
Simulation Time	50,000 TTI

[i] http://eurane.ti-wmc.nl/eurane/

5 SIMULATION MODEL

The performance of scheduling schemes in HSDPA system is evaluated by using a dynamic system-level simulator. Table 1 summarizes the main simulation parameters.

The system model which is used in simulation, comprises of 24 cell sites with a hexagonal layout using omni-directional antennas. Users are created in each cell site randomly and at random locations from centre of the cells using uniform distribution. The site-to-site distance is equal to 2.8 Km.

6 RESULTS AND DISCUSSION

In the simulation model, we considered the performance of scheduling schemes in the HSDPA system at network level at different user speeds in a cellular environment. For this purpose, the tests are carried out in a Vehicular-A environment with macro-cells having a radius of 1.4 Km.

One of the performance metric taken into consideration is the service throughput. It is defined as "the average number of information bits that are successfully decoded during unit time T_s " [1, 4]. It is calculated as:

$$\phi_s = \frac{\sum_{i}^{N_{sec}} D_i \Big/ N_{sec}}{T_s} \qquad (1)$$

where D_i is the information bits successfully decoded in each sector, N_{sec} is the number of sectors in which transmission has occurred and T_s is the unit time.

Figure 3 shows the average service throughput attained by various scheduling schemes being simulated at different user speeds.

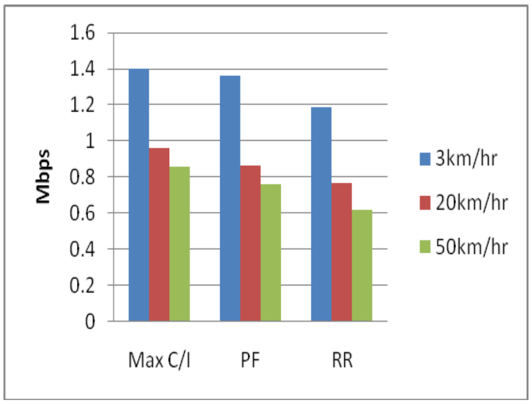

Figure 3. Average Service Throughput vs UE Speed in Vehicular-A

The distinction between the channel dependent scheduling schemes and non-channel dependent scheduling schemes can also be seen in Figure 3. Channel dependent scheduling schemes such as Max C/I and PF take into account the channel conditions of the users while scheduling. Thus, they exploit the user's channel conditions by scheduling the user whose channel conditions are most favorable. In this way, the service throughput attained by such schemes is higher than non-channel dependent scheduling schemes such as Round Robin as it doesn't take into account the channel conditions of the users when performing scheduling decisions. Thus it has lower service throughput. Moreover, with the increase in speed of user, the average service throughput decreases as shown in Figure 3. With the increase in user speed, the variations in channel condition of the users are higher with much faster rate. Thus, it induces the link adaptation error resulting in decrease in average service throughput. However, the average service throughput with Max C/I algorithm is higher at all user speeds than PF and other scheduling schemes as it schedules user having better channel conditions among all othe scheduling schemes. In this way, it exploits the channel conditions of the user better than PF. On the other hand, the PF scheme tries to provide fairness to all users in the cell site thus reducing the attained service throughput.

Another performance metric used to highlight the link adaptation error problem is retransmission ratio. It is defined as "the number of retransmissions that has been occurred within a system" [2]. It depicts the link adaptation error occurred within the network. It depends on a number of factors such as user speed, ever changing propagation conditions and CQI delay etc [2]. Figure 4 shows the retransmission ratio attained by different scheduling schemes in Vehicular-A environment at different user speeds. As discussed earlier, it can be deduced from the results that with the increase in user speed, the retransmissions increases. This is particularly due to link adaptation error occurred as the link adaptation mechanism is unable to adapt the transmission parameters to the user's channel conditions efficiently. Moreover, the CQI processing delay also has a significant impact over the retransmissions. It has been observed that the PF scheduling scheme is affected most from the link adaptation error at high speed as it schedules users over top of their fades. Thus, there is high probability that user when scheduled is not over top of its fades due to CQI processing delay and faster changing channel conditions.

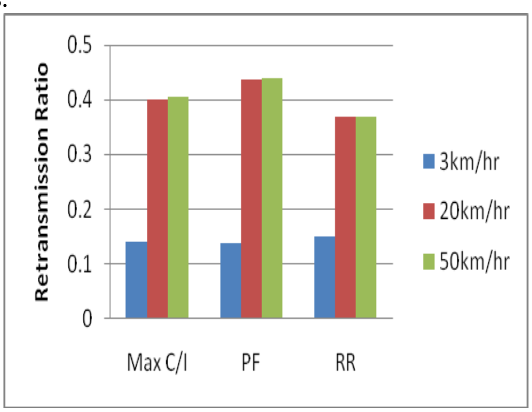

Figure4. Network Retransmission Ratio vs UE Speed in Vehicular-A

By combining *Pre-emptive Approach* with Proportional Fair scheme (P-PF), the effect of the said approach over the network retransmission ratio is shown in Figure 5.

At a slower speed of 3km/hr, the gain is appropriate because at slow speed, the rate of change in channel condition of users is slow as the average fade duration is larger with fewer number of fades. At the speed of 20 km/hr, the same gain is obtained as in case of speed 3km/hr. From this, it can be deduced that the *Pre-emptive Approach* has the potential of reducing the number of retransmissions occurred in the network. At a speed equal to 50 km/hr, the rate of change in channel condition of the user increases. The prediction technique used in this research is unable to tract those

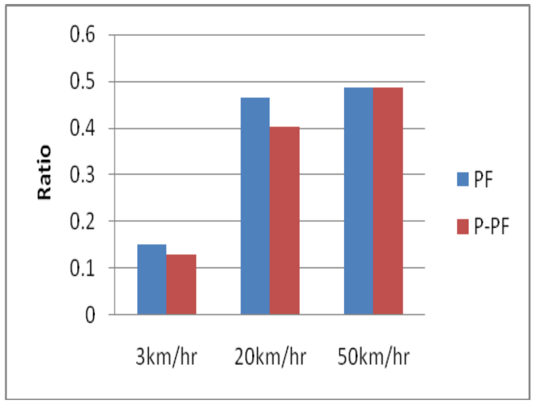

Figure 5. Network Retransmission Ratio vs UE Speed in Vehicular-A

changes more efficiently. Thus, the retransmissions become equal to conventional approach. With the use of pre-emptive approach, the effect of link adaptation error is lowered as it tries to schedule those users which are moving towards their positive fade peak.

In case of average service throughput of cell site, the Pre-emptive Proportional Fair (P-PF) approach provides reduced average service throughput than the conventional Proportional Fair approach (PF) as shown in Figure 6.

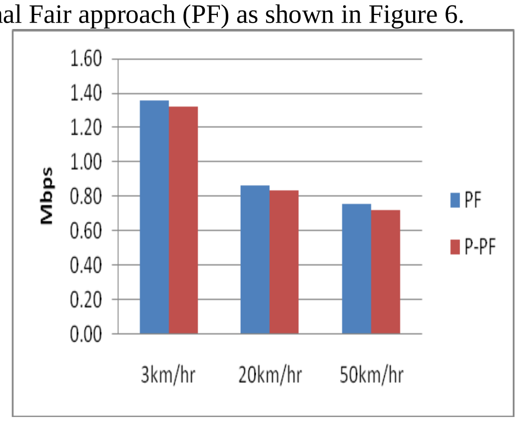

Figure 6. Average Service Throughput vs UE Speed in Vehicular-A

However, this decrease is minimal. The decrease in throughput is due to the fact that it also tries to schedule those users also which have poor channel conditions on average. Moreover, the service throughput is lower than conventional approach as it provides more chance to those users which have poor channel conditions. In case of high speed equal to 50 km/hr, the service throughput lowers as compared with the conventional proportional fair scheme as the relative link adaptation error effect is increased. The prediction technique doesn't track resulting in lower service throughput. However, the fairness increases as the approach gives more chance of scheduling to those users whom are being deprived in conventional PF scheme.

At user level, the proposed approach also provides improved performance than conventional approach at moderate speeds. The user packet retransmission percentage is shown in Figure 7, 8 and 9. It can be seen that with the use of pre-emptive approach, the number of retransmissions decreases. As the speed increases up to 20 km/hr, the percentage of retransmissions is significantly reduces to approx 8%. At higher speed of 50 km/hr, the gain in reduction of number of retransmissions is reduced. This is due to the prediction technique which doesn't track down the behaviour trend of the faster changing channel conditions of the user more efficiently.

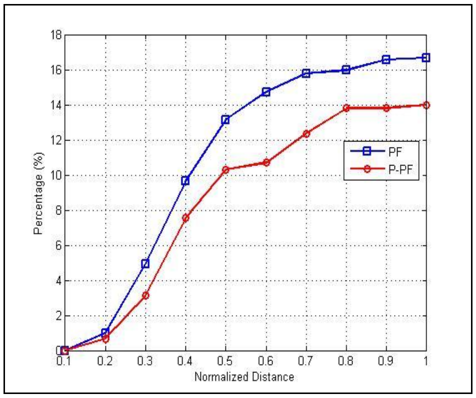

Figure 7. User Retransmissions Percentage vs Normalized Distance in Vehicular-A at 3 km/hr

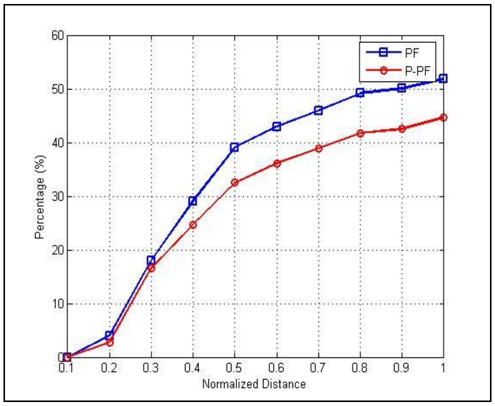

Figure 8. User Retransmissions Percentage vs Normalized Distance in Vehicular-A at 20 km/hr

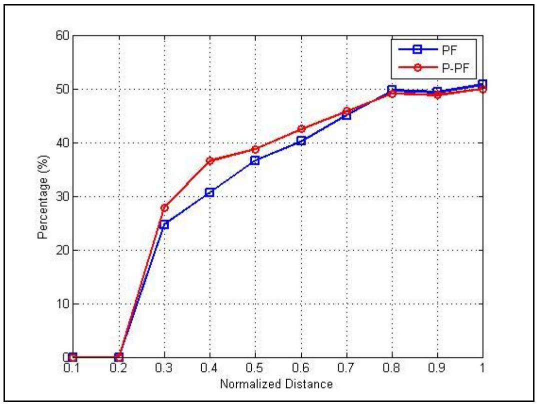

Figure 9. User Retransmissions Percentage vs Normalized Distance at 50km/hr

7 CONCULUSIONS

In this paper, the performance of scheduling algorithm in HSDPA system at different user speed ranging from 3km/hr to 50 km/hr is analyzed. The performance metrics include service throughput, fairness, retransmissions both at system level and user level. Three packet scheduling schemes are used namely Maximum C/I, Proportional Fair, and Round Robin. It has been observed that the average service throughput per Node B decreases with the increase in user speed. Furthermore, the effect of high speed over the performance of scheduling schemes taking channel conditions into consideration during scheduling is higher as compared to non-channel dependent scheduling schemes. It has been observed that the proportional fair scheduling scheme is more prone to the link adaptation error occurred at high user speeds. Also, the number of retransmissions increases with the increase in user speed. To counter the effect of high user speed over the performance of scheduling algorithm, a pre-emptive approach has been introduced for scheduler before applying scheduling schemes. Simulation results show the considerable gain in terms of retransmissions at slower and moderate speeds.

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REFERENCES

1. *Mahmood, H., 2011. Performance Analysis of Scheduling Algorithms for 3.5G Mobile Cellular Systems. MS Thesis, Electrical Engineering Department, CIIT Lahore, Pakistan.*
2. *Holma, H., Toskala, A., 2006. HSDPA/HSUPA for UMTS. John Wiley and Sons.*
3. *Holma, H., Toskala, A., 2004. WCDMA for UMTS (3rd ed.). John Wiley and Sons.*
4. *Malkowski, M., Kemper, A., Wang, X., 2007. Performance of Scheduling Algorithms for HSDPA. In Proceedings of Second International Conference on Communications and Networking in China, CHINACOM '07, pp: 1052-1056.*
5. *Haider, A., Harris, R., 2007. A Novel Proportional Fair Scheduling Algorithm for HSDPA in UMTS Networks. In Proceedings of The 2nd International Conference on Wireless Broadband and Ultra Wideband Communications, AusWireless, pp: 1-7.*
6. *John, J. U., Trianon, A. M., Pillay, S., 2006. A Study on the Characteristics of the Proportional Fairness Scheduling Algorithm in HSDPA. In Proc. of The 4th Student Conference on Research and Development, Selangor, Malaysia, SCOReD, pp: 33-37*
7. *Jalali, A., Padovani, R., Pankaj, R., 2000. Data Throughput of CDMA-HDR a High Efficiency- High Data Rate Personal Communication Wireless System. In Proc. of The IEEE 51st Vehicular Technology Conference Proceedings, VTC 2000-Spring Tokyo, vol. 3, pp: 1854-1858.*
8. *Ameigeiras, P., 2003. Packet Scheduling And Quality of Service in HSDPA, PhD Thesis, Institue of Electronic Systems, Aalborg University, Denmark.*
9. *ETSI/SMG2, 1998. Evaluation Report for ETSI UMTS Terrestrial Radio Access (UTRA), ITU-R RTT Candidate Submission, Tdoc SMG2 260/98.*

10. *Members of 3GPP TSG-RAN Working Group 1, 2000. Common HSDPA System Simulation Assumptions, 3GPP, TSGR1#15(00)1094.*
11. *Musolesi, M., Mascolo, C., 2009. Mobility Models for Systems Evaluation A Survey. Book Chapter in B. Garbinato, B., Miranda, H., & Rodrigues, L., Middleware for Network Eccentric and Mobile Applications, Springer.*
12. *Gudmundson, M., 1991. Correlation model for shadow fading in mobile radio systems. Electronics Letters, vol. 27, issue 23, pp: 2145-2146.*
13. *Members of 3GPP TSG-RAN Working Group 4, "Revised HSDPA CQI Proposal. 3GPP", Technical Report R4-020612, April 2002.*
14. *3GPP Technical Specification Group Radio Access Network, 2008. Medium Access Control (MAC) Protocol Specifications, 3GPP TS 25.321, Release 5, V5.14.0.*
15. *Ofuji, Y., Morimoto, A., Abeta, S., Sawahashi, M., 2002. Comparison of Packet Scheduling Algorithms Focusing on User Throughput in High Speed Downlink Packet Access. In Proc. of The 13th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, vol. 3, pp: 1462-1466.*
16. *Jain, R., Chiu D., Hawe, W., 1984. A Quantitative Measure of Fairness and Discrimination for Resource Allocation in Shared Computer System. Technical Report, Digital Equipment Corporation, DEC-TR-301.*
17. *Ying-Hong Wang; Kuo-Feng Huang; Cheng-Yi Le, "Packet Scheduling Algorithm with QoS Provision in HSDPA," Advanced Information Networking and Applications, 2009. AINA '09. International Conference on , pp.616-623, 26-29 May 2009 doi: 10.1109/AINA.2009.15*
18. *Li, W., Gulliver, T. A., "Performance of enhanced proportional fair scheduling in HSDPA for multimedia service streaming," IEEE Pacific Rim Conference on Communications, Computers and Signal Processing, 2009. 23-26 Aug. 2009. pp. 314-318 doi: 10.1109/PACRIM.2009.5291352*
19. *Deng, R. et. Al, "A delay prediction based content and channel aware packet scheduler for real-time video over HSDPA," The 14th IEEE International Symposium and Workshops on a World of Wireless, Mobile and Multimedia Networks (WoWMoM) 2013.*