Novel 3-Stage Scheduler for Real Time Traffic in an OFDMA System with Delay and Retransmission Constraints

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***Abstract*—Emerging wireless communication systems use MIMO-OFDM with adaptive modulation and Hybrid Automatic Repeat Request (HARQ) techniques to enables high bit rate and low packet error rate. In this work, a 3-Stage packet scheduling algorithm that is HARQ aware is proposed, which supports real time service with multi-level delay constraints and retransmission constraints in OFDM systems. For performance analysis, three Quality of Service (QoS) parameters namely packet loss rate, fairness, and throughput are studied. Corresponding to these three metrics and depending upon the delay and retransmission constraints, a 3-Stage scheduling strategy is proposed. It is assumed that the packets are lost due to violation of the delay constraint and/or channel induced error, even after allowing the maximum number of retransmissions. Simulation result shows that this novel 3-Stage scheduler achieves a balance between the three QoS metrics, and could therefore be preferred over Modified Largest Weighted Delay First, Proportion Fair, and Max Rate schedulers, which can not simultaneously satisfy all the three QoS metrics.**

***Index Terms*—Proportion Fair, Max Rate, MLWDF, HARQ, Throughput, Fairness, PLR**

I. Introduction

Orthogonal Frequency Division Multiple Access (OFDMA) technology enables frequency agile resource allocation where a set of sub-carriers can be allocated to a user terminal based on the scheduling logic used. Hybrid Automatic Repeat Request (HARQ) is essentially a combination of Forward Error Correction (FEC) with Automatic Retransmission Request (ARQ). The Third generation partnership project Long term evolution (3GPPLTE) uses OFDM with link adaptation and HARQ techniques to enable low packet error rate. Therefore, it is essential to have a HARQ packet scheduler. In some of the early work on wireless packet schedulers, errors in wireless transmission have not been considered. However, unless HARQ attempts are given some priority by the schedular, it is well known that overall performance of the application would suffer [1], [2].

The Max Rate rule schedules those user whose channel condition (In interference limited deployment typical in reuse 1 OFDMA cellular system, it is the post processing Signal to Interference Noise Ratio that is used in deciding which user gets scheduled. For brevity, we refer this here simply as channel condition.) is better than the other users and thereby maximizes the throughput. A user whose channel condition is bad, gets scheduled rarely and thus Max Rate does not guarantee fairness. To increase the Fairness among users Proportional Fair (PF) scheduler [3] was proposed. It schedules the user by comparing the ratio of current data rate to average data rate of a particular user so that fairness can be addressed. Along with fairness and throughput, packet delay is a key parameter to measure the performance of highly delay sensitive, real time application like video streaming. PF scheduler as such does not consider packet delay. Modified Largest Weighted Delay First (MLWDF) algorithm [4] is able to handle delay sensitive traffic well. It schedules the user by comparing the combination of packet delay, current data rate and average data rate in an optimal way.

In this paper, we consider all the three Quality of Service (QoS) parameters namely: (i) packet loss rate (PLR), (ii) fairness and (iii) sum throughput. Corresponding to the three metrics we propose a scheduling strategy which has three stages. From the quality of service (QoS) perspective of real time traffic, it is essential to give priority to minimize packet loss rate (PLR), maximize fairness and maximize throughput simultaneously that is what this 3-Stage scheduler aim to do. The 3-Stage scheduler is compared for real time traffic with the Max Rate, the PF, and the MLWDF algorithm. Using simulation results we show that the proposed scheduler gives a good compromise between the three QoS metrics.

The remainder of the paper is organized as follows. In Section 2, the LTE-like simulation model are presented that is considered in this paper. Section 3 discusses about the 3-Stage scheduler followed by simulation results are shown in Section 4, while conclusion are given in Section 5.

II. LTE-like Simulation Model

Fig. 1. depicts the downlink frame structure LTE Standard. On frequency axis total bandwidth is divided into N sub bands and in time axis into transmission time interval (TTI) each with length of 1 ms. Here 1 sub band contains 3 physical resource

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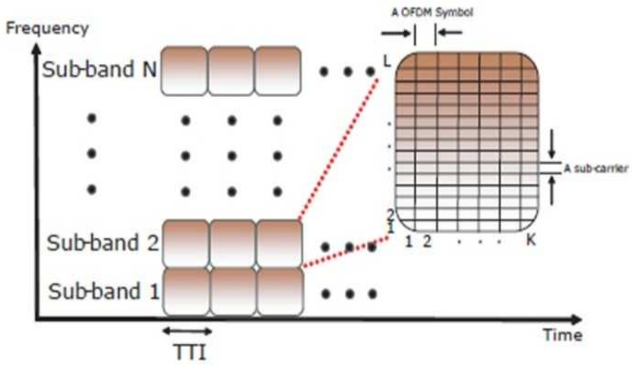

Fig. 1. Shows OFDMA framing and channelization

block (PRB) and 1 PRB has 12 sub-carriers and 14 OFDMA symbols. The simulation of 3-Stage, MLWDF, PF and Max Rate have performed using seven hexagonal cells of 10 MHz bandwidth with 50 PRBs and 2 GHz carrier frequency. There are 3 sectors in a cell and each sector contains 10 users. Users are uniformly located within the cell and constantly moving at a constant speed of 8.33 Km/h in random directions. It is assumed that each user reports its instantaneous downlink SNR values on each PRB and at the beginning of each TTI to the serving node. The reported instantaneous downlink SNR value is used to determine the feasible data rate for one PRB. The 3GPP LTE Downlink system parameters are given in Table I.

An incremental redundancy HARQ protocol is used. The HARQ process takes 2ms, i.e., 2 TTI round trip time and maximum number of retransmission is limited to 4. It is assumed that the scheduling interval is 1 TTI i.e. 1ms and the number of PRBs that may be allocated to a user in each scheduling interval is variable.

MLWDF [1], PF [4], Max Rate [4] algorithms are proposed for the single carrier transmission. We modified these algorithms to support multi-carrier transmission in the downlink LTE system. In this simulation, retransmissions takes place for each algorithm, if transmission of any packet fails. The following QoS in equations (1), (2), (3) are used for performance analysis.

$$Average\ throughput = \frac{1}{N*T}\sum_{i=1}^{N}\sum_{t=1}^{T} t\_put_i(t) \quad (1)$$

$$PLR = \frac{\sum_{i=1}^{N}\sum_{t=1}^{T} pd_i}{\sum_{i=1}^{N}\sum_{t=1}^{T} pa_i} \quad (2)$$

$$Fairness = \frac{1}{N}\frac{(\sum_{i=1}^{N} t\_put_i)^2}{\sum_{i=1}^{N}(t\_put_i)^2} \quad (3)$$

where $t\_put_i(t)$, pd_i , pa_i are the throughput, total size of discarded packets and the total size of all packets that have arrived into the buffer of user i at time t respectively. T and N are the total number of slots for which simulation has done and total number of users respectively. Referred to [5].

TABLE I
SIMULATION PARAMETERS

Parameters	values
Carrier Frequency	2 GHz
Bandwidth	10 MHz
Number of Sub-carriers	600
Number of PRBs	50
Number of Sub-carriers per PRB	12
Slot Duration	1ms
Scheduling Time(TTI)	1ms
Number of OFDMA Symbols per Slot	14
FFT size	1024
HARQ scheme	Incremental redundency
Maximum Allowed retransmission number	4
Total number of User	210
Number of Interferer cell	2

III. DESCRIPTION OF 3-STAGE SCHEDULER

3-Stage scheduler divides the users into three stage based on how close the packets are from transmission deadline.

TFT_i= Time for Transmission [2] is defined as the time duration up to which packet i can stay in the buffer for transmission. It has an integer value normalized by TTI duration.

$TFL_i(n)$ = Time duration upto which packet is not dropped. Equations (4) and (5) shows analytical description of TFT_i and $TFL_i(n)$.

$$TFT_i = k * TTI \quad (4)$$

$$TFL_i(n) = TFT_i - W_i(n) \quad (5)$$

Where $W_i(n)$ is waiting time for a Head of Line (HOL) packet in ith buffer in nth TTI and k is an integer. The proposed 3-Stage scheduler has following steps:

Step A. Divide the users into three stages depending upon the value of K_{max} (maximum value of k among all user) and $TFL_i(n)$ such that distribution of $TFL_i(n)$ along the stages is in Geometrical Progression (GP). Stage 1 contains the users whose $TFL_i(n)$ is one. Stage 2 contain the users whose $TFL_i(n)$ value are 2, 3 or 2, 3, 4 or 2, 3, 4, 5 (depending upon the value of k_{max}) and the remaining users will be in stage 3. Distribution of users for different value of K_{max} is given in Table II, users will be distributed similarly for higher values of K_{max}. GP is used here, because it gives a good compromise

TABLE II
DISTRIBUTION OF USERS BASED ON TFL

	TFL	TFL	TFL
stage1	1	1	1
stage2	2, 3	2, 3, 4	2, 3, 4, 5
stage3	4, 5, 6, 7	5, 6....13	6, 7...21
	$K_{max} \leq 7$	$8 \leq K_{max} \leq 13$	$14 \leq K_{max} \leq 21$

TABLE III
EXAMPLE OF A SUB-BAND ALLOCATING IN STAGE 1

	user 1	user 2	user 3
subband 1	5	6	7
subband 2	7	6	5
subband 3	7	5	6
Allocated band	Subband 3	Subband 2	Subband 1

among the three QoS metrics as shown by extensive simulation results, some of which are shown in section IV . Instead of GP, other progressions can be used to divide the users into stages depending on the QoS requirement. For example if we keep more number of users in the third stage compared to what GP provides, it will give more throughput than GP gives. However this increase will come at the cost of higher packet loss rate and degraded fairness. Similarly if we put more number of users into second stage performance of fairness may improve at the cost of degradation of the performance of packet loss rate and throughput.
In summary the purpose of the three stages are: -
Stage 1: To minimize the Packet Loss Rate.
Stage 2: To maximize the Fairness.
Stage 3: To maximize the Throughput.

From the QoS perspective of real time traffic it is essential to give priority to minimize the packet loss rate, maximize the Fairness and maximize the throughput respectively therefore we schedule stages 1, 2 and 3 respectively.

Step B. Schedule the users of stage 1:- Consider the channel matrix, where each column corresponds to the different user of stage 1 and each row corresponds to a sub band. C_{ij} denotes the number of bits can be transmitted through sub band i to the user j. Depending upon the modulation and coding scheme levels, C_{ij} will have N different Number of bits values i.e. NOB_1, NOB_2, NOB_3, NOB_4.........NOB_N. Define coordinate of each C_{ij} which is defined as (s_i, u_j) and coordinate group of NOB_i i.e CG_{NOB_i} which contains coordinate of all C_{ij} which is equal to NOB_i. Assuming $NOB_1 < NOB_2 < NOB_3 < NOB_4$ $<$.........$< NOB_N$, then to improve QoS CG_{NOB_N} must be allocated prior to the $CG_{NOB_{N-1}}$ and so on. Among the C_{ij} in coordinate group CG_{NOB_i}, C_{ij} is allocated when its coordinate is unique in that particular group. Otherwise choose an unique combination from all possible combinations such that sum throughput is maximized and allocate them.
Here in Table III NOB_3 is 7, NOB_2 is 6 and so on. Coordinate Groups are defined by
CG_{NOB_3}= {(s_1,u_3),(s_2,u_1),(s_3,u_1)}
CG_{NOB_2}= {(s_1,u_2),(s_2,u_2),(s_3,u_3)}
To minimize the PLR CG_{NOB_3} should be allocated first. Since only coordinate(s_1,u_3) is unique so subband 1 is allocated to user 3. Now user 1 can be served by subband 2 or subband 3 so following are the possible combinations
combination 1: (s_2,u_1) + (s_3,u_2) = 12
combination 2: (s_2,u_2) + (s_3,u_1) = 13
choose combination 2 since sum throughput is maximum and allocate them.

Step C. Schedule the users of stage 2:-
Schedule the users of stage 2 when its C_{ij} is more then C_{avg} in round robin fashion so that fairness can be maximized.

$$C_{avg} = \frac{1}{M*N} \sum_{i=1}^{M} \sum_{j=1}^{N} C_{ij}$$

Where N = no of users in stage 2 and
M = number of sub bands left.

Step D. Schedule the users of stage 3:
Among all the users of stage 3 schedule the user whose C_{ij} value is equal to NOB_N. There may be a case where a user contains more than one C_{ij}, whose value is equal to NOB_N in that case we schedule the user more than one time provided available bits for transmission are sufficient. Again we schedule the user whose C_{ij} value is equal to NOB_{N-1} followed by NOB_N and so on. This process will continue till sub-band left.

IV. SIMULATION RESULT AND DISCUSSION

We simulate downlink physical layer Long Term Evolution release 8 [6] along with the parameter mentioned in Section II. Four types of real-time traffic sources with different delay constraints are used, as given in Table IV. Fig. 2. shows PLR performance of 3-Stage, PF, MLWDF and Max Rate with the increasing number of arrival bits. 3-Stage scheduler improves PLR performance by giving more priorities to the HARQ users and the users closing to transmission deadline. A significant degradation of the PLR performance in the Max Rate and PF are because they do not consider delay of packets. As MLWDF consider waiting time of packet so PLR of MLWDF is just followed by 3-Stage scheduler.

Fig. 3. shows average user throughput of the 3-Stage, PF, MLWDF, and Max Rate. From the figure, it can be observed that among the PF, MLWDF, Max Rate, and 3-Stage, Max Rate achieves the highest throughput as it consider only channel

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condition. The proposed scheduler gives throughput slightly lower than Max Rate but higher than PF. MLWDF returns the lowest throughput as it consider both channel condition and waiting time of a packet however all four schedulers achieve almost same throughput performance at a higher number of arrival bits per frame.

The fairness performance of each scheduling algorithm is shown in Fig. 4. It can be observed that the 3-Stage scheduler achieves a fairness almost equal to that of PF and MLWDF. The Max Rate returns the lowest fairness as it only considers the best channel condition for the scheduling decision.

TABLE IV
TFT FOR FOUR REAL-TIME TRAFFIC SOURCES

Service	Traffic class	TFT
Voice	Conversational	200ms
Gaming	Conversational	400ms
Audio streaming	Streaming	1500ms
Video streaming	Streaming	2000ms

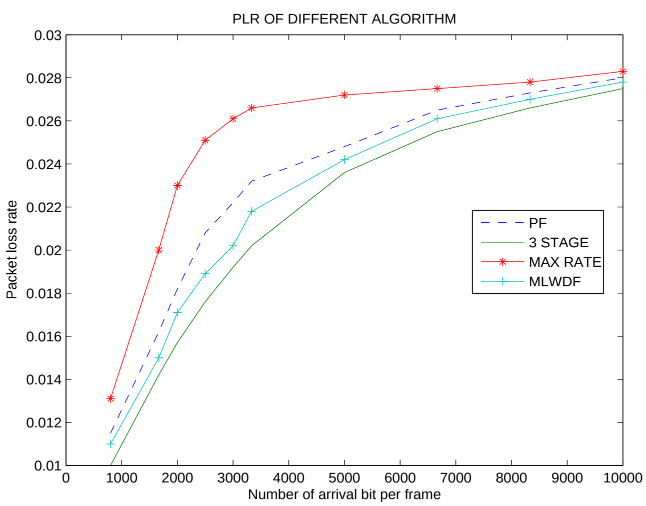

Fig. 2. Shows plr vs. no of arrival bit per frame.

V. Conclusion

This paper investigated the performance of proposed algorithm along with well known scheduling algorithm in the downlink 3GPP LTE system. Using the TFL parameter, an efficient scheduling scheme that always prioritizes urgent real time traffic users and HARQ users in OFDMA environment has developed. Simulation results have shown that the proposed scheduler scheme gives a good compromise among the three QoS metrics.

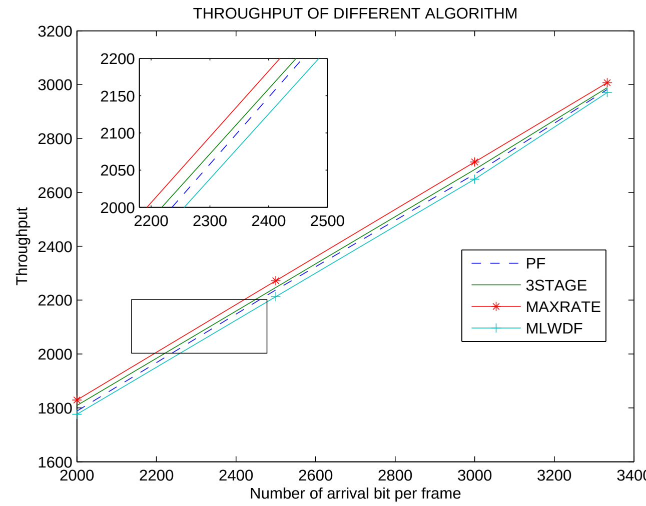

Fig. 3. Shows Average throughput vs. no of arrival bit per frame.

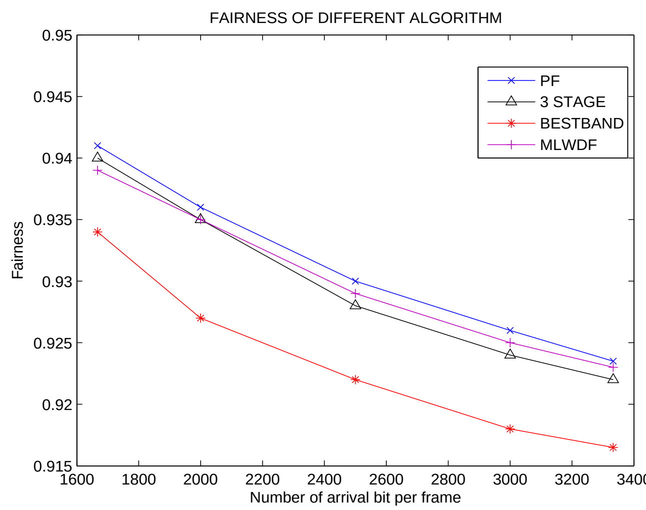

Fig. 4. Shows fairness vs. no of arrival bit per frame.

References

[1] M. Andrews, K. Kumaran, K. Ramanan, A. Stolyar, P. Whiting, and R. Vijayakumar, "Providing quality of service over a shared wireless link," *IEEE Communications Magazine*, vol. 39, no. 2, pp. 150–154, feb 2001.
[2] J. Park, S. Hwang, and H. Cho, "A packet scheduling scheme to support real-time traffic in OFDMA systems," in *IEEE 65th Vehicular Technology Conference, 2007. VTC2007-Spring.* IEEE, 2007, pp. 2766–2770.
[3] A. Jalali, R. Padovani, and R. Pankaj, "Data throughput of CDMA-HDR a high efficiency-high data rate personal communication wireless system," in *IEEE 51st Vehicular Technology Conference Proceedings, 2000. VTC 2000-Spring Tokyo*, vol. 3. IEEE, 2000, pp. 1854–1858.
[4] H. Ramli, R. Basukala, K. Sandrasegaran, and R. Patachaianand, "Performance of well known packet scheduling algorithms in the downlink 3GPP LTE system," in *2009 IEEE 9th Malaysia International Conference on Communications (MICC).* IEEE, 2009, pp. 815–820.
[5] H. Ramli, K. Sandrasegaran, R. Basukala, and T. Afrin, "HARQ aware scheduling algorithm for the downlink LTE system," in *2011 4th International Conference on Modeling, Simulation and Applied Optimization (ICMSAO).* IEEE, 2011, pp. 1–4.
[6] Long Term Evolution Release 8, "www.3gpp.org/LTE."

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