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Customized Packet Scheduling Algorithm for LTE Network

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Abstract

Advanced mobile networks are expected to provide omnipresent broadband access to a continuously growing number of mobile users. LTE system represents 4G mobile network. The key feature thereof is the adoption of advanced Radio Resource Management procedures in order to increase the system performance up to Shannon's limit. Packet scheduling mechanisms, in particular, play a fundamental role, because they are responsible for choosing, with fine time and frequency resolutions, how to distribute scarce radio resources among different mobile stations, taking into account channel conditions and QoS requirements. This objective should be accomplished by providing an optimal trade-off between spectral efficiency and fairness. In this context, this paper proposes customized packet scheduling algorithm designed to adaptively alter scheduling schemes considering multiple input variables in order to maximize spectral efficiency as well as overall system performance.

Keywords: LTE; RRM; Packet Scheduling Algorithm; CQI; Throughput; Spectral Efficiency; Fairness; System Delay.

1. Introduction

The focus of this paper is to develop a customized packet scheduling algorithm that takes into account the following variables – UE (User Equipment) reported CQI, UE distance from eNB (LTE radio base station), packet delay, UE buffer status and cell load - while adaptively switching different scheduling schemes in order to optimize radio resource allocation mechanism within highly unpredictable wireless environment.

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The packet scheduler in general works at the radio base station and it is in charge of assigning portions of spectrum shared among users, by following specific policies. In a wireless network, the packet scheduler plays an additional fundamental role: it aims to maximize the spectral efficiency through an effective resource allocation policy that reduces or makes negligible the impact of channel quality drops. In fact, on wireless links, the channel quality is subject to high variability in time and frequency domains due to several causes, such as fading effects, multipath propagation, Doppler effect, and so on and so forth. For these reasons, channel-aware solutions are usually adopted in LTE system because they are able to exploit channel quality variations by assigning a higher priority to users experiencing better channel conditions.

In this context, the design of effective resource allocation strategies becomes crucial. In fact, the efficient use of radio resources is essential to meet the system performance targets and to satisfy user needs according to specific Quality of Service (QoS) requirements [1].

2. Packet Scheduling in LTE System

Multi-user scheduling is one of the main features in LTE systems because it is in charge of distributing available resources among active users in order to satisfy their QoS needs. Data channel (e.g. PDSCH – Physical Downlink Shared Channel) is shared among the users, meaning that portions of the spectrum should be distributed every TTI among them. Packet schedulers for both downlink and uplink path are deployed at the eNB and they work with a granularity of one TTI and one RB in the time and frequency domain, respectively.

Resource allocation for each UE is usually based on the comparison of per-RB metrics: the k-th RB is allocated to the j-th user if its metric $m_{j,k}$ is the biggest one, i.e., if it satisfies the equation:

$$m_{j,k} = \max_{i}\{m_{i,k}\} \qquad (1)$$

These metrics can be somehow interpreted as the transmission priority of each user on a specific RB. Based on the desired performance requirement, their computation is usually evaluated starting from information related to each flow and used to drive the allocation decision:

- Status of transmission queues: the status of transmission queues at UEs could be used for minimizing packet delivery delays (e.g., the longer the queue, the higher the metric).
- Channel Quality: reported CQI values could be used to allocate resources to users experiencing better channel conditions (e.g., the higher the expected throughput, the higher the metric).
- Resource Allocation History: information about the past achieved performance can be used to improve fairness (e.g., the lower the past achieved throughput, the higher the metric).
- Buffer State: receiver-side buffer conditions might be used to avoid buffer overflows (e.g., the higher the available space in the receiving buffer, the higher the metric).
- Quality of Service Requirements: the QCI value associated to each flow might be used to drive specific policies with the aim of meeting QoS requirements.

Every TTI the scheduler performs the allocation decision valid for the next TTI and sends such information to UEs using the PDCCH (Physical Downlink Control Channel). DCI messages in the PDCCH payload inform UEs about RBs allocated for data transmission on the PDSCH in the downlink direction. Moreover, DCI messages are used to inform users about the dedicated radio resources for their data transmission on the PUSCH in the uplink direction.

A relevant importance in LTE schedulers is assigned to the 'channel sensitivity' concept. The basic idea is to schedule transmission for UEs that, at the current time and on a given frequency, are experiencing 'good' channel conditions based on the selected metric. This approach, also known as Frequency Domain Packet Scheduler (FDPS), counteracts the time-varying and frequency-selective nature of the wireless channel. Furthermore, the characteristic of the fast fading to be independent on users can be exploited by allocation procedures, obtaining what is usually addressed as 'multi-user diversity' gain. In [2], authors show that the overall system capacity grows with the number of users. Therefore, we can define the multi-user diversity gain as the advantage, in terms of system capacity, of serving more than one user. In fact, in a scenario with many users experiencing independent fading effects, the probability to find a user with good channel conditions at a given time is very high. The advantage of this behavior is twofold: it enables the transmission when high data rates are achievable (i.e., under good channel conditions the AMC module will select a more effective MCS) and, at the same time, it is naturally immune to frequency-selective fading effects (i.e., a user experiencing very bad channel condition will not be served). Nevertheless, multi-user diversity gain appears to be upper bounded, and this should be taken into account during the design phase. As matter of fact, increasing the number of users in the system also increases the control overhead.

Figure 1 represents the main RRM modules that interact with the downlink packet scheduler. The whole process can be divided in a sequence of operations that are repeated, in general, every TTI:

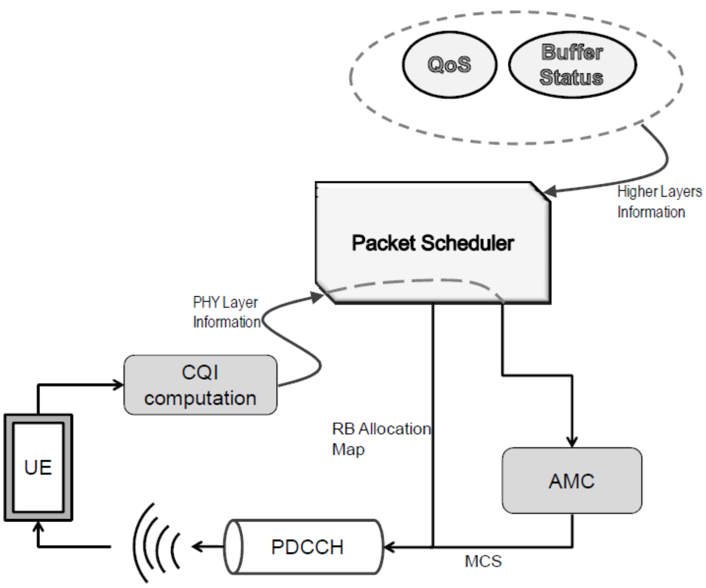

Figure 1: Simplified model of a packet scheduler

1. Each UE decodes the reference signals, computes the CQI, and sends it back to the eNB.
2. The eNB uses the CQI information for the allocation decisions and fills up RB ‘allocation mask’.
3. The AMC module selects the best MCS that should be used for the data transmission by scheduled users.
4. The information about these users, the allocated RBs, and the selected MCS are sent to the UEs on the PDCCH.
5. Each UE reads the PDCCH payload and, in case it has been scheduled, accesses the proper PDSCH channel.

Above outlined workflow slightly differs in the uplink direction as the eNB does not need any additional information on the uplink channel quality [3].

3. Channel Unaware / Aware Packet Scheduling Schemes

Channel unaware packet scheduling strategies were firstly introduced in wired networks [4], they are based on the assumption of time-invariant and error-free transmission media. While their direct application in wireless LTE network is not realistic, they are typically used jointly with channel-aware approaches to improve system performance. Below the authors are going to overview a couple of channel unaware strategies deployed in current commercial wireless networks.

Round Robin also is known as Resource Fair: It is one of the simplest scheduling algorithms which assigns resources to each mobile station in equal portion and order with the same priority. In this context, the concept of fairness is related to the amount of time in which the channel is occupied by users. Of course, this approach is not fair in terms of user throughput, that, in wireless systems, does not depend only on the number of occupied resources, but also on the experienced channel conditions. Furthermore, the allocation of the same amount of time to users with very different application-layer bitrates is not efficient.

Blind Equal Throughput: Throughput Fairness can be achieved with Blind Equal Throughput (BET) which stores the past average throughput achieved by each user and uses it as metric [5]. In this case, the metric (for the i-th user) is calculated as follows:

$$m_{i,k}^{BET} = 1/\overline{R^i}(t-1) \qquad (2)$$

where

$$\overline{R^i}(t) = \beta\overline{R^i}(t-1) + (1-\beta)r^i(t) \qquad (3)$$

and $0 \leq \beta \leq 1$ whereas $r^i(t)$ is data rate achieved by the i-th user at time t.

Thanks to its interesting properties, this metric is widely used in most of the state of the art schedulers. First of all, it is easy to note that every TTI, BET allocates resources to flows that have been served with lower average throughput in the past. Under this allocation policy, the user experiencing the lowest throughput, performs, in practice, resource preemption: he will be served as long as he does not reach the same throughput of other users in the cell. In this way, users with bad channel conditions are allocated more often than others, with a consequent fairness improvement. The factor $R^i(t)$, that represents the past average throughput experienced by the i-th user at time t, is calculated as a moving average and it is updated every TTI for each user. Its role will be better explained below, where we will also highlight how BET metric assumes a great importance for guaranteeing fairness in channel-aware schemes.

As far as channel aware scheduling strategies are concerned, thanks to CQI feedbacks, which are periodically sent (from UEs to the eNB) using ad hoc control messages, the scheduler can estimate the channel quality perceived by each UE; hence, it can predict the maximum achievable throughput.

Let $d^i(t)$ and $d^i_k(t)$ be the achievable throughput expected for the i-th user at the t-th TTI over the entire bandwidth and over the k-th RB, respectively. The mentioned values can be calculated using the AMC module or simply estimated, considering the well-known Shannon expression for the channel capacity:

$$d_k^i(t) = \log[1 + SINR_k^i(t)] \tag{4}$$

This definition gives a numerical explanation of the relevance of channel-awareness in the wireless context. Below the authors are going to overview several channel aware strategies also deployed in current commercial wireless networks.

Maximum Throughput also is known as Best CQI or Maximum C/I [6]: The strategy known as Maximum Throughput (MT) aims at maximizing the overall throughput by assigning each RB to the user that can achieve the maximum throughput in the current TTI. Its metric can be simply expressed as:

$$m_{i,k}^{MT} = d_k^i(t). \tag{5}$$

MT is obviously able to maximize cell throughput, but, on the other hand, it performs unfair resource sharing since users with poor channel conditions (e.g. cell-edge users) will only get a low percentage of the available resources (or in extreme case, they may suffer starvation).

Proportional Fair Scheduler: A typical way to find a trade-off between requirements on fairness and spectral efficiency is the use of Proportional Fair (PF) scheme. Its metric is obtained merging the ones of MT and BET; it can be expressed as:

$$m_{i,k}^{PF} = m_{i,k}^{MT} \cdot m_{i,k}^{BET} = d_k^i(t)/\overline{R^i}(t-1) \tag{6}$$

The idea is that the past average throughput can act as a weighting factor of the expected data rate so that users in bad conditions will be surely served within a certain amount of time.

Several algorithms have been proposed in the literature to extend PF strategy. In [7], the approach of PF was formulated as an optimization problem, with the objective of maximizing the achieved throughput under the typical constraints of an LTE system. Results showed that performance obtained by using different PF implementations increases the complexity of the optimization problem.

The Generalized Proportional Fair (GPF) approach is developed in [8]. The PF metric is slightly modified by means of two novel parameters, ξ, and ψ:

$$m_{i,k}^{GPF} = \frac{\left[d_k^i(t)\right]^{\xi}}{\left[\overline{R^i}(t-1)\right]^{\psi}} \tag{7}$$

The role of ξ and ψ is to modify the impact on the allocation policy of the instantaneous data rate and of the past achieved throughput, respectively. Intuitively, setting $\xi = 0$, the GPF metric would become equal to the BET metric, meaning that fairness can be achieved by the system regardless of the channel conditions. On the other hand, setting $\psi = 0$ would bring to an MT policy with no fairness. Note that the basic PF metric defined in Eq. (6) results as a particular case of the GPF with $\xi = \psi = 1$. Similarly, to the GPF approach, in [9] and in [10] authors use adaptive schemes capable of tuning the achievable fairness level, depending on the system conditions.

Furthermore, in [11] authors developed Enhanced PF (EPF) algorithm whereby the level of fairness as well as delivered spectral efficiency is being modified by parameter α. This proposed EPF algorithm aims to achieve a significant increase in system throughput with a slight reduction in fairness performance compared to the conventional PF scheduling algorithm. The new metric of the proposed scheduling algorithm can be written as follows:

$$m_{i,k}^{Enh} = \log_2\left(r_k^i(t)\right) - \alpha\log_2\left((t_c-1)\bar{R}^i(t) + r_i(t)\right) \tag{8}$$

So, according to the new metric the $k-th$ RB should be allocated to the $j-th$ UE such that:

$$j = \arg\max_i \log_2\left(r_k^i(t)\right) - \alpha\log_2\left((t_c-1)\bar{R}^i(t) + r_i(t)\right). \tag{9}$$

The new parameter α introduced in the proposed metric equation is responsible for controlling the trade-off between throughput and fairness achieved by the proposed EPF algorithm. The operating range of α is between 0 and 1 ($0 < \alpha < 1$), when α=1 the proposed EPF scheduling algorithm shows the same performance as the conventional PF scheduling algorithm which is characterized by high fairness but with low spectral efficiency. On the other hand, when α=0, the proposed enhanced scheduling algorithm shows the same performance of the best-CQI scheduling algorithm which is characterized by high throughput but with poor fairness index.

4. Customized Packet Scheduling Algorithm

This section of the paper expounds proposed adaptive packet scheduling algorithm and evaluates performance thereof as opposed to multiple different scheduling schemas based upon LTE system simulation results. The customized scheduling algorithm incorporates above mentioned enhanced proportional fair scheduler and dynamically adapts the parameter α every 10 seconds in accord with a cell load and radio conditions. The logical representation of the algorithm is shown below:

$$\alpha = \begin{cases} 1 & \text{if } T_{Cell} < 1.5 \text{ and } N_{UE} < 90, \\ 0.9 & \text{if } T_{Cell} > 1.5 \text{ and } N_{UE} > 90, \\ 1 & \text{if } Q_{Avg} < 4, \\ 0.9 & \text{if } 4 < Q_{Avg} \le 5, \\ 0.7 & \text{if } 5 < Q_{Avg} \le 6, \\ 0.5 & \text{if } 6 < Q_{Avg} \le 7, \\ 0.3 & \text{if } 7 < Q_{Avg} \le 8, \\ 0.1 & \text{if } 8 < Q_{Avg} \le 10, \\ 0 & \text{if } 10 < Q_{Avg}. \end{cases} \tag{10}$$

Where T_{Cell} stands for System/Cell throughput expressed in Mbps, Q_{Avg} – channel quality indicator expressed in index points, N_{UE} – the number of the user equipment.

The logic is as follows – if Cell Throughput is less than 1.5 Mbps and number of connected UEs is more than 90 per cell or UE reported CQI is less than 4 the algorithm deploys parameter α with the value of 1, that is the schema is operating with high level of fairness without consuming much processing power of eNB's baseband unit. As radio link conditions get better the value of the parameter α reduces and approaches the value of zero maximizing the overall system capacity.

The performance of above developed customized scheduling algorithm APF – Adaptive Proportional Fair is being compared with six different scheduling schemas: RR – Round Robin, PF – Proportional Fair, PF07 – Proportional Fair with α = 0.7, PF05 – Proportional Fair with α = 0.5, PF03 – Proportional Fair with α = 0.3 and CQI – Best CQI for non-GBR resource type QCI 6-9 services. The detailed simulation results are listed in Table 1.

Total Cell throughput is simulated (Figure 2) for 7 different scheduling algorithms with increasing number of users. The simulation starts with 10 UEs and thereafter, every second a new UE comes in with random CQI value and buffer status.

Table 1: Simulation Parameters

Simulation Parameters	**Values**
Cellular layout	1 Cell
Radius (Range)	0 - 15 km
Bandwidth	20 MHz
Carrier frequency	1900 MHz
Mode of operation	FDD
MIMO Mode	4x4
Number of PRBs	100
Number of sub-carriers per PRB	12
Total number of Sub-carriers	1200
Sub-carrier spacing	15 kHz
Scheduling interval (TTI)	1 ms
Number of OFDMA symbols per TTI	14 (Normal CP)
Total eNB transmit power	52.04 dBm
Path Loss Cost	Cost 231 Hata model
Shadow Fading	Gaussian lognormal distribution
Multi-path	Rayleigh fading
Modulation and Coding Scheme	QPSK, 16QAM, and 64QAM
Packet Scheduling Algorithm	RR, PF, PF07, PF05, PF03, Best CQI and APF
Simulation Frequency	1 sec
Simulation Duration	3 hours
Erroneous CQI type	Perfect CQI knowledge at eNB

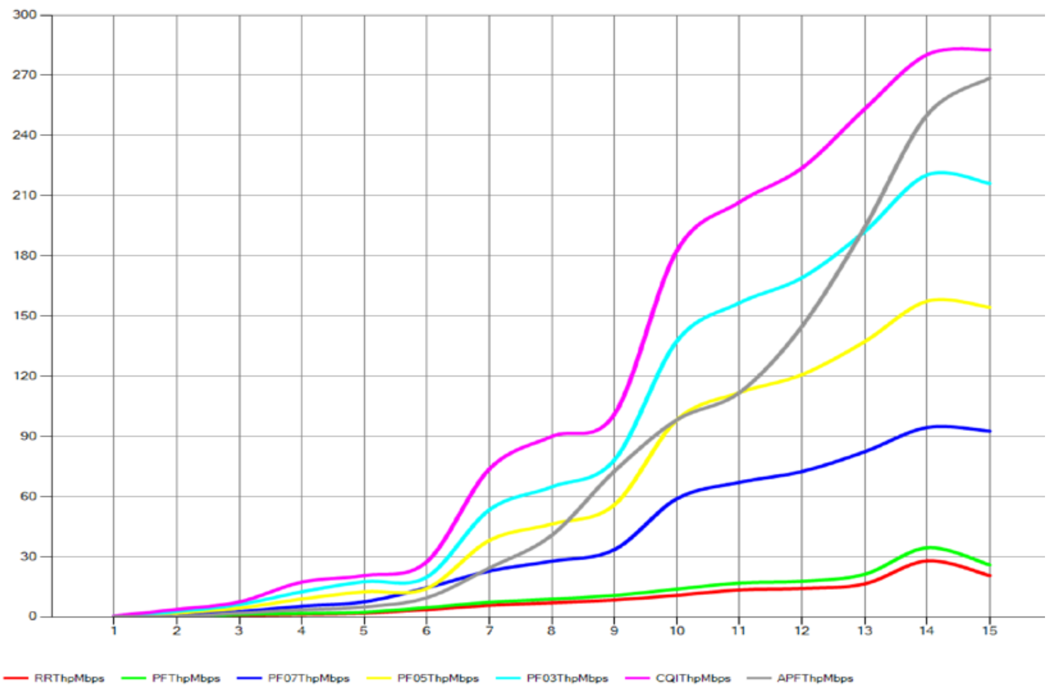

Figure 2: Cell Throughput (Mbps) vs CQI (Ind.) Distribution

Table 2: Cell Throughput of RR, PF, PF07, PF05, PF03, Best CQI and APF Algorithms

CQI (Ind.)	RRThpMbps	PFThpMbps	PF07ThpMbps	PF05ThpMbps	PF03ThpMbps	CQIThpMbps	APFThpMbps
1	0.1	0.1	0.2	0.3	0.4	0.5	0.1
2	0.2	0.2	1.2	1.9	2.7	3.8	0.2
3	0.9	1.3	2.6	4.4	6.2	7.5	2.0
4	1.4	1.7	5.4	9.0	12.5	17.4	3.5
5	1.9	2.4	7.5	12.6	17.6	20.6	5.0
6	3.7	4.6	14.5	14.2	19.9	27.5	9.6
7	5.8	7.3	22.9	38.2	53.4	73.7	24.4
8	7.0	8.9	27.8	46.3	64.9	90.0	40.8
9	8.5	10.7	33.6	55.9	78.3	101.1	72.7
10	10.8	13.9	59.0	98.3	137.6	182.7	98.3
11	13.5	16.9	67.1	111.9	156.6	206.9	111.9
12	14.2	17.8	72.5	120.8	169.1	223.8	145.0
13	16.4	21.3	82.3	137.2	192.1	253.2	194.2
14	28.0	34.5	94.5	157.4	220.4	280.4	250.4
15	20.6	25.9	92.6	154.4	216.1	282.8	268.7

The simulation results show us that Best CQI scheduling schema delivers best system throughput, as it was expected, as it schedules the users with instantaneously best radio link conditions. Nevertheless, in terms of fairness, this scheduling principle is not fair in all situations and could be very biased. In a live network, different UEs will experience variable channel conditions, due to differences in the distance and shadow fading between the base station and the mobile terminal. In other words, this scheduling strategy may 'starve' the UEs with the bad radio channel conditions – e.g. users at the cell edge. Although resulting in the highest system capacity, this situation is often not acceptable from a quality of service point of view. On the other hand, Round Robin (a.k.a. Recourse Fair) scheduling schema uses a different approach as it does not take into account the instantaneous channel conditions, but rather schedules all users sequentially, in a round-robin fashion, consequently it has the lowest system throughput figures.

Proportional Fair (PF) scheduling schema is one of the states of the art algorithms widely used in commercial wireless networks as it maintains a fair balance between capacity and fairness. Whereas, PF07/PF05/PF03 schemas are the variations of PF that favor more capacity rather than fairness. Similar variants of PF packet scheduling algorithms are also widely deployed in live commercial LTE networks by several telecom equipment providers. In light of this statement, let us compare the results of system throughput metric of these scheduling algorithms with the newly developed Adaptive PF (APF). Figure 2 and Table 2 show us the results of the simulation from where we see that APF achieves a way better system throughput (THP) than generic PF algorithm at any given CQI index point – e.g. at CQI value 6 (MCS order used at this RF conditions is QPSK), we gained 108% improvement; at CQI value 9 (MCS order used at this RF conditions is 16QAM), we gained 30% over PF05 and at CQI value 14 (MCS order used at this RF conditions is 64QAM [13]), we gained 14% improvement over PF03 scheduling schema. That is, with APF scheduling algorithm we are maximizing system capacity and therefore, enhancing spectral efficiency.

Figure 3 shows us system Fairness index, computed based upon Jain's equation, distribution against CQI index points for all 7 packet scheduling algorithms. As expected, RR exhibits the best Fairness index 1 that equates to 100%, whereas Best CQI the worst at any given CQI point. It is important to underscore that the customized APF schema yields higher Fairness index than PF07/PF05/PF03 at CQI < 7 (at this point MCS Order used is QPSK). As the radio conditions improve and average UE reported CQI along with it, the Fairness index also degrades for APF schema which is apprehensible due to the fact that the algorithm maximizes system capacity in line with the channel quality index.

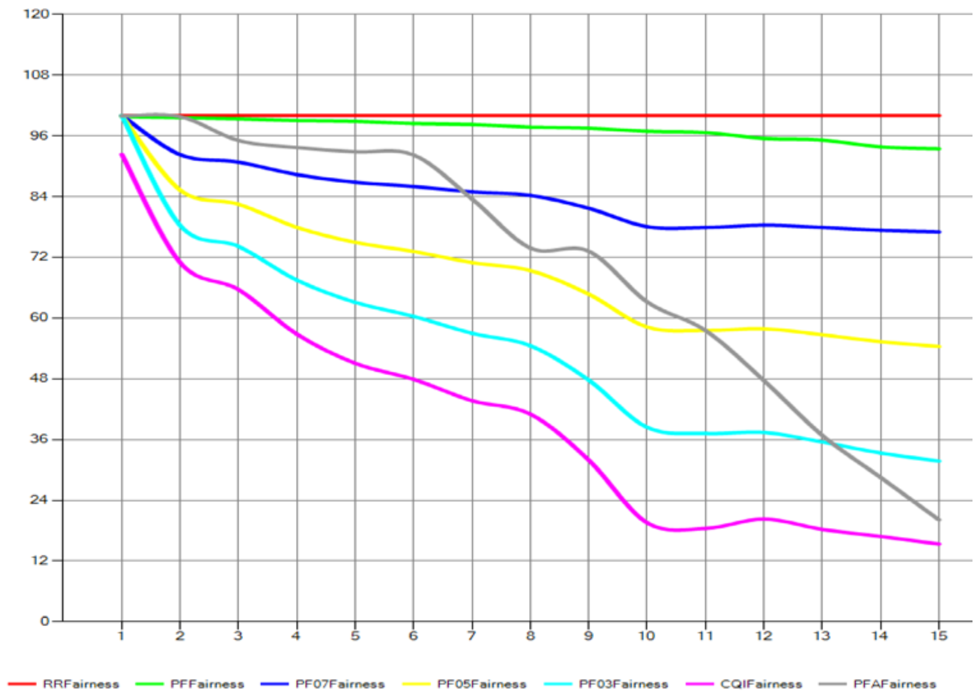

Figure 3: Fairness (Index) vs CQI (Ind.) Distribution

Table 3: Fairness of RR, PF, PF07, PF05, PF03, Best CQI and APF Algorithms

CQI (Ind.)	RRFairness	PFFairness	PF07Fairness	PF05Fairness	PF03Fairness	CQIFairness	PFAFairness
1	100.0	99.8	100.0	100.0	100.0	92.3	99.9
2	100.0	99.6	92.3	85.3	78.3	70.9	99.8
3	100.0	99.3	90.8	82.5	74.1	65.6	95.1
4	100.0	99.0	88.3	77.9	67.5	56.8	93.7
5	100.0	98.9	86.8	75.0	63.1	51.1	92.8
6	100.0	98.4	86.0	73.2	60.3	47.9	92.2
7	100.0	98.2	84.9	71.0	57.0	43.7	83.5
8	100.0	97.7	84.2	69.4	54.5	41.0	73.8
9	100.0	97.5	81.7	64.7	47.7	31.9	73.2
10	100.0	96.9	78.0	58.2	38.4	19.6	63.2
11	100.0	96.6	77.9	57.5	37.2	18.4	57.5
12	100.0	95.5	78.4	57.9	37.4	20.3	47.7
13	100.0	95.2	77.9	56.7	35.5	18.2	36.8
14	100.0	93.8	77.3	55.3	33.3	16.9	28.5
15	100.0	93.4	77.0	54.4	31.8	15.4	20.1

Figure 4 shows us system Delay (expressed in milliseconds), distribution against CQI index points for all 7 packet scheduling algorithms. Basically, it represents an average time that eNB's packet scheduler needs to serve UEs and empty its buffer. It can be seen from Table 4 that APF is able to better serve UEs with less delay as opposed to PF schema at any given CQI value. E.g. at CQI value 4 (MCS order used - QPSK), we attained around 9% improvement; at CQI value 7 (MCS order used - 16QAM), we attained 36% over PF05 and at CQI value 13 (MCS order used - 64QAM [13]), we attained around 37% improvement over PF03 scheduling schema.

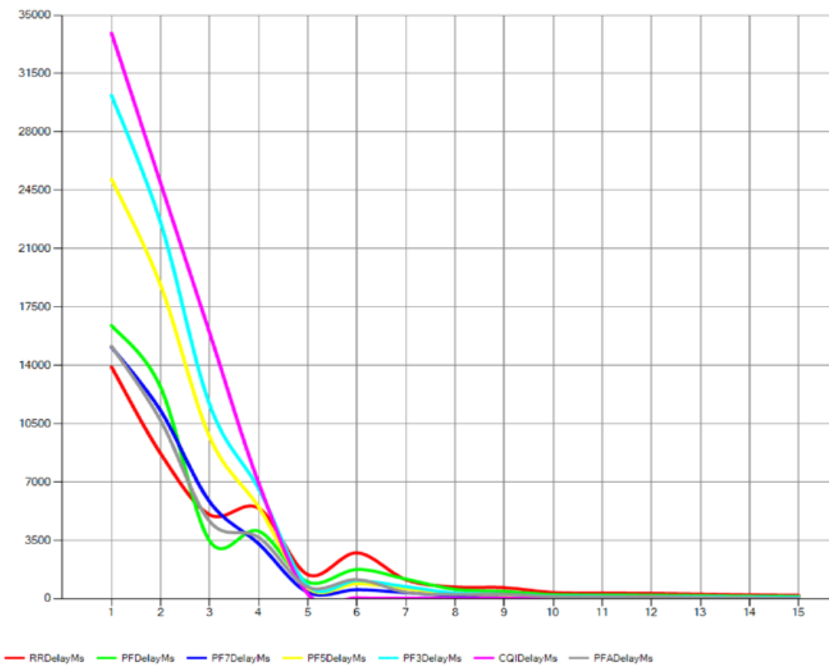

Figure 4: System Delay (ms) vs CQI (Ind.) Distribution

Table 4: System Delay of RR, PF, PF07, PF05, PF03, Best CQI and APF Algorithms

CQI (Ind.)	RRDelayMs	PFDelayMs	PF7DelayMs	PF5DelayMs	PF3DelayMs	CQIDelayMs	PFADelayMs
1	13899.1	16393.0	15094.9	25158.2	30189.8	33923.3	15146.1
2	8707.1	12688.0	11283.4	18805.6	22566.8	24923.3	10697.6
3	5033.3	3455.0	5813.5	9689.1	11627.0	15923.3	4634.2
4	5427.7	4051.5	3292.5	5487.4	6584.9	6923.3	3672.0
5	1438.7	1000.5	383.2	638.6	766.3	276.7	691.8
6	2751.1	1755.0	540.9	901.5	1081.7	48.0	1147.9
7	1137.9	1177.5	361.0	601.7	722.0	25.8	385.1
8	698.1	559.1	172.1	286.9	344.2	14.6	252.4
9	663.6	438.0	136.1	226.8	272.1	15.6	275.1
10	370.6	242.6	75.1	125.2	150.3	7.9	116.9
11	339.7	219.3	67.9	113.2	135.9	7.2	105.7
12	317.1	205.0	63.5	105.8	127.0	6.7	116.4
13	272.3	178.0	55.1	91.9	110.2	5.7	69.3
14	227.6	148.4	46.2	77.0	92.4	5.6	49.0
15	199.4	129.7	40.4	67.3	80.8	4.9	4.6

In order to recap the simulation results – newly developed customized adaptive proportional fair scheduling algorithm demonstrates a way better overall system performance compared to the state-of-the-art PF scheduling schema by improving system capacity, cell throughput, spectral efficiency as well as the system's ability to serve the users in a timely manner. At the same time, the customized algorithm maintains a good level of fairness in relatively poor radio conditions in order to ensure none of the users are left unserved.

5. Conclusion

The focus of this paper is to expound existing state of the art Packet Scheduling Algorithms for LTE wireless network, their variations and finally, develop the customized adaptive scheduling algorithm with the intention to maximize system capacity, enhance spectral efficiency and improve overall system performance. For that matter, system level simulations were conducted in order to compare seven different scheduling schemas - RR, PF, PF07, PF05, PF03, Best CQI and APF – based upon the evaluation of three important performance management metrics – System Throughput, Fairness and System Delay.

The simulation results show that the proposed Adaptive Proportional Fair (APF) packet scheduling algorithm is capable of delivering a better trade-off between system capacity and fairness. And most importantly, the results also depict that by deploying the proposed algorithm we are enhancing spectral efficiency while maintaining a reasonable level of fairness. **The authors would also like to underscore the importance of the developed APF algorithm's practical implementation.**

During the simulation APF takes into account two variables – UE reported CQI and Cell load. Nonetheless, for the sake of more optimal decision making, we could have considered other variables, likes of UE distance from eNB, Packet Delay, and UE buffer status, however, it would make its practical implementation more unrealistic by increasing its computational complexity and limiting the fundamental capability of rapidly responding to wireless network changes due to the computational overheads required by each decision.

6. Recommendation

The lion share of mobile traffic is dominated by video streaming content, all delivered over the top (OTT) applications mostly using non-GBR bearers (QCI-6 to QCI-9). Packet scheduling algorithms can be assigned to a specific quality of service class identifier. Given that statement, the authors would like to emphasize the need to further investigate quality of experience (QoE) based traffic and radio resource management for adaptive HTTP video delivery in advanced wireless networks which would consider the playout buffer time of the UEs and propose a novel playout buffer-dependent approach that would determine for each UE the streaming rate for future video segments according to its buffer time and the achievable QoE under current radio conditions.

It would bridge the gap between client based and network-based optimization approaches by jointly optimizing the multi-user network resource allocation and the streaming rate of the DASH (Dynamic Adaptive Streaming over HTTP) clients. Its objective would be to proactively adapt the adaptive HTTP mobile video delivery by considering the radio conditions, content characteristics, and playout buffer levels of the clients [14]

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