Science and Technology 2016, 6(2): 25-35
DOI: 10.5923/j.scit.20160602.01

Prioritised Fairness Packet Scheduling Algorithm for Long Term Evolution

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Abstract Long Term Evolution (LTE) is a digital system designed to meet the need of growing mobile subscribers which the analog could not handle. It has ALL-IP network architecture and provides better quality of service than the previous cellular systems. Though LTE remains one of the most embraced and fastest growing technologies in communications, the resources on LTE network are limited and it has to be allocated in a way that highest throughput and fairness are maintained among all connections. Hence, many scheduling algorithms have been proposed. This research evaluated various scheduling algorithms in LTE network and developed a Prioritized Fairness Packet Scheduling (PFPS) algorithm that improves on the limitations of the existing algorithms. The proposed model was simulated using SIMULINK. The performance of PFPS was evaluated using throughput and fairness among users equipment while the results were validated with Round Robin (RR) and Best CQI scheduling algorithms.

Keywords Algorithms, Fairness, Long Term Evolution, Prioritized Fairness Packet Scheduling, Real Time, Resource Allocation, Resource Block

1. Introduction

Ttelecommunications technologies are evolving at an unbelievable pace, driven by innovation, speed, quality, convenience, and cost [1] such that there has been a clear shift from fixed to mobile cellular telephony. Recent advances in research has brought about the development of large varieties of smart mobile devices that have the capability to support a wide range of multimedia traffic such as VoIP, video streaming, multiplayer interactive gaming and as well as traditional mobile services like voice and SMS [2]. These new multimedia applications require high data rates and power to provide better Quality of Service (QoS).

Moreover, due to low transmission rate and high service costs, the third generation (3G) technology has been unsuccessful in delivering ubiquitous and high-speed mobile broadband [3]. To address the mobile broadband requirements, the Third Generation Partnership Project (3GPP) introduced the new radio access technology, LTE, which has the capability to evolve towards fourth generation (4G) wireless systems.

LTE is an important technology to transfer from circuit switch networks to All-IP network architectures. LTE has been identified as a new wireless standard by the 3GPP. It could provide the downlink peak rate of 100 Mbps through the OFDMA and SC-FDMA to provide a higher bandwidth, lower latency, and better QoS [4], [5]. LTE started with the 3GPP release 8 and continued in release 10 with the objective of meeting the increasing performance requirements of mobile broadband [6]. Release 8 Important features are; high spectral efficiency, very low latency, support of variable bandwidth, simple protocol architecture, and support for Self-Organizing Network (SON) operation. LTE Advanced which is a product of Release 10 has fourth generation (4G) specifications that provide enhanced peak data rates of 100 Mb/s for high mobility and 1Gb/s for low mobility to support advanced services and applications [6], [7]. Dikamba in [8] stated that LTE should support a data rate up to 100 Mb/s within a 20 MHz downlink spectrum allocation and 50 Mb/s within a 20 MHz uplink or, equivalently, spectral efficiency values of 5bps/Hz and 2.5 bps/Hz. Also, LTE uses bandwidth ranging from 1.4 MHz up to 20 MHz.

All LTE devices supports Multiple Input Multiple Output transmissions (MIMO). The several data streams are transmitted by the base station over the same carrier simultaneously. Its network architecture designed with the aim to support packet-switched traffic with seamless mobility and better quality of service. Due to increase in the usage of mobile data and appearance of new applications such as Multimedia Online Gaming (MMOG), mobile TV, Web 2.0, streaming contents have encouraged the 3GPP to work on the LTE regarding fourth-generation mobile [9].

The two modes of LTE are Time Division Duplex (TDD)

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Published online at http://journal.sapub.org/scit

and Frequency Division Duplex (FDD). LTE is easy to use which is having higher privacy and security. It improved the speed and data rate. LTE-A is the improved version of LTE. It includes the feature of LTE and some more features to improve its version like wider bandwidth; advanced MIMO technique, coordinated multipoint transmission and reception (COMP), relaying to increase its capacity [10]. Orthogonal Frequency Division Multiplexing (OFDM) which divides the available bandwidth into narrow band and data transmission on these subcarriers are in parallel which results in better spectral efficiency.

LTE has stood to be one of the most embraced and fastest growing technologies in the field of communications. The resources on LTE network are limited and they have to be allocated such that the highest throughput is attained while fairness is maintained among all types of network connections. Thus, the allocation of network resources over the LTE network has been of major concern leading to so many scheduling algorithms being proposed and related works reviewed.

Optimized resource block allocation and scheduling for real-time services in LTE networks was studied [11] because there has been a huge increase in the demand for real-time multimedia applications from mobile users. They proposed a resource block allocation scheme based on users channel state information. However, this work only considered real-time connections.

Wu in [5] studied A Channel Quality-aware Scheduling and Resource Allocation Strategy for Downlink LTE Systems with the purpose of provision of better resource utilization and channel quality for mobile devices. The objective of the designed scheduling algorithm is to avoid the latency or starvation of lower priority connections and to maintain system performance in downlinks of LTE. It was implemented using a priority-based scheduling algorithm that indicated the transmission ranking by the assigned priority to each connection but it restrictively adjusts the priority of the users according to the Channel Quality Indicator (CQI).

Ramli [12] studied Video streaming performance under well-known packet scheduling algorithms due to the difficulty in supporting video streaming over the wireless network. The study evaluated the video streaming performance of Max-Rate, Performance Fair (PF) and Round Robin (RR) algorithms and discovered that PF outperforms the other algorithms but it only considered non-content aware packets.

El-Gawad et al in [13] came up with a research on LTE QoS dynamic resource block allocation with power source limitation and queue stability constraints and proposed a new cross-layer scheduling algorithm to satisfy better quality of service (QoS) parameters for real time applications because the exhaustive search over all possible allocations is impractical for large scale systems. The algorithm allocates RBs to different users proportional to their CQIs and their traffic profiles, then, it performs MCS assignment for each RB in a way to minimize the overall average packet delay while taking into account queue dynamics, power limitation, channel condition and MCS capability of each user. It focuses only on real time applications and the algorithm proposed does not take the system-level QoS. [3] carried out performance analysis for QoS-aware two-layer scheduling in LTE networks because scheduling and resource allocation in LTE still face huge design challenges due to their complexity. His objective was to solve the optimization problem of scheduling and resource allocation for separate streams. By separating streaming scheduling and packet sorting effectively, a new QoS-aware Two-layer downlink scheduling algorithm for delay sensitive traffic (Video) was proposed. QoS-aware Two-layer scheduling algorithm is divided into the streaming scheduling and packet sorting by introducing dynamic QoS-related factors, such as the packet urgency and fairness among the streams. Notwithstanding, the channel status was not investigated.

Sahoo in [9] carried out a research on performance comparison of packet scheduling algorithms for video traffic in LTE cellular network with the main goal of providing results that would help in the design process of LTE cellular networks, aiming to get better overall performance. The performance evaluations of these three algorithms were conducted over video traffic in a vehicular environment using LTE-Sim simulator. In view of the foregoing, it is obvious that the focus of most of the researches is on real-time (RT) connections. Whereas, some urgent non real-time transactions like downloading of criminal pictures or video for security investigations are downplayed. In this work we propose a new model that gives fairness to every class of users (real-time and non-real-time) on the LTE network. Consequently, this study aims to develop prioritized fair packet scheduling algorithm (PFPS) for LTE networks.

2. LTE Frame Structure

Two frame types are defined for LTE: Type 1, used in Frequency Division Duplexing (FDD) and Type 2, used in Time Division Duplexing (TDD). In FDD, a separate uplink and downlink channel are utilized, enabling a device to transmit and receive data at the same time. The spacing between the uplink and downlink channel is referred to as the duplex spacing. The uplink channel operates on the lower frequency. This is done because higher frequencies suffer greater attenuation than lower frequencies and, therefore, it enables the mobile to utilize lower transmit levels while TDD mode enables full duplex operation using a single frequency band and time division multiplexing the uplink and downlink signals [14].

2.1. Type-2 Frame Structure

This contains two half frames, where at least one of the half frames contains a special subframe carrying three fields of switch information including Downlink Pilot Time Slot

(DwPTS), Guard Period (GP) and Uplink Pilot Time Slot (UpPTS) [15]. If the switch time is 10 ms, the switch information occurs only in subframe one. If the switch time is 5 ms, the switch information occurs in both half frames, first in subframe one, and again in subframe six. Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following UpPTS are reserved for uplink transmission [18]. Other subframes can be used for either uplink or downlink as shown in Figure 1.

3. Resource Allocation Scheduling Algorithm

Scheduling is the process of allocating resources to a user to get better throughput and to increase system efficiency. Some various types of scheduling algorithm are discussed as follows.

3.1. Round Robin (RR) Scheduling Algorithms

The scheduler assigns resources at regular intervals to the users without taking channel conditions into account. This is a simple procedure which gives the best fairness and results in poor throughput [20]. Each user can use the resources in proper time interval; the first user will use the resource for the given time interval thereafter the resources will be assigned to another user. The new user is placed at the end of waiting queue [8]. It is simple to implement and easy to use. Hence, it is the most commonly used scheduling algorithm.

3.2. Proportional Fair (PF) Scheduling Algorithm

The most commonly used scheduling algorithm is PF. It results in high cell throughput and fairness. The channel condition is calculated and then resources are allocated to the user with the highest priority and further the allocation is given to the next priority user [20], [21]. PF was originally developed to support NRT service in code division multiple access high data rate (CDMA-HDR) system.

Assuming $r_i(t)$ is the achievable data rate of user i, PF algorithm selects a user with the highest metric k defined as follows:

$$k = \arg\max_i \left(\frac{r_i(t)}{R_i(t)} \right) \quad i \in NRT \tag{1}$$

$$R_i(t) = \left(t - \frac{1}{t_c} \right) * R_i(t-1) + \frac{1}{t_c} * r_i(t-1) \tag{2}$$

where $R_i(t)$ is the average data rate of user i over a time window (t_c) of an appropriate size. This update window size determines between maximizing throughput and satisfying fairness of each user in PF algorithm.

3.3. Best CQI Scheduling Algorithm

The highest value of CQI means that the channel quality is good. It provides excellent throughput as well as fairness satisfactorily. It assigned resources to users according to their link quality [22]. During scheduling the terminals which are located far away from the base station are not scheduled and nearby terminals are scheduled by sending CQI to the base station. CQI is 5 bit information. A higher CQI value indicates that the channel has a better channel quality and lower value indicate low better channel quality. 5-bit CQI value ranges from 0-30, a higher CQI gives transport-block size, a modulation scheme, and the number of channelization codes [20].

3.4. Maximum-Largest Weighted Delay First (M-LWDF)

M-LWDF algorithm was proposed to support multiple real-time data users with different QoS requirements in CDMA-HDR system [23], [24]. A user is scheduled based on the following priority metric:

$$M = \arg\max \left(a_i \cdot W_i(t) \cdot \frac{r_i(t)}{R_i(t)} \right), \quad i \in RT \tag{3}$$

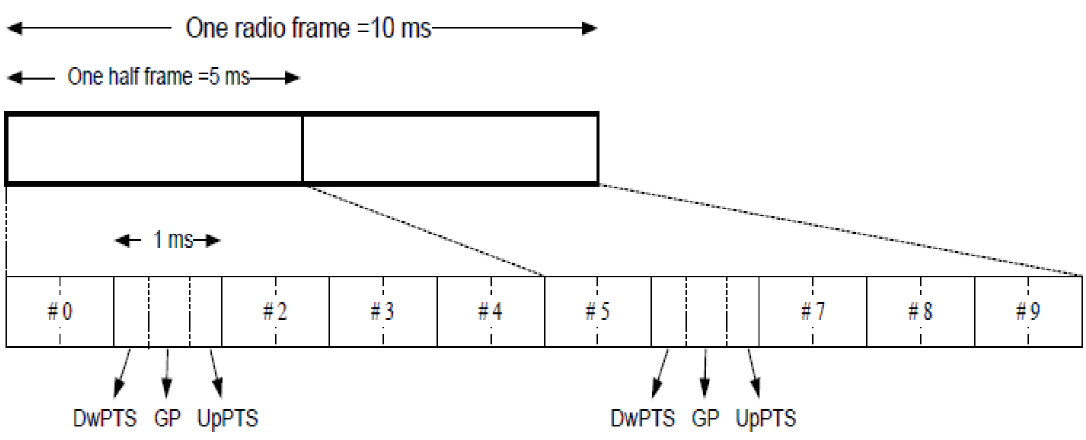

Figure 1. Type2 frame type [15], [19]

and

$$a_i = -\frac{\log(\delta_i)}{\tau_i} \tag{4}$$

where $W_i(t)$ is the head of line (HOL) packet delay (time difference between the current time and the arrival time of a packet) of user i at time *t*, is the delay threshold of user *i* and δ_i is the maximum probability for HOL packet delay of user *i* to exceed the delay threshold of user *i*. M-LWDF algorithm achieves a relatively low packet loss ratio (PLR) with a good throughput and fairness performance since it incorporates HOL packet delay together with PF properties when determining users' priority.

3.5. Frame Level Scheduler (FLS)

Quality of Service (QoS) aware packet scheduling algorithm was proposed in [25] for RT downlink communications. The FLS is a two-level scheduling scheme with one upper level and lower level. Two different algorithms are implemented in these two levels. A low complexity resource allocation algorithm based on discrete time linear control theory is implemented in the upper level. It computes the amount of data that each real-time source should transmit within a single frame, to satisfy its delay constraint implemented in the lower level to assign radio resources to the user, to ensure a good level of fairness among multimedia flows. At lower level in every TTI, RBs are allocated to the UEs using Proportional Fair scheme with taking into consideration the bandwidth requirements of FLS [23]. Particularly, the scheduler at the lower layer defines the number of TTIs/RBs through which each RT source will send its data packets. The amount of data to be transmitted is given by the following equation:

$$v_i(k) = h_i(k) * q_i(k) \tag{5}$$

Where $v_i(k)$ is the amount of data to be transmitted by the *i*-th flow in *k*-th LTE frame, "*" is the convolution operator, $q_i(k)$ is the queue level. $h_i(k)$ is the impulse response of the time-invariant linear filter through which $q_i(k)$ is filtered.

3.6. The Modified-Largest Weighted Delay First (MLWDF) Algorithm

The Modified-Largest Weighted Delay First (MLWDF) algorithm belongs to the LWDF family. It tries to meet delay guarantees by prioritizing data according to the queuing delay the packets have experienced. It combines both channel conditions and the state of the queue with respect to delay in making scheduling decisions. It ensures that the probability of delay packets does not exceed the discarded bound below the maximum allowable packet loss ratio [24], [26].

$$P_r = \left(D_{HOL,i} > \tau_i\right) \le \delta_i \tag{6}$$

The scheduler allocates resources to the user with the maximum priority index which is made up of the product of the HOL packet delay of the user, the channel capacity with respect to flow and the QoS differentiating factor

$$M_{i,k}^{MLWDF} = \alpha_i \cdot D_{HOL,i} \cdot \frac{d_k^i(t)}{R^i(t-1)} \tag{7}$$

Where $D_{HOL,i}$ is waiting time of the packet at the head of the line and $\alpha_i = -\log \delta_i / \tau_i$; δ_i represents acceptable packet loss rate (i.e. the maximum probability for HOL packet delay of user *i* to exceed the delay threshold of user *i*) and defines Delay threshold for the *i*-th user [27].

3.7. Resource Fair Scheduler (RF)

RF scheduler scheme allocates equal amount of resources for all user eequipments (UEs). RF maximizes the sum rate of all UEs while ensuring fairness with respect to the number of RBs assigned to a UE. In order to achieve this goal the following additional constraint is imposed:

$$b_k = \frac{N}{K} \quad \text{for all K} \tag{8}$$

If N/K is non-integer, some UEs will $\left\lfloor \frac{N}{K} \right\rfloor$ get

while others UEs get $\left\lceil \frac{N}{K} \right\rceil$

This decision has to be made at random in order to guarantee fairness [28].

4. The Proposed Prioritized Fairness Packet Scheduling Algorithm

In formulating this model, some related works were reviewed. Some concepts of Global System for Mobile Communication (GSM), General Packet Radio Service (GPRS), Enhanced Data rate for GSM Evolution (EDGE), Long-Term Evolution (LTE) and other wireless networks were studied. The incoming connections are classified based on their service request. The characteristics of the different types of connections are Real-Time (RT), Urgent Non Real-Time (UR), and Non real-Time. The Real-Time (RT) are connections that do not accommodate delay and needs to be served almost immediately. Examples of RT connections include voice calls, video conferencing and video streaming. The NRT are in two categories; the Urgent NRT (UR) and the Non-Urgent NRT. Urgent Non Real-Time (UR are connections that are not real time but needed to be treated with utmost urgency as a result of its importance, examples of UR are downloading of criminal pictures or uploading pictures of accident victims. Non Real-Time (NRT) are the connections that can tolerate delay. For example, browsing and chatting on social media. The allocatable Radio Blocks (RBs) are divided using a partial sharing system where some resources are partitioned for real time (RT) and some for non-real time (NRT). Also, some are made available in the central pool for RT and UR. Table 1 shows the pictorial diagram of the resource allocation.

Table 1. Partial Sharing System in PFPS

Non Real-Time (NRT)	Real-Time (RT) & Urgent Non Real-Time (UR)	Real-Time (RT)
q1	q2	q3

The upper and lower bounds for each partition in table 1 are to be set by the operator using the previous statistics of users on their network.

5. Procedure for PFPS Algorithm

The following procedures take place whenever a service connection is being made in An LTE network. We assumed that the channel qualities are equal and the connections come in a random manner:

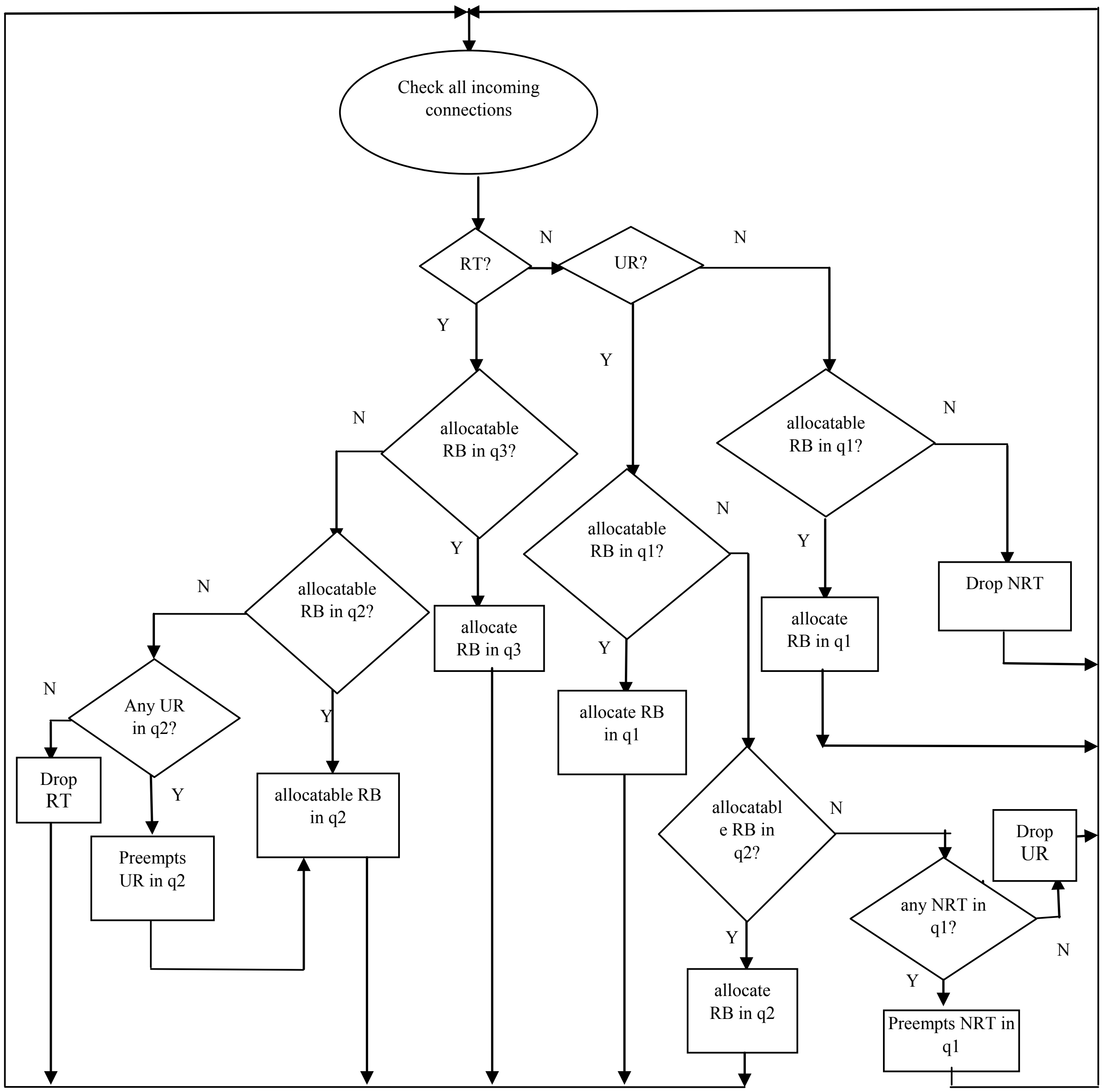

Figure 2. PFPS flowchart

i check all incoming connections.

ii if it is a Real-time connection, check for a free allocatable resource block (RB) in q3 on Table 1, if there is any, then allocate Resource Block (RB) in q3, else check for a free allocatable resource block in q2, if there is then allocate RB in q2 else, pre-empt a UR connection in q2 and allocate the free RB to the RT connection.

iii if the connection is a Non Real-Time connection, check whether it is an Urgent NRT (UR) or a non Urgent NRT (NRT), if it is an UR connection, check for free allocatable RB in q1, if there is, allocate RB in q1 else, check for a free allocatable RB in q2, if there is then allocate RB in q2 else check for any an NRT connection in q1. If found, preempt NRT in q1 then allocate the free RB to the UR connection else drop UR.

iv If the connection is a Non Real-Time (NRT), check for a free allocatable RB in q1, if there is then allocate RB in q1 else drop the NRT connection.

v return to (i) and repeat the process.

The flow chart of the system which shows the flow of program control in the order of execution is shown in Figure 2.

6. Performance Measures

The main purpose of this simulation is to test the performance of the proposed scheduling strategy (PFPS) which takes both real-time and non-real-time connections into consideration. The following metrics were employed to analyze the performance of this algorithm:

6.1. Throughput

This was measured as the total number of bits successfully transmitted over the air interface from the UE up to the eNodeB over the total simulation time. That means the system average throughput is the sum of average throughput of all users. Equation 9 shows the relationship.

$$Throughput = \frac{B}{t_{sim}} \tag{9}$$

where B is the total amount of bits received and t_{sim} is the total simulation time.

6.2. Fairness

This term measures the fairness among UEs of the same class, and it used to determine whether UEs are receiving a fair share of LTE system resources. There are many approaches to measure fairness, one of the most famous one is Jain's fairness index [28], [29], [30]. Raj Jain fairness index is used to measure the fairness among UEs as given in equation 10.

$$f\left(R_{1,}R_{2,}R_3 \cdots R_K\right) = \frac{\left[\sum_{K=1}^{K} R_K\right]^2}{K \sum_{K=1}^{K} \left(R_K\right)^2} \tag{10}$$

Where there are K UEs in the LTE system and R_K is the number of RBs given to UEs. When all UEs have the same throughput, the value of fairness index is 1 and this indicates the highest fairness. Here, we assume absolute fairness, which means that we do not take the SNR differences into account in our measure of fairness.

6.3. Selection of Simulation Parameters

The PFPS algorithm was implemented with SIMULINK in MATLAB. The data/parameter used for simulation is listed in table 2.

Table 2. Simulation Parameters

PARAMETER	VALUE
LTE transmission bandwidth	3.0MHz
Number of RBs	15
Maximum occupied bandwidth	2.7 MHz
Number of UEs	20
Number of BS	1
Percentage of real-time services	50%
Percentage of urgent non real-time services	30%
Percentage of non-real-time services	20%

6.4. Simulation Results and Discussions

The results of the comparison between prioritised fairness packet scheduling algorithms (PFPS), round robin (RR) and best channel quality indicator (Best CQI) are discussed in this section. The algorithms were implemented with varying number of users and random connection types and CQIs and number of allocated resource blocks to get maximum throughput and highest level of fairness.

6.4.1. Simulation Results for Real-Time Network Connections

Table 3 shows the number of resource blocks that is being requested by real-time connections and the number of resource blocks allocated by each scheduling algorithms. The parameters in this table were plotted in Figure 3.

Table 3. Resource allocation for Urgent Non Real-Time connections

Number of Resource Blocks (RB)	PFPS	RR	Best CQI
Requested	16	16	12
Allocated	7	3	4

As shown in Figure 3, the number of resource blocks allocated for Real-Time connections is higher in PFPS than in BestCQI with RR having the lowest allocated resource blocks. This is because PFPS allows all the Real-Time connections to complete their task before recovering the resource blocks, unlike RR which allocates resource blocks to connections at regular intervals thereby cutting the Real-Time connections off immediately their time interval is completed whether or not it has finished execution which results in poor usage of the available resource blocks. While Best CQI has a poor resource usage because it assigns resource blocks based on the channel quality indicator (CQI) of the user equipment (UE) which is not effective because a Real-Time connection had been made while in motion may experience a change in CQI and thereby cutting off. This shows that PFPS performs better than the other two algorithms because of its highest efficiency in terms of resource block allocation for RT services.

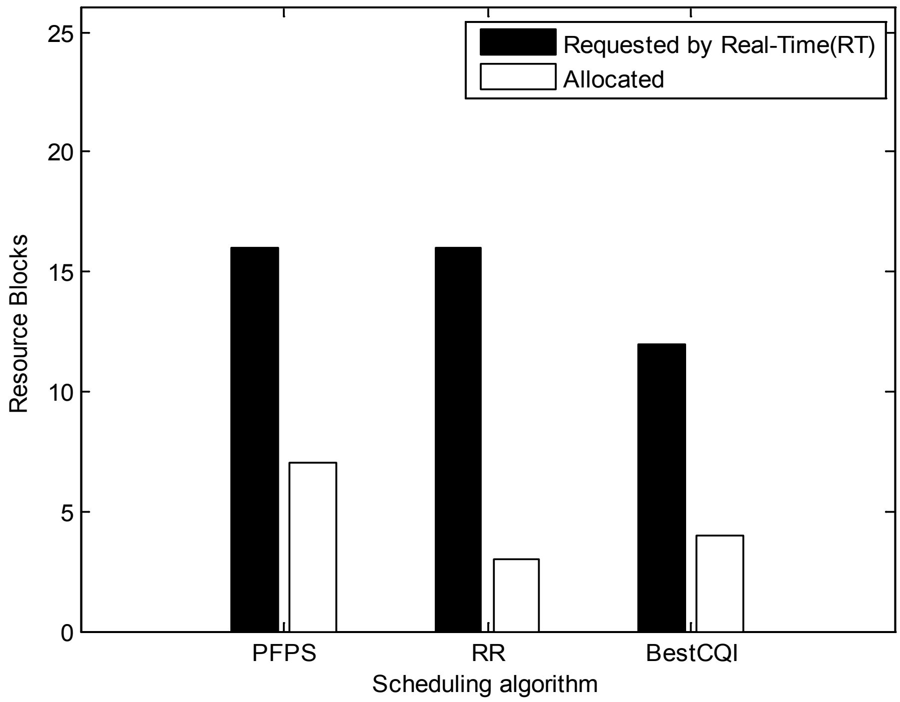

Figure 3. Number of allocated resource blocks in PFPS, RR and Best CQI

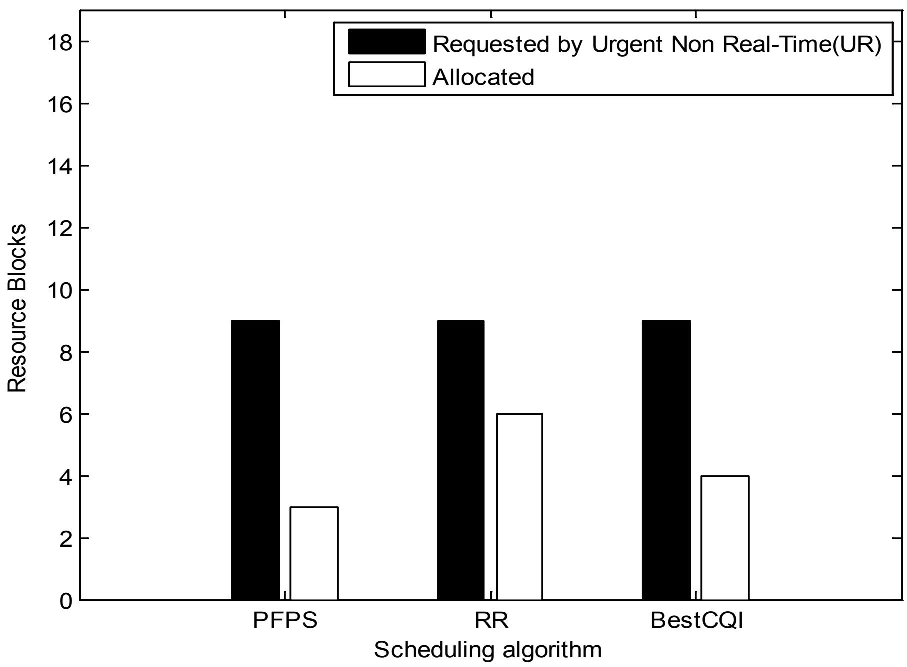

Figure 4. Resource block allocation for Urgent Non Real-Time services (UR)

6.4.2. Simulation Results for Urgent Non Real-Time Connections (UR)

Table 4 shows the number of requested blocks for UR connections and the number of resource blocks allocated by each scheduling algorithms. The graph in Figure 4 was plotted based on these parameters.

Table 4. Resource allocation for Urgent Non Real-Time Connections

Number of resource blocks (RB)	PFPS	RR	BestCQI
Requested	9	9	9
Allocated	3	6	4

Observation in Figure 4 shows that RR has the highest usage of resource blocks because it allocates resource blocks to Urgent Non Real-Time (UR) connections at intervals whether they there are UR connections at that particular time interval or not, thereby leading to wastage of resources. On the other hand, BestCQI has a slightly lower number of allocated resource blocks, though Best CQI does not allocate resources at intervals, it makes allocations based on the CQI ranking. UR connections with high priority will be served continuously while UR connections with low CQI will be perpetually starved. PFPS has the lowest and thus minimized number of resource blocks because it considers fairness and allocates resources based on the available resources, the amount of resources needed and the number of UR connection at that particular time interval.

6.4.2.1. Simulation Results for Non Real-Time Connections (NRT)

The table 5 shows the number of requested resource blocks by non-real-time connections and the corresponding number of resource blocks that was allocated to them by the algorithms. The parameters in Table 5 were used to plot the graph in Figure 5.

Table 5. Resource allocation to Non Real-Time connections

Number of resource blocks (RB)	PFPS	RR	BestCQI
Requested	9	9	9
Allocated	3	6	4

The graph in Figure 5 shows that BestCQI and RR have higher number of resource blocks while PFPS has the lowest. BestCQI has the highest number of resource blocks because CQI of the UE is sent to the base station thereby allocate resource blocks to the NRT that are near the base station with higher CQI to the detriments of the NRT connections that are farther from the base station with low CQI ranking. However, PFPS whose aim is to maximize throughput and give fairness with minimum number of resource blocks has an efficient number of allocated resource blocks for NRT services.

6.4.3. Simulation Result for Throughput

The throughput obtained by the scheduling algorithms was computed by their average throughputs on the different categories of connections. The values are shown in Table 6.

Table 6. Throughput for the Scheduling Algorithms

Scheduling Algorithms	Throughput (Mbps)
Proportional Fair Packet Scheduling Algorithm (PFPS)	8.4254
Round Robin (RR)	1.6359
Best CQI	2.9505

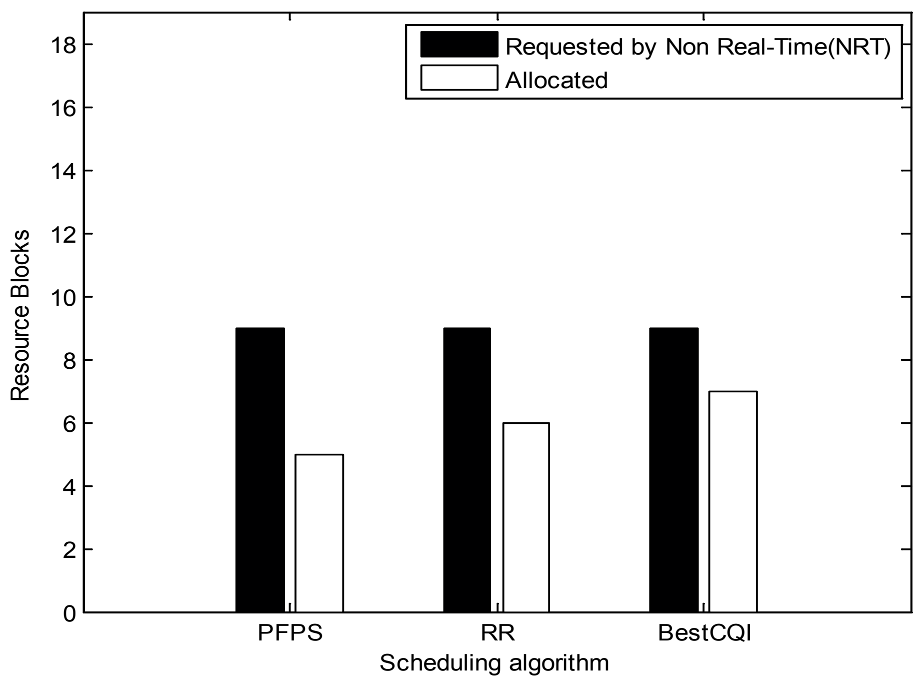

Figure 5. Resource blocks allocation for Non Real-Time connections

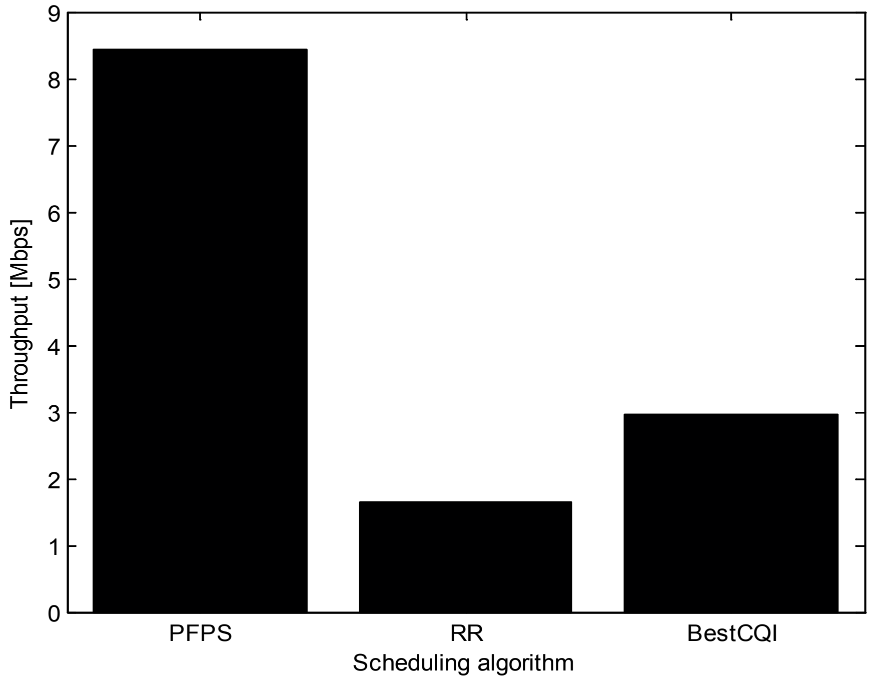

Figure 6. Throughput for PFPS, RR and BestCQI

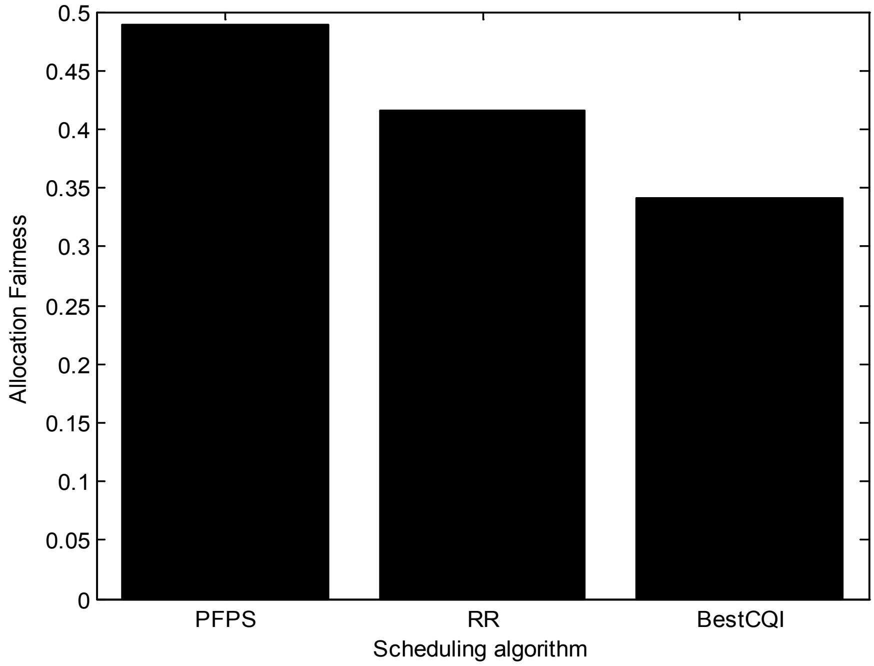

Figure 7. Allocation fairness in PFPS, RR and BestCQI

Figure 6 shows that the PFPS has the highest level of throughput because it maximizes the use of the available resource blocks by the use of a partial sharing system where all the network connection are grouped into three different pools which are the RT, UR and NRT and the resources are allocated based on the type of connection. This increases the throughput better that BestCQI because in real world scenarios not all connections are Real-Time and not all UE are close to the base station. Also, it outperforms Round Robin (RR) as it does not just allocate resources whether it is needed or not and does not cut off the connection after a particular time interval for connections with long transmission time but allows for successful completion of their tasks.

6.4.4. Simulation Results for Allocation Fairness

The fairness achieved by the scheduling algorithms were computed by the fairness given in the allocation of resources to service the request of the categories of network connections request. The graph in Figure 6.0 was plotted from the parameter in Table 7.

Table 7. Allocation Fairness for the scheduling algorithms

Scheduling Algorithms	Allocation Fairness
Proportional Fair Packet Scheduling (PFPS)	0.48913
Round Robin (RR)	0.41667
Best CQI	0.34091

Figure 7 shows that the PFPS achieved the highest fairness because it allows both RT, UR and NRT connections of the system to be served in so doing, avoiding latency or starvation while RR has lower fairness since a connection is cutoff after a specified time interval and this might lead to incomplete tasks or the connections will have to wait until it gets to it turns before resuming it's execution. This might not be feasible for RT connections or UR connection while BestCQI has the lowest level of fairness because the only thing it takes into consideration is the CQI of the user equipment (UE) and the UE with low CQI will continue to be starved.

7. Conclusions

The resources on LTE network are limited and they have to be allocated in such a way that the highest throughput is attained while fairness is maintained among all types of network connections. As a result of this, the allocation of network resources over the LTE network has been of major concern over the past years and so many scheduling algorithms have been proposed. In this work, a new model for resource allocation was proposed and simulated, then, it was compared with two existing scheduling algorithms (Round Robin and Best CQI).

The result shows that PFPS performs better than the two algorithms in terms of throughput and allocation fairness. Thus, this model can be used to maximize system's throughput and fairness. Due to the numerous benefits expected to be derived from this model, it is strongly recommended for network operators and service providers to exploit the Prioritised Fairness Packet Scheduling (PFPS) model.

REFERENCES

[1] Iliev T., and Mihaylov G., (2012) "3GPP LTE system model analysis and simulation of video transmission", Advanced Research in Scientific Areas.

[2] Kumar A., Liu Y, Sengupta J., Divya, (2010) "Evolution of Mobile Wireless Communication Networks: 1G to 4G", IJECT, 1(1).

[3] Tsang T., (2013) "Performance Analysis for QoS-Aware Two-Layer Scheduling in LTE Networks.", International Journal of Emerging Trends & Technology in Computer Science (IJETTCS) , 2 (2), 2013.

[4] Kausar R., Chen Y., Chai K. and Schormans J., (2011) "Packet Scheduling Architecture with Service Specific Queue Sorting and Adaptive Time Domain Scheduling Algorithms for LTE-Advanced Networks", International Journal on Advances in Networks and Services, 4(3), 2011.

[5] Wu S., (2012) "A Channel Quality-Aware Scheduling and Resource Allocation Strategy For Downlink Lte Systems", Journal of Computational Information Systems, 13, 2012.

[6] Dahlman E., Parkvall S., Sköld J., and Beming P., (2011) "4G LTE/LTE-advanced for Mobile Broadband", 1st edition. 2011.

[7] Aderemi A., Matthew K.L., Martha K. and Iruemi O.J., (2011) "3GPP Long Term Evolution: Architecture, Protocols and Interfaces", International Journal of Information and Communication Technology Research, 1(7).

[8] Dikamba T., (2011) "Wireless and Mobile Communication (WMC) Group Downlink Scheduling in 3GPP Long Term Evolution (LTE)". Master of Science Thesis, 2011.

[9] Sahoo B., (2013) "Performance Comparison of Packet Scheduling Algorithms for Video Traffic In Lte Cellular Network", International Journal of Mobile Network Communications & Telematics (IJMNCT), 3(10).

[10] Mohammed A.A., Moshen M.T. and Mohamed E., (2013) "LTE QoS Dynamic Resource Limitation and Queue Stability Constraints" International Journal of Computer Networks and Communications. Vol. 5. 2013.

[11] Kanagasundaram K. and Nawaz G.K., (2013) "Optimized Resource Block Allocation and Scheduling For Real-Time Services In Lte Networks", Journal of Theoretical and Applied Information Technology, 58 (1), 9, 2013.

[12] Ramli H.M., Kumbesan S., Riyaj B., Rachod P. and Toyoba A.S., (2011) "Video Streaming Performance Under Well-known Packet Scheduling Algorithms", International Journal of Wireless & Mobile Networks (IJWMN), 3(1),14, 2011.

[13] El-Gawad M.A., Tantawy M.M. and El-Mahallawy M (2013), "LTE QoS Dynamic Resource Block Allocation with Power Source Limitation and Queue Stability Constraints", International Journal of Computer Networks & Communications (IJCNC), 5 (3), 13, 2013.

[14] Elnashar A., and El-saidny M., (2015) Design, Deployment and Performance of 4G-LTE Networks: A Practical Approach", (first ed.). John Wiley & Sons, Ltd.

[15] LTE Resource Guide (n.d.). www.us.anritsu.com.

[16] Zyren J., (2007) White Paper: Overview of the 3GPP Long Term. (W. McCoy, Ed.) 27.

[17] Astely A., (2009) "LTE: The Evolution of Mobile broadband", IEEE Communication Magazine,47(4), p.44-51.

[18] Sukar M.A., and Pal M.I., (2014) SC-FDMA & OFDMA in LTE physical layer", International Journal of Engineering Trends and Technology (IJETT), 12(2).

[19] Tripathi S., Kulkarni V., and Kuma A., (2011) LTE E-UTRAN and its Access Side Protocols", p. 17, 2011.

[20] K.aur R., and Kumar M., (2013) "An Efficient Resource Block Allocation in LTE System", International Journal of

Advanced Research in Computer Science and Software Engineering, 3(10).

[21] Shampy R.S., and Singh P., (2014) “Scheduling Algorithms of Resource Allocation in LTE system”, 2 (6).

[22] Phunchongharn P., Hossain E. and Kim D.I. (2013) "Resource Allocation For Device-To-Device Communications Underlaying Lte-Advanced Networks", IEEE Wireless Communications, vol.20 no.4, pp.91-100.

[23] Afroz F., Barua S., Sandrasegaran K. (2014) “Performance Analysis of FLS, EXP, LOG and M-LWDF Packet Scheduling Algorithms in Downlink 3GPP LTE System”. International Journal of Wireless & Mobile Networks (IJWMN) Vol. 6, No. 5.

[24] Ramli H., Basukala R., Sandrasegaran K., and Patachaianand R., (2009) “Performance of well-known packet scheduling algorithms in the downlink 3GPP LTE system,” in Proc. of IEEE Malaysia International Conf. on Comm., MICC, Kuala Lumpur, Malaysia, pp. 815–820.

[25] Piro G., Grieco L.A.,. Boggia G, and Camarda P., (2010) "A Two-level Scheduling Algorithm for QoS Support in the Downlink of LTE cellular networks", Wireless Conference (EW).

[26] Singh D., and Preeti. (2013) “Performance Analysis of QOS-aware Resource Scheduling Strategies in LTE Femtocell Networks”, International Journal of Engineering Trends and Technology (IJETT), 4 (7), 7.

[27] Naik U.P., Shirgeri S., Udupi R. G., and Dias F.P., (2013) “Design and Development of Medium Access Control Scheduler in LTE eNodeB”, International Journal of Computational Engineering Research, 3 (4), 7.

[28] AlQahtani S., and Mohammed A., (2014) “Performance Modeling and Evaluation of Novel Scheduling Algorithm for LTE Network”, Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Telecommunications (JSAT), January Edition, 4 (1).

[29] Chisung B., and Dong C.. (2007) Fairness-Aware Adaptive Resource Allocation Scheme in Multihop OFDMA System, Communication letters IEEE, 11 (2007) 134-136.

[30] Lin X.., Laurie C. (2008) Improving fairness in relay-based access networks, in ACM MSWIM, pp. 18-22,.