LTE Packet Scheduling with Bandwidth Type Consideration

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Summary

LTE (Long-Term Evolution, sometimes known as 4G LTE) is a wireless high-speed data communication technology for mobile phones and data terminals. The Packet Scheduler (PS) is an important component in improving network performance. Physical Resource Blocks (PRBs) are assigned to associated User Equipment by the packet scheduler (UEs). The primary contribution of this study is a comparison of the eNodeB throughput between a suggested method and the Round Robin (RR) Algorithm. The RR Algorithm distributes PRBs among all associated UEs without taking channel circumstances into account. In this research, we present a new scheduling method that takes into account the number of PRBs and associated UEs and produces higher throughput than the RR algorithm.

Key words:
LTE, Packet Scheduling, 4G, RR.

1. Introduction

GPP established the Long Term Evolution (LTE) standard for mobile networks. The LTE standard is the next step in the evolution of 3G mobile networks, allowing for increased capacity and lower latency. The upgraded design of the LTE network provides for more efficient radio access networks in terms of the expansion of high-data-rate applications. LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink and Single Carrier Frequency Division Multiple Access (SC-FDMA) in the uplink to offer a wide range of applications and Internet services. OFDMA splits a given bandwidth into subcarriers with orthogonal frequencies. One OFDMA symbol, which is acknowledged as a unit of data transmission, is made up of a total of 12 subcarriers.

Packet Scheduling (PS) is one of the radio resource management operations that contributes significantly to network performance. Several Packet Scheduling techniques have been presented in recent years. Assigning a portion of the system bandwidth to a User Equipment (UE) with better channel conditions is one technique to build a PS algorithm. Because the PS mechanism is not standardized, the scheduling method must be considered to achieve optimal performance and at least oriented performance which tailored to specific goals and objectives. The eNodeB entity in LTE serves as all-IP network architecture, and it corresponds to the RNC entity in WCDMA [1]. The Channel Quality Indicator (CQI) is used to assess channel quality in LTE, and its value may be determined using BER [2]. The suitable modulation technique for a given channel connection would be chosen based on the CQI predicted value [3].

The focus of this paper is on the performance achieved by using the proposed algorithm on a set of network deployments. The findings are compared to the round robin approach [4], which schedules all UEs without taking channel conditions into account. The remainder of this work is structured in the following manner. The second section is devoted to a review of the literature. In the third part, the frame structure of LTE is discussed. The packet scheduling technique is discussed in the fourth part, along with the suggested mechanism. The simulation results are shown in part five, and the work's conclusion is presented in the concluding section.

2. Related Work

This section presents a literature review of LTE scheduler ideas. In terms of performance measures, the majority of the literature on proposed LTE scheduling stresses optimizing fairness and data throughput. PRBs will be awarded to the UE with the greatest CQI in the Best-CQI algorithm, for example. In order to maximize the entire system's throughput, certain algorithms distribute PRBs to UEs with the highest throughput. The authors of [5] discussed the round robin scheduler, which is the most fundamental scheduling approach. The round robin scheduler is used to maximize the UEs' fairness objectives. The number of UEs that can be planned is limited by the number of physical downlink control channels (PDCCH). This is because the PRBs are communicated to the UEs through the available PDCCH. Furthermore, the system's throughput is impaired. The round robin scheduler was identified using two distinct domains: time domain (TD) and frequency domain (FD). The scheduler will assign the available PRBs to one UE per TTI in the time domain. The UE is selected from a planned list of UEs that includes the number of available UEs.

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Multiple users, on the other hand, can be supplied by a single TTI. [6] proposes four greedy heuristic methods. One of the techniques they presented is carrier-by-carrier. The available RBs were arranged from RB-1 to RB-m in this approach to fulfill the restriction of allocating contiguous RBs to each UE with the greatest metric value. Furthermore, proportional fairness is the performance parameter that the algorithm uses to assign the collection of contiguous RBs. [6] also introduced the Largest- Metric-Value-RB-First method. The authors sought to address the contiguity limitation to some extent in this algorithm. The method tries to compel non-candidate RBs to be allocated to a scheduled user while placing these non-candidate RBs between two separate candidate RBs to satisfy the contiguity requirement. In addition, the opportunistic scheduling technique, known as the Heuristic Localized Gradient Algorithm (HLGA), was developed and studied in [7]. As a result, the HLGA may manage the retransmission request and resource allocation at the same time. When PRBs are allocated to a certain UE, they must adhere to the contiguity restriction. If the algorithm assigns two PRBs that are not next to each other to the same UE, the method imposes additional PRBs that are put between those PRBs and are to be assigned to the same UE. In the event of a transmission failure, the algorithm employs the same principle on the ARQ-blocks. Following that, a pruning step will be considered. The pruning step is when the algorithm ensures that no PRBs remain. When some PRBs remain, the remaining PRBs are allocated and dispersed to unsatisfied UEs. The HLGA, on the other hand, necessitates a large amount of memory for assigning PRBs to the UEs.

3. The Structure of LTE Frame

Figure 1 depicts the frame structure for the LTE down- link and uplink schemes. Even if the techniques change, the downlink/uplink frame structure is the same. In terms of time domain, an LTE downlink/uplink frame is equivalent to a 10- millisecond radio frame. The System Frame Number (SFN) identifies and classifies frames, allowing for the control of various transmission cycles. Each LTE downlink/uplink frame is broken into 10 sub-frames, each with a time period of one millisecond. A sub-frame is made up of two slots, each of which is 0.5 milliseconds long. Finally, the 0.5 millisecond slot is made up of OFDM/SCFDMA symbols. The amount of OFDM/SC-FDMA symbols is determined by the CP mode used in the network. LTE defines two types of CP mode: conventional CP mode and extended mode. The number of OFDM/SC-FDMA symbols involved in the 0.5 millisecond slot is set to seven in standard CP mode, default mode. In other words, if the CP mode is extended, the number of OFDM/SC-FDMA symbols used in a 0.5 millisecond slot increases to six. The amount of data bits delivered by a certain OFDM/SC- FDMA symbol may be computed using the Modulation and Coding Scheme (MCS) based on the predicted CQI value [2][3]. The frequency grid structure of an LTE frame in the 0.5 millisecond time slot is seen in Fig. 2. As shown, the frequency grid of the OFDM/SC-FDMA time slot is divided into many pieces, each of which equals 180 kHz. As a result, each section is made up of twelve contiguous OFDM/SC-FDMA subcarriers. The Physical Resource Block (PRB) radio resource unit is made up of 180 kHz X 0.5 millisecond frequency- time blocks, as depicted in Fig. 2. The PRB is made up of twelve OFDM/SC-FDMA subcarriers. Each subcarrier has seven OFDM/SC-FDMA symbols in the standard CP case and six in the extended CP scenario.

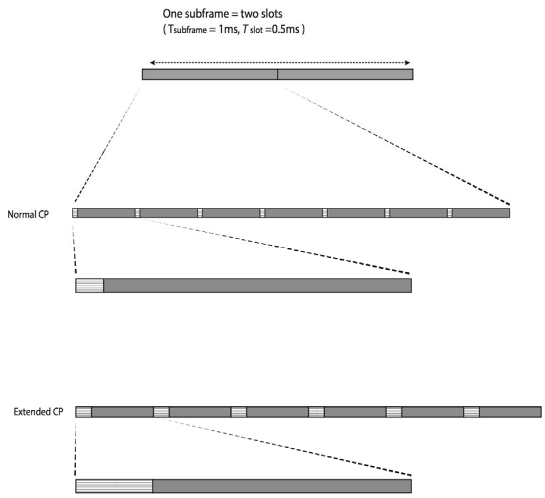

Fig. 1 Frame Structure [10].

LTE defines two duplexing modes, Time Division Duplexing (TDD) and Frequency Division Multiplexing (FDM), to devote LTE frames for both downlink and uplink directions (FDD). Uplink and downlink broadcasts can be contained in a frame in TDD mode, and the allocation of subframes between uplink and downlink transmissions is influenced by the TDD configuration. Furthermore, a specific subframe is employed to differentiate between uplink and downlink broadcasts. In the case of FDD, the uplink and downlink transmissions are separated into different frequency bands, allowing a single subframe to be defined as a whole unit for each uplink or downlink transmission.

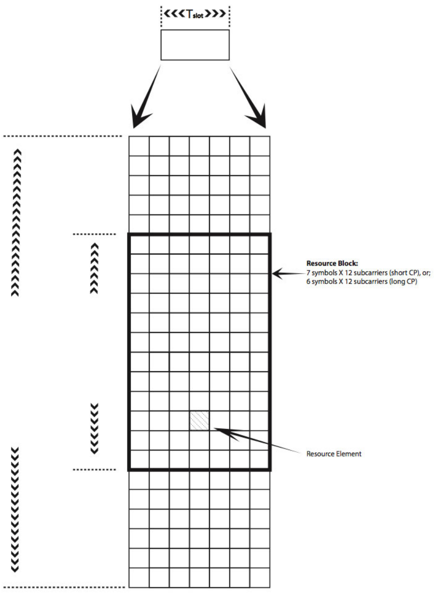

Fig. 2 The Radio Resource Block [10].

4. The Packet Scheduling in LTE

Packet Scheduling is the process of distributing available PRBs to UEs in the network for a set period of time. A Transmission Time Interval is the time period in which Packet Scheduling operates (TTI). TTI is equal to one millisecond, which is the duration of one subframe. The Packet Scheduler is in charge of selecting a set of UEs within its range and scheduling them each TTI. The scheduler maps the available PRBs to the specified group of UEs to determine which set of PRBs will be applied to valid UEs to obtain the maximum performance measure. The performance metric refers to the measurement of some UE attributes, such as average packet delay or data rate, for each UE. The measurement of a specific performance parameter can affect system performance, allowing the Packet Scheduler to optimize the acceptable level of system needs. Link Adaptation is another job performed by the Packet Scheduler (LA). The Link Adaptation function is important because it guarantees that data packets are sent to the proper destination. The message sent between the UE and the eNodeB, as well as the signaling control, are the real mechanisms for requesting (from the UE to the eNodeB) or granting (from the eNodeB to the UE) resources. However, the LTE standard does not specify a specific method or procedure for the packet scheduler. This algorithm is available for study.

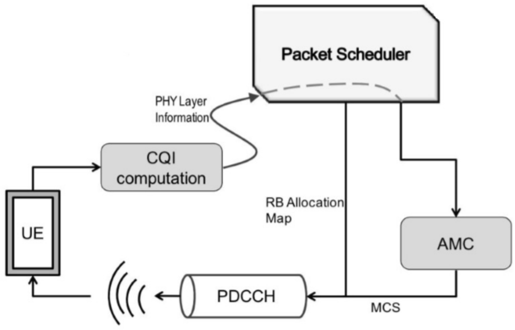

Fig. 3 The Model of Packet Scheduler [8].

4.1 The Standard Procedure of LTE Packet Scheduler

To achieve better downlink packet scheduling operation, the UE would provide a channel status report to eNodeB. The downlink scheduling can make an intelligent choice to allot suitable PRBs to the correct UE based on the measurement of the channel status report. An interaction between the radio resource management function and the downlink scheduler may be seen to accomplish this job. The eNodeB sends a reference signal to the UE first. The UE then decodes it, computes the CQI, and returns it to the eNodeB. The CQI is a quantized and scaled metric based on the Signal to Interference plus Noise Ratio (SINR). The eNodeB uses this CQI information to decide when to schedule the PRBs. As a result, the Adaptive Modulation and Coding module will pick the optimal MCS. The Physical Downlink Control Channel (PDCCH) takes over and transmits data about the assigned PRBs and the chosen MCS. Eventually, each UE will read the PDCCH information and, if a Physical Downlink Shared Channel payload is planned, will access it. The relationship between the RRM functions and the downlink scheduler is depicted in Fig. 3.

4.2 Proposed Scheme

The round robin scheduler algorithm is a common scheduling method that is used to compare with other suggested algorithms. The RR algorithm ensures that the UEs are treated fairly. However, the system's throughput might be reduced. To boost the system's throughput, we must design an algorithm for that purpose. Therefore, the proposed algorithm schedules UEs depending on the number of PRBs and the number of UEs. The number of PRBs is proportional to the system's bandwidth. As a result, if the bandwidth is known, the number of PRBs can be calculated and its distribution across UEs also can be measured. The link between bandwidth and the number of PRBs is depicted in Table I.

Table 1: Bandwidth and Number of PRBs

Bandwidth	***PRBs***
1.4 MHz	6 PRBs
3 MHz	15 PRBs
5 MHz	25 PRBs
10 MHz	50 PRBs
20 MHz	100 PRBs

If the number of UEs exceeds the number of accessible PRBs, the suggested scheduling algorithm considers the following metric Equation 1. [8]

$$m(i,j) = \frac{D_j^i\,(t)}{T^i\,(t-1)} \qquad (1)$$

Where $D_j^i\ (t)$ is the received data rate for i UE at time t on the j PRB and $T^i\ (t-1)$ is the previous received average throughput computed by i UE.

Accordingly, the percentage of allocation of UEs with poor channel conditions can be increased [8]. If the number of UEs is lower than the number of available PRBs, the proposed scheduler algorithm schedules the UE with the highest CQI. Algorithm 1 depicts the pseudo-code of the proposed scheduler algorithm.

Algorithm 1 Proposed Algorithm

N: *The number of active UEs*
X: *The expected data rate*
R: *The number of PRBs*
Y: *The past average throughput for each UE*
$M = X/Y$
  For *all UEs* ***do***
    If $N >= R$ *then*
      assign RB to UE with highest value of M
    Else
      assign RB to UE with best CQI
    EndIF
  End For

5. Simulation and Results

The suggested method and the round robin algorithm are evaluated and compared in terms of performance. The findings are based on studies carried out with the LTE system simulator created in [9]. We analyze two scenarios: one with three UEs and one with eight UEs, both with a system bandwidth of 1.4 MHz and six PRBs. The goal of the simulation setup is to compare the results of the proposed algorithm to the results of the round robin scheduler method when the number of UEs becomes either larger or fewer than the number of RBs. Both the UEs and the eNodeB's throughput and Block Error Ratio (BLER) are collected and monitored. Every TTI will be run by the simulator (50 TTIs in this experiment). According to the transmission pilot obtained from the eNodeB, each UE provides feedback information concerning SINR and MCS. The eNodeB then gets feedback from each associated UE, and the scheduler allocates PRBs according on the resource allocation criterion. The Zero Forcing (ZF) receiver with two transmit antennas serves as the foundation for the channel model. The first scenario is to limit the number of UEs to three, which is less than the number of PRBs, in order to test the proposed algorithm's performance under these conditions. The second situation is to increase the number of UEs (8 UEs in this example) over the number of PRBs. Parameters for simulation are presented in Table 2.

Table 2: Simulation Parameters

Parameter	***Value***
System Bandwidth	1.4 MHz
Subcarriers	6
Subcarrier Bandwidth	180 KHz
Noise Power Spectral Density	- 174 dBm/Hz
Subcarrier Spacing	15 KHz
Channel Model	PedB
Carrier Frequency	2000 MHz
Number of Users	3/8
Number of Transmit/Receive Antenna	2/2
Transmit Mode	Spatial Multiplexing
Simulation Time	50 TTIs
Macrocell Transmit Power	43 dBm
Scheduler	(RR)/Proposed
Cyclic Prefix Type	Normal

5.1 Three UEs Scenario

In this case, three UEs are joined to the eNodeB, reducing the number of UEs to less than the number of available PRBs. The throughput of the eNodeB is shown in Fig. 4, and the suggested approach has a higher throughput in this situation. Figures 4–7 show the BLER for the three attached UEs scenario for both schedulers, the round robin technique, and the suggested approach.

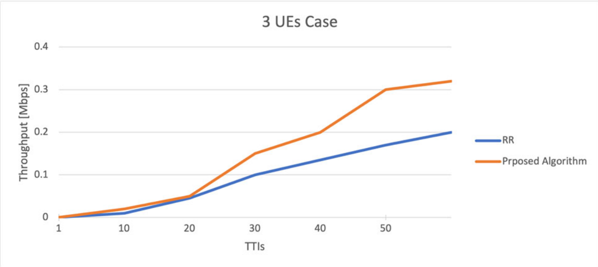

Fig. 4 Overall Cell Throughput in 3 UEs Scenario.

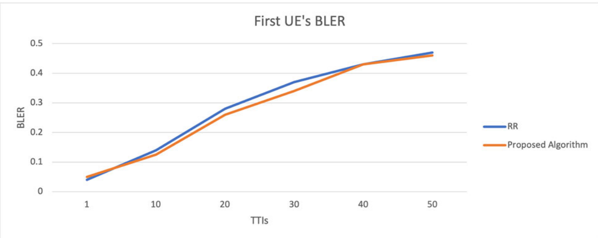

Fig. 5 BLER of First UE in 3 UEs Scenario.

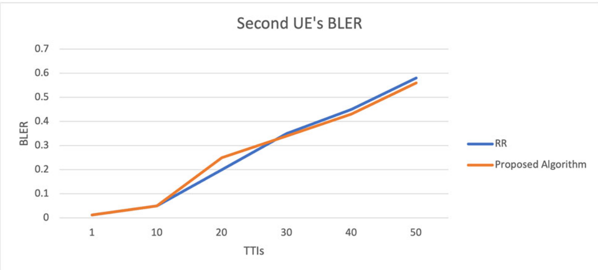

Fig. 6 BLER of Second UE in 3 UEs Scenario.

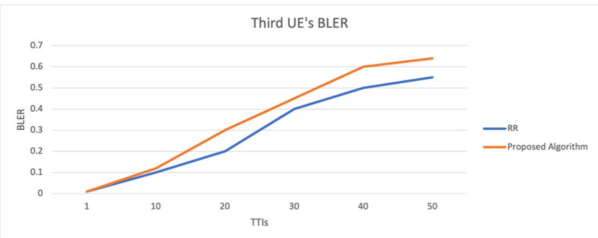

Fig. 7 BLER of Third UE in 3 UEs Scenario.

5.2 Eight UEs Scenario

In this situation, the number of UEs attached to the eNodeB is increased to eight in order to fulfill the suggested algorithm's second criterion (Number of UEs is more than Number of PRBs). The eNodeB throughput in Fig. 8 is compared to the round robin approach and the suggested technique; the disparity between them is fairly large, as can be seen. Furthermore, the suggested approach outperformed the 3 UEs case in terms of throughput. The graphs in Figs. 9–16 show the BLER for the eight attached UEs for both schedulers, the round robin approach, and the proposed algorithm.

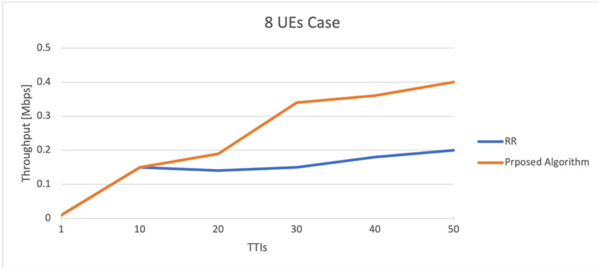

Fig. 8 Cell Throughput in 8 UEs Scenario.

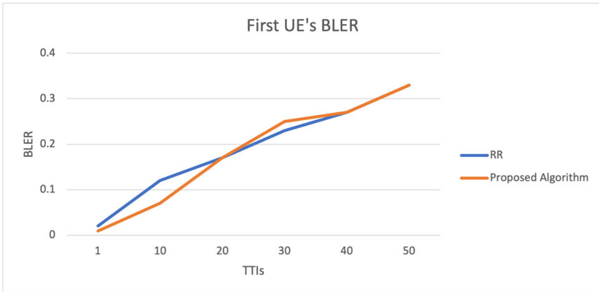

Fig. 9 BLER First UE in 8 UEs Scenario.

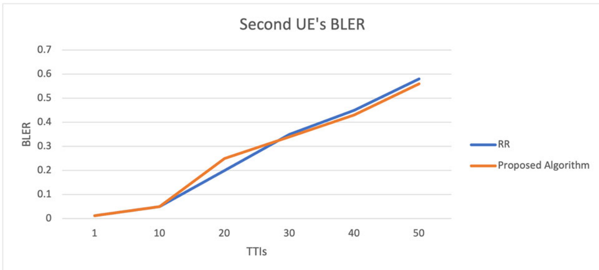

Fig. 10 BLER Second UE in 8 UEs Scenario.

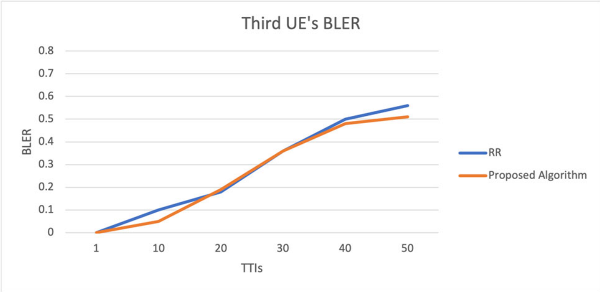

Fig. 11 BLER Third UE in 8 UEs Scenario.

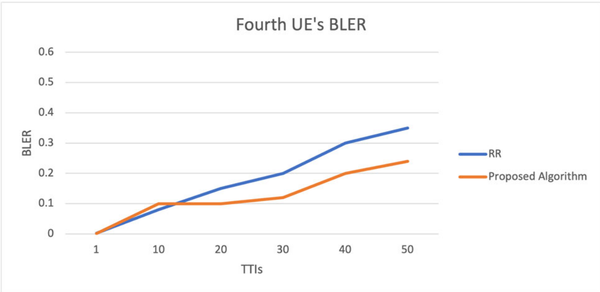

Fig. 12 BLER Fourth UE in 8 UEs Scenario

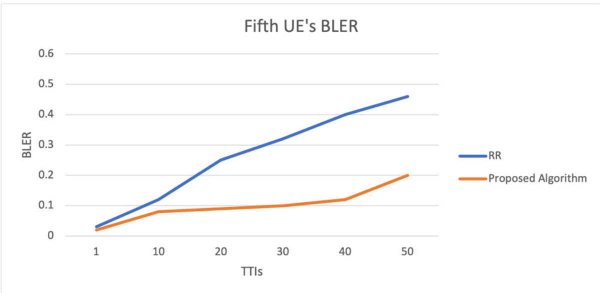

Fig. 13 BLER Fifth UE in 8 UEs Scenario.

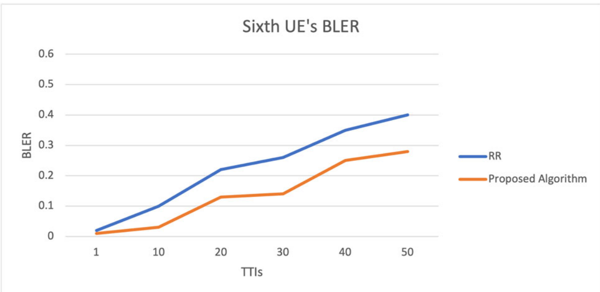

Fig. 14 BLER Sixth UE in 8 UEs Scenario.

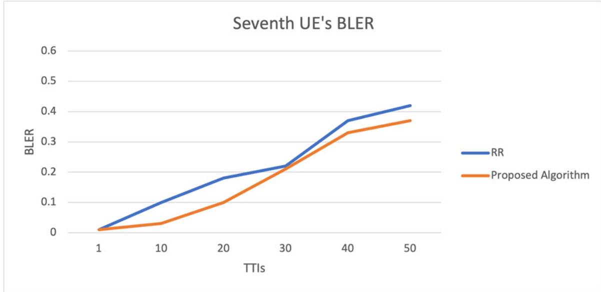

Fig. 15 BLER Seventh UE in 8 UEs Scenario.

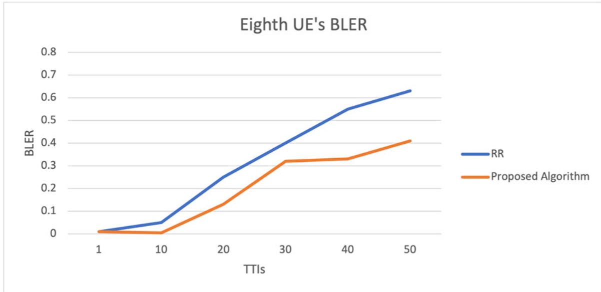

Fig. 16 BLER Eighth UE in 8 UEs Scenario.

6. Conclusion

In this article, a scheduling system based on the number of UEs connected to the eNodeB is suggested. It behaves differently depending on the number of UEs, thus when the number of UEs exceeds the number of PRBs, it prefers to assign the PRBs to the UEs fairly and with the highest possible throughput. When the number of UEs is minimal, however, the scheduler assigns the PRBs to the UE with the greatest CQI. The simulation was carried out in two situations. The suggested method was put up against the round-robin algorithm. As a result, when compared to the round robin approach, the scheduler using the suggested algorithm could give good overall throughput in both circumstances, with relative fairness in the second. When the round robin scheduler technique was developed, all UEs had a chance to be scheduled. However, because to poor channel circumstances, the throughput of several UEs was extremely low. However, because they did not fulfill the criteria for the proportional fairness metric, certain UEs were not scheduled and remained idle when the suggested method was deployed. As a result, when generating scheduling decisions for the UEs, our proposed method takes into account the channel circumstances as well as the proportional fairness metric. Because of the extra factors considered into the scheduling decision, the findings show that the proposed method outperforms the round robin approach. The proposed approach will be compared to other LTE scheduler techniques. In addition, a channel aware method will be examined in this scheme to limit the negative impact of interference.

References

[1] Technical Specification Group RAN, ”E-UTRA; LTE RF system scenar- ios,” 3GPP Tech. Rep. TS36.401, Jan. 2007.

[2] Mourad, A. M., Brunel, L., Okazaki, A., & Salim, U. (2007, April). Channel quality indicator estimation for OFDMA systems in the downlink. In *2007 IEEE 65th Vehicular Technology Conference-VTC2007-Spring* (pp. 1771-1775). IEEE.

[3] Dahlman, E., Parkvall, S., Skold, J., & Beming, P. (2010). *3G evolution: HSPA and LTE for mobile broadband*. Academic press.

[4] (2006) "E-UTRA Downlink User Throughput and Spectrum Efficiency" in Ericsson, Shanghai, China, (pp. 8-12).

[5] Iosif, O., & Banica, I. (2011, November). LTE uplink analysis using two packet scheduling models. In *2011 19thTelecommunications Forum (TELFOR) Proceedings of Papers* (pp. 394-397). IEEE.

[6] Lee, S. B., Pefkianakis, I., Meyerson, A., Xu, S., & Lu, S. (2009, April). Proportional fair frequency-domain packet scheduling for 3GPP LTE uplink. In *IEEE INFOCOM 2009* (pp. 2611-2615). IEEE.

[7] Al-Rawi, M., Jantti, R., Torsner, J., & Sagfors, M. (2007, November). Opportunistic uplilnk scheduling for 3G LTE systems. In *2007 Innovations in Information Technologies (IIT)* (pp. 705-709). IEEE.

[8] Capozzi, F., Piro, G., Grieco, L. A., Boggia, G., & Camarda, P. (2012). Downlink packet scheduling in LTE cellular networks: Key design issues and a survey. *IEEE communications surveys & tutorials*, *15*(2), 678-700.

[9] Ikuno, J. C., Wrulich, M., & Rupp, M. (2010, May). System level simulation of LTE networks. In *2010 IEEE 71st Vehicular Technology Conference* (pp. 1-5). IEEE.

[10] Alotaibi, S. (2018, August). Radio Resource Control Approaches for LTE-Advanced Femtocell Networks, dissertation; Denton, Texas., University of North Texas Libraries, UNT Digital Library.

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