Mobility analysis of Modified Proportional Fair scheduler in LTE/LTE-Advanced system

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Abstract. Packet scheduling is one of the key schemes used in Radio Resource Management (RRM) for Long Term Evolution (LTE) cellular network. It serves as the resource allocation for each time and frequency dimensions in LTE baseband processing. In previous research, a new scheduling algorithm was developed, namely the Modified-Proportional Fair (PF) scheduler that splits a single subframe into multiple time slots and allocates the resource block (RB) to the identified User Equipment (UE) in some chosen time slots and it is done continuously for each subframe depending on the instantaneous Channel Quality Indicator (CQI) feedback received from UEs. Results have shown that the Modified-PF scheduler produces the most outstanding overall performance in terms of spectral efficiency and throughput with comparable fairness as compared to other state-of-the-art schedulers, namely, Round Robin and Proportional Fair schedulers. However, the performance of the new scheduler is not analysed in UE mobility scenario. Hence, this research will determine the type of response by the scheduler towards different mobility condition by simulating the throughput and the spectral efficiency of the three schedulers for various UE velocities. It is observed that the Modified-PF again shows significant performance improvement for various mobility condition in terms of average UE throughput and average UE spectral efficiency in both single cell omnidirectional and tri-sector eNodeB. This shows that Modified-PF can be considered as one of the packet scheduling options for the LTE cellular network.

1. Introduction

The demands of wireless communications services have increased dramatically over the last few years. In the near future, more challenges are in sight as performance of wireless communications are becoming more demanding especially when pressures are coming from data hungry multimedia services for multiple users. Furthermore, the quality of service (QoS) provision for all customers must always be maintained while allowing users to move around. Orthogonal Frequency Division Multiple Access (OFDMA) which has been suggested by the International Telecommunication Union (ITU) to be the core Physical (PHY) layer technology for the International Mobile Telecommunication-Advanced (IMT-Advanced) systems are driven by the exploding demand for high speed mobile broadband services.

Radio Resource Management (RRM) which is the main element of OFDMA, is critical in achieving the required performance for higher system loads in which each of the main elements of Medium Access Control (MAC) and Physical (PHY) layers has to be managed accordingly[1]. In
contrast to its counterpart, namely mobile WiMAX (IEEE802.16m), LTE-Advanced is the leading competitor for IMT-Advanced as it provides backward compatible technology which is capable of applying LTE-Advanced to the available spectrum provided for LTE without adversely affecting the LTE terminal[2].

In the MAC layer of the LTE eNodeB contains the scheduler. The scheduler's function is to distribute radio resources among UEs served by a given cell and represents a methodology for the assignment of radio resources[3]. The methodology chosen by the planning algorithm affects the performance of each UE and the performance of the entire cell area. Therefore, the efficiency of different scheduling methods must be evaluated in most circumstances before any practical deployment. In fact, the scheduling algorithm is the core part determining the overall.

In recent years, a new type of LTE packet scheduler named Modified-Proportional Fair (Modified-PF) has been researched[8]. The Modified-PF scheduler splits a single subframe into multiple time slots and allocates the Resource Blocks (RBs) for each slot for identified users depending on the CQI feedback from the UEs. It thus achieves a compromise between spectral efficiency, throughput and fairness which enables UE capabilities and cell performance to be improved. However, this scheduling technique is not tested for its performance in UE mobility condition.

2. Packet Scheduling Modelling
Packet scheduling in LTE networks decides which BS and terminal are used to transport the data to and from which set of RB [4]. Data packet scheduling is one of the key technologies for the transport of multimedia traffic across wireless networks and for QoS categorisation and provision because it dictates the overall system behaviour[5]. The basic operation of the scheduler should be dynamic in nature to serve its function in transmitting the scheduled information from the eNodeB to the assigned terminal in 1 ms Transmit Time Interval (TTI). Generally, the downlink traffic from the eNodeB is always busier as opposed to the uplink traffic [6]. Apart from that, in order to solve the buffer overflow issues and to ensure latency requirements, it is necessary for data packets to be relayed as fast as possible [7].

2.1. Modified Proportional Fair Scheduler Model
The idea of Modified-PF scheduling algorithm is dividing a single subframe channel into multiple slots of RB that contains at least six rows and two columns for 1.4MHz channel bandwidth [8]. Once the respective UEs have been identified, the RBs will be allocated to them in each column. The first column matrix represents the first time slot of sub-frame and the second column of the matrix represents the second time slot of the same subframe. Figure 1 shows the illustration of the concept in Modified-PF. The Modified-PF algorithm improves the ability of conventional PF scheduler to achieve better spectral efficiency and throughput performance, but still provides an acceptable level of fairness in the systems.

![Illustration of the RBs mapping in the Modified-PF scheduling](image)

Figure 1. Illustrations of the RBs mapping in the Modified-PF scheduling
The scheduling procedure begins in the eNodeB by comparing the instant CQI feedback from various terminals and when more than one terminal responded, the scheduler selected one UE randomly. Once the CQI feedback from the UEs is received for the first round, the RBs are allocated. After that, the scheduler will consistently track the moving average throughput for each UE on the assigned RBs. The overall process can be defined in the flow chart in Figure 2 to reveal the functions of the modified PF scheduling algorithm.

![Flowchart](image)

**Figure 2.** Modified-PF scheduling algorithm flowchart.

3. **Simulation Methodology**

In order to realise the modified proportional fair scheduling process, there are several scenarios with specific parameter setup have been created to analyse and investigate the mobility response on the performance of Modified-PF by comparing with other state-of-the-art scheduling algorithms.

3.1. **Single Cell eNodeB Simulation**

In this simulation, 10 UEs were located randomly in a single cell eNodeB. The key parameters were defined according to 3GPP requirements and were tested with various scheduling algorithms; namely Round Robin, Proportional Fair and Modified-PF. Table 1 summarises the essential simulation parameters and settings and Figure 3 shows the UE topology in the single cell eNodeB.

| Parameter                      | Value                  |
|--------------------------------|------------------------|
| Bandwidth                      | 5MHz                   |
| Frequency                      | 2.10GHz                |
| Transmission Scheme            | MIMO (2x2)             |
| Scheduler                      | PF, RR, Modified-PF    |
| Transmit Time Interval (TTI)   | 1 ms                   |
| UE velocity                    | 0 km/h – 400km/h       |
| eNodeB Distance                | 1000 m                 |
| Number of UEs                  | 10                     |
| Transmit Power                 | 1 Watt                 |
3.2. Tri-Sector Simulation

The number of UEs used in three sectors of the single cell eNodeB were 30. The 10 UEs were located in three sectors of the eNodeB at various distances. Table 2 shows the simulation parameter setup and Figure 4 shows the UE topology in single cell Tri-Sector eNodeB.

Table 2. Simulation Parameter for single cell Tri-Sector eNodeB

| Parameter                       | Value                  |
|--------------------------------|------------------------|
| Bandwidth                       | 20MHz                  |
| Frequency                       | 2.14GHz                |
| Number of Transmitter           | 1                      |
| Number of Receiver              | 1                      |
| Scheduler                       | PF, RR, Modified-PF    |
| Transmit Time Interval (TTI)     | 1 ms                   |
| UE velocity                     | 0 km/h – 400km/h       |
| eNodeB Distance                 | 1000 m                 |
| Number of UEs                   | 10                     |
| Transmit Power                  | 1 Watt                 |
4. Simulation Results

4.1. Single Cell eNodeB Simulation
The single cell that have 10 UEs are simulated using omnidirectional antenna and implementing MIMO 2x2 transmission scheme with 10 UEs. The UE’s average throughput and spectral efficiency in the simulation using the Modified-PF are analyzed and compared with RR and PF scheduling algorithms. In this simulation the UE’s speed start at 0 km/h and increased to 400 km/h with 40km/h increment each time the simulation restart. All UE velocities are similar with each other, but the movement within the cell is in random direction for each user. The comparison of average user throughput and the average spectral efficiency in this simulation is presented in Figure 5 and Figure 6.

Figure 5. Average UE throughput for single cell eNodeB

Figure 5 indicates the performance of each user with different types of scheduling algorithms: RR, PF and Modified-PF. At 0-400 km/h the average user throughput for Modified-PF significantly performs better than RR and PF scheduler. RR scheduler show the least performance compared to PF and Modified-PF.
The average UE spectral efficiency performance of Modified-PF scheduler shows improvement at the speed of 0 to 40 km/h as compared to those of the RR and PF schedulers. However, the performance dropped as the speed increases and the result shows the average UE spectral efficiency were nearly similar with UEs using PF scheduler.

According to the overall results from single cell omnidirectional eNodeB simulation, it is observed that the modified-PF scheduler has significantly improved the UE throughput performance, however, its performance with respect to user spectral efficiency is somewhat similar with that of the PF scheduler performance.

4.2. Tri-Sector Simulation
In this section, Tri Sector antenna was adapted into the simulation to analyze the performance of all scheduler: RR, PF and Modified-PF. The cell was divided into three different sector which all sector consists of 10 UEs. In this simulation, all UEs are moving at the speed of 0 to 400 km/h. The result of average user throughput and spectral efficiency in this simulation is shown in Figure 7 and Figure 8.
Figure 7 indicates the average UE throughput performance for three schedulers under various UE velocities. It is observed that the RR scheduler is the worst performer in terms of UE throughput. In contrast, the Modified-PF provides the best throughput which is the highest among the three schedulers. At any speed from 0 to 400 Km/h, the average throughput of UEs using Modified-PF scheduler performs better than the other two schedulers.

Figure 8. Average UE spectral efficiency for Tri Sector cell

Figure 9 indicates that by using RR scheduler, the lowest UE spectral efficiency can be observed at the speed of 0 km/h in which all users are in stationary mode. The spectral efficiency dropped as the user start to move within the cell. For PF and Modified-PF, UEs spectral efficiency was nearly similar, but the Modified-PF scheduler give a slightly better performance than PF scheduler.

For the results of the Tri-Sector antenna simulations, it has be shown that the Modified-PF scheduler is the greatest performer in terms of average UE throughput and average UE spectral efficiency as compared to the other two schedulers.

5. Conclusion
The Modified-PF scheduling algorithm for the LTE downlink packet transmission in mobile environment has been analysed and proven that this algorithm can still provide the best performance in terms of average UE throughput and average UE spectral efficiency as compared to RR and PF schedulers. This shows that the modified-PF can still dynamically assign the suitable RBs to the respected users depending on the channel state information feedback from the UEs even during mobile condition. Based on this conclusion, modified-PF can be chosen as one of the options for scheduling methods in LTE/LTE-Advanced due to its superiority in mobile environment.

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