International Journal of Technology (2015) 2: 130-138
ISSN 2086-9614

MODIFICATION OF ROUND ROBIN AND BEST CQI SCHEDULING METHOD FOR 3GPP LTE DOWNLINK

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(Received: February 2015 / Revised: April 2015 / Accepted: April 2015)

ABSTRACT

In the downlink LTE, the scheduler is an important element that assigns resource block (RB) allocation for different users in a cell. RB is the smallest element that can be assigned by the scheduler. This paper proposed a new scheduler algorithm by considering the tradeoff balance between throughput and fairness among users. The benefits of both *Best CQI* and *Round Robin* schedulers have been combined in this proposed scheduler. The proposed scheduler has two main time slots that apply the combined algorithms. The primary time slot applies a *Round Robin* algorithm that has a continuous user sequence in the entire sub frame, and the second time slot then applies the *Best CQI* algorithm with a fairness enhancement. For 15dB SNR, the system has various throughput values in each scheduler, which is 61.2Mbps for the *Best CQI* scheduler, 32.3Mbps for the *Round Robin* scheduler, and 48Mbps for the proposed scheduler. For the results, in reference to Jain's fairness index, the proposed scheduler gains a fairness index of 0.97. Furthermore, for 20 users at 5MHz bandwidth, it is found that the average queuing delay is 5ms for the *Round Robin* scheduler, 29.38ms for the *Best CQI* scheduler, and 0.94ms for the proposed scheduler.

Keywords: Best CQI; Fairness; LTE; Round Robin; Scheduling; Throughput

1. INTRODUCTION

The demand for enhanced technology in the field of telecommunication has been growing rapidly, raising the need for innovation in the telecommunication standard. The Third Generation Partnership Project (3GPP), which is a telecommunication group, collaborates to meet the challenge of human needs in telecommunication technology with HSPA and LTE (3gpp.org). LTE was created from the evolution of HSPA to increase the capacity and data rate in the telecommunication channel. LTE provides a high data rate with a range of 1.4–20MHz and can support the data rate up to 100Mbps at the downlink and 50Mbps at the uplink with low latency (10ms) (Dalman et al., 2008). Downlink, which consists of a few resource elements (RE) in one resource block (RB), is represented as the time and frequency grid. RB is the smallest element that can be assigned and controlled by the scheduler. The scheduler has an important task in controlling the RB allocation for each user. In LTE, there are two general scheduling algorithms: *Best CQI* and *Round Robin*. *Round Robin* is a scheduling algorithm that manages the RB allocation sequentially to the users in circular term (Dikamba, 2010). *Best CQI* is a suitable algorithm to maximize the throughtput by allowing the RB allocation to be given to the user with the highest CQI (Gavrilovska, 2011).

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Permalink/DOI: http://dx.doi.org/10.14716/ijtech.v6i2.964

In March 2011, Tshiteya Dikamba (Ku, 2012) proposed a new scheduling algorithm that combines the *Best CQI* and *Round Robin* at different time slots, so that there is a good tradeoff between fairness and throughput. In November 2011, a novel scheduling algorithm was created by Liljana Gavrilovska (Li et al., 2011) that optimizes the fairness of the *Best CQI* scheduler. The fairness enhancement is done with a consideration of the previous TTI allocation. In this case, the user who has received the RB allocation in the previous TTI is set to be unreachable for the RB allocation in the current TTI (Li et al., 2011). From both these new algorithm ideas, a new scheduler is created by combining the *Best CQI* and *Round Robin* algorithms using the fairness enhancement, by giving the RB allocation to the user with the lowest RB allocation along the previous TTI. The aim of the proposed combined algorithm is to improve the fairness (Ku, 2012) where the selections are done randomly to the user in the *Best CQI* time slot. This paper is organized as follows: Section 2 describes the LTE downlink system. Section 3 explains the new scheduling algorithm. The traffic model will be explained further in Section 4, with the result and analysis in Section 5. Section 6 will discuss the conclusions of this paper.

2. METHODOLOGY

2.1. LTE Downlink System

LTE at the downlink uses the OFDMA concept as a solution to overcome the interference in the free space propagation model. The downlink physical layer contains the resources that will be allocated to each user. A frame of downlink transmission has a length of 10ms, which is made from 10 sub frames with duration of 1ms each. The downlink physical resources in LTE are represented as the grid of time and frequency (electronicdesign.com). The total allocation of resource block (RB) in each time slot is determined by the bandwidth. Each RB has a duration of 0.5ms (1slot) and 180kHz bandwidth, and the width between each subcarrier is 15kHz (ee.ui.ac.id/wasp). The width between each subcarrier results in the total subcarrier in each resource block being equal to 12. It is further calculated that RB has $12 \times 7 = 84$ resource elements (RE) in the short cyclic prefix and $12 \times 6 = 72$ RE in the extended cyclic prefix. The scheduler is located in eNodeB and has a role in allocating RB to each user in that cell. Each RB will be allocated to the users based on the scheduler in that system. Users will send the Channel State Information (CSI) in the case of informing the channel condition in order to ensure that the eNodeB may respond to the data transmission immediately by using an Adaptive Modulation Code (AMC). This code will be transmitted based on the channel condition for each TTI (Zyren, 2007).

2.2. New Proposed Scheduler

The scheduler plays an important role in carrying out the RB allocation for each user. The scheduler is used to produce a good value of throughput and fairness for each user respectively. The two commonly used scheduler algorithms are *Best CQI* and *Round Robin* (Silberchatz et al., 2010).

Best CQI will select the user with the highest CQI value in order to get the RB allocation for each time, despite the disadvantage that there is no good *fairness* for each user. As a result, the given RB allocations are only addressed to users with the highest CQI. In contrast, the *Round Robin* algorithm will sequentially select the user in a circular term and give a good *fairness* by neglecting the throughput.

The novel proposed scheduler algorithm will facilitate the tradeoff between throughput and fairness. The principle of this algorithm scheme combines the abilities of *Best CQI* and *Round Robin*. In the first time slot (TS1) in each sub frame, an RB will be given to the user by the *Round Robin* method and in the second time slot (TS2) in each sub frame, the user with the highest CQI value will get the RB allocation. In cases when there is more than one user in the second time slot with the highest CQI value, the scheduler will select the user based on the priority rank in each TTI. The flowchart of the new scheduler is presented in Figure 1.

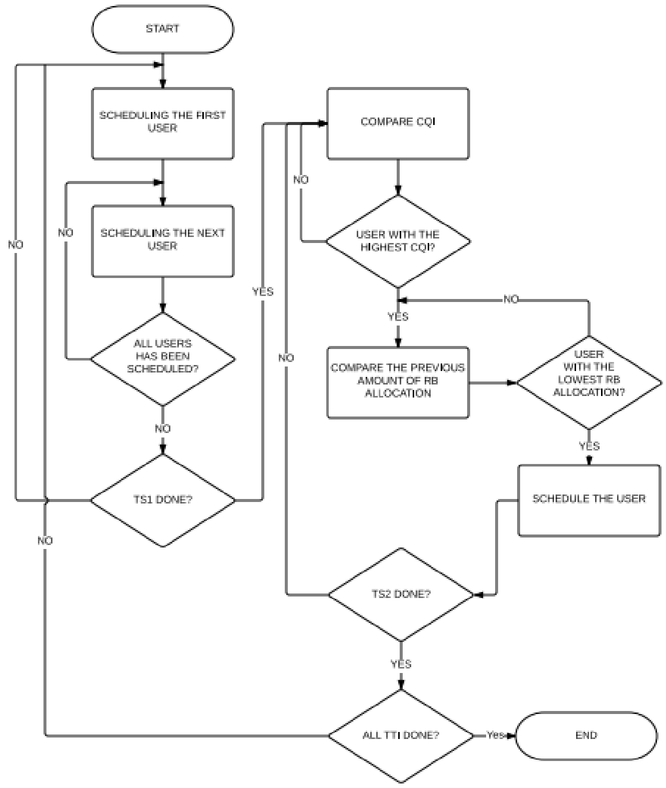

Figure 1 Proposed Scheduler Flowchart

In the proposed scheduler, the existence of two scheduler algorithms in two different time slot has the aim of stabilizing the fairness between *Round Robin* and *Best CQI*. In the second time slot, the fairness enhancement was done by implementing the RB allocation to the user with the highest CQI value and lowest RB allocation within the TTI transmission. It was found that the enhancement of fairness is done without reducing the throughput. The scheduling process will be done repeatedly for every transmission until the whole TTI is successfully sent.

2.3. Simulation Parameters

The simulator was created to carry out a comparison against the other commonly used schedulers, i.e., Round Robin and Best CQI. The comparisons were made based on the existing performance parameters. The three performance parameters used as references are throughput, fairness, and average queuing delay. The parameters are defined as follows:

- Throughput value: the amount of data that is successfully received and that carries the information to the user. Its value is the accumulation of data throughput rate of the entire UE in terms of bits/s.
- Fairness from RB allocation: the amount of resource allocation obtained by each user. RB allocation fairness that is obtained by each user can be represented by the following parameters:
  - Comparison of RB allocation range is obtained by the difference between the highest number and the lowest number of RB allocation of the user.

$$\Delta RB = \max RB - \min RB \tag{1}$$

A rise in the difference indicates that the value of its fairness has worsened and vice versa.

- Standard deviation
  The standard deviation shows the deviation that occurs at a time. Higher value standard deviations may indicate that the fairness value has worsened.
- Jain's fairness index

$$J(x_1, x_2, \ldots, x_n) = \frac{(\sum_{i=1}^{n} x_i)^2}{n \sum_{i=1}^{n} x_i^2} \quad (2)$$

This is a reference parameter value of fairness where there are n users. x_i shows the value for each connection that provides the value of the RB allocation for each user for each SNR. Actual results will vary from 1/n (worst condition) to 1 (best condition). The best conditions will be obtained when all the users receive the same amount of allocated RB.

- Average queuing delay: the value of the average waiting time that occurs for a user to get RB allocation in a TTI. The timing is based on the lapse of time between the RB allocation completions for users. This is done with respect to the time when the user gets the next RB allocation.

$$Average\ Delay = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{J}\sum_{j=1}^{J} W_j(t) \quad (3)$$

Description:
– J is the number of users in a system
– T indicates the total simulation time (number of TTI)
– $W_j(t)$ shows the delay of user j at time t

The simulation parameters shown in Table 1 used for throughput and fairness analysis are 4×4 MIMO, 100 users, 20MHz bandwidth, and transmission of 1000 TTI.

Table 1 Simulation parameters

Parameter	**Value**
TTI simulation length	1000 TTI
Fading model	Rayleigh fading
UE speeds	60km/h
CRR (CQI Reporting rate)	1
Frame Structure	FDD
Carrier Frequency	1800MHz
Bandwidth	20MHz
Number of subcarriers	1200
Number of subcarriers per RB	12
Number of RBs	100
Subcarrier Spacing	15kHz
Slot duration	0.5ms
TTI	1ms
Number of OFDM Symbols per slot	7

The parameters to obtain the value of the average waiting delay are 5MHz bandwidth parameters and number of users, which are 10, 20, 30, 40, and 50 users. Additionally, a length of 100TTI is also used in the proposed system.

3. RESULTS AND DISCUSSION

In this chapter, the results of the proposed new scheduler will be compared with those of the other schedulers. The simulation results will be compared with the reference scheduler in the case of throughput, fairness, and average queuing delay.

3.1. Throughput Comparison

Figure 2 shows the throughput value comparison between *Round Robin*, *Best CQI*, and the proposed scheduler. From the graph, we can conclude that the *Best CQI* scheduler has the highest value compare with both *Round Robin* and the new scheduler. The throughput quality of the proposed scheduler lies between the throughput values of *Round Robin* and *Best CQI*.

At 15dB SNR, the throughput results are 61.2, 48, and 32.3Mbps for *Best CQI*, the new scheduler, and *Round* Robin, respectively. At all sample points in each SNR, we can see that it will give similar results and that the new scheduler throughput will always lie between those of *Best CQI* and *Round Robin*. The results in Figure 2 also show that the throughput appropriately fits the expected throughput value. The proposed scheduler has a higher throughput than the *Round Robin* scheduler.

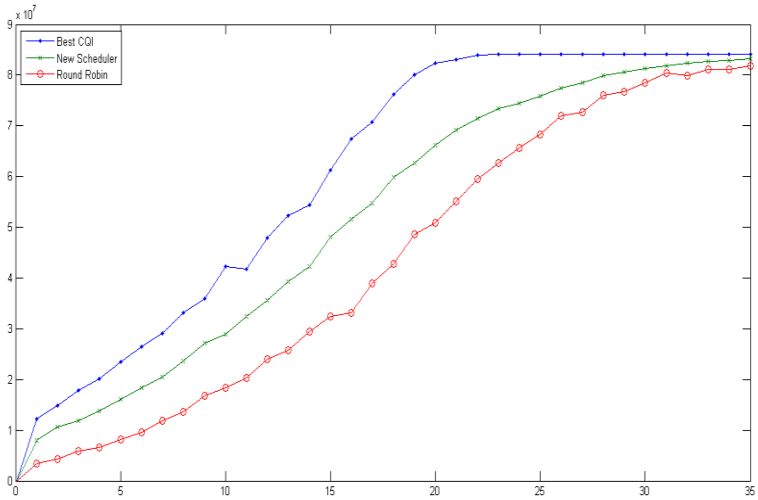

Figure 2 Comparison between *Best CQI*, new scheduler, and Round Robin throughput value

3.2. Comparison of *Fairness* Value

a) Max Min value

Figure 3 shows the RB allocation at each SNR among users by using the *Best CQI* scheduler. From Figure 3, the value of RB allocation for each user varies from 0 to 20268 RB. This large range indicates that *Best CQI* does not give good fairness among users. This is due to the existence of one user who has a very large RB allocation value and impact on the decreasing number of RB allocations, which manage to be further distributed to other users.

Figure 4 shows the RB allocation at each SNR among users using the *Round Robin* and *Best CQI* scheduler combination without the implementation of fairness enhancement on the second time slot.

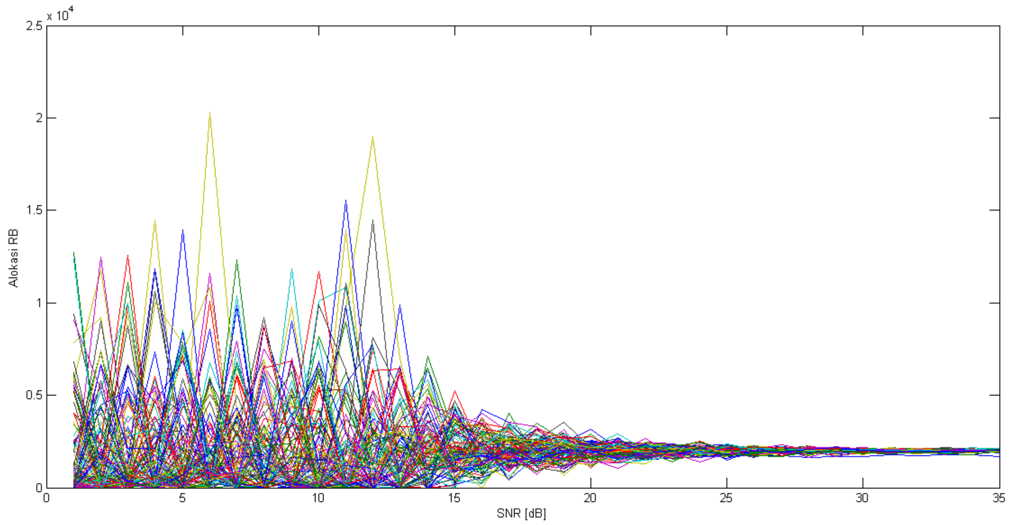

Figure 3 *Best CQI* new scheduler

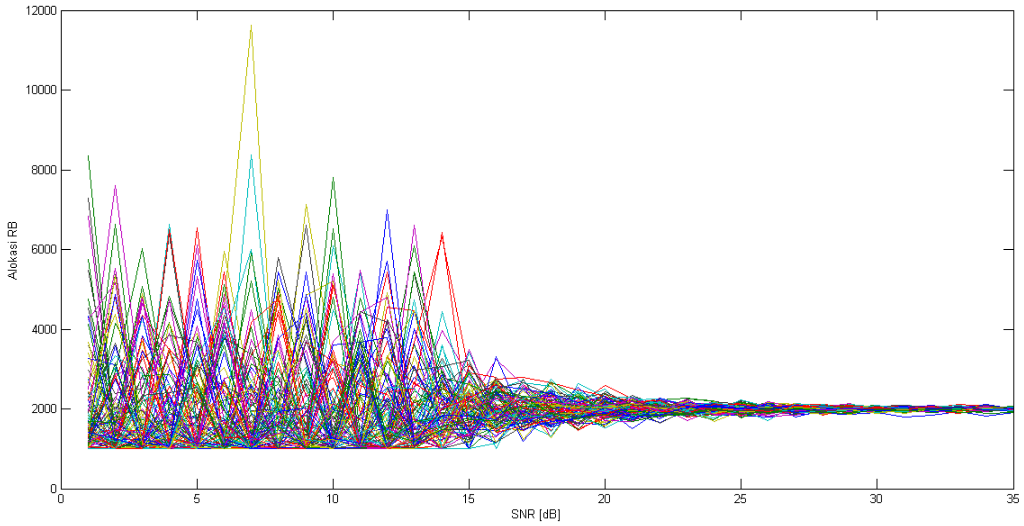

Figure 4 *Best CQI* + RR without fairness optimization

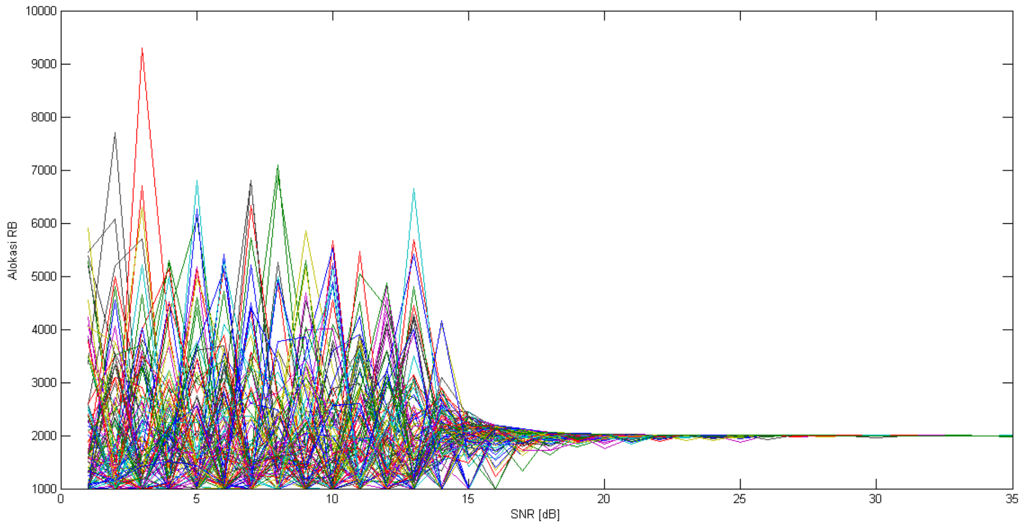

Figure 5 New scheduler RB allocation

From Figure 4, the value of RB allocation for each user varies from 1000 to 11633 RB. The calculation of this range shows 10633 RB, which is almost two times smaller than that of the *Best CQI* scheduler. Another advantage of this scheduler is no newbie users who have not received the RB allocation over time.

Figure 5 shows the RB allocation at each SNR among users using the proposed scheduler. In the new scheduler, the proposed fairness optimization is based on the RB allocation along previous TTI. Furthermore, it is shown that the value of RB allocation for each user varies from 1000 to 9300 RB. The range of data value is 8300 RB. This value is lower than that of the *Best CQI* algorithm and even lower than that of the combination of *Round Robin* and *Best CQI* without fairness enhancement.

b) Comparison of schedulers' standard deviations

Figure 6 shows that for every increment in SNR, the standard deviation for each scheduler, except for *Round Robin*, will be reduced due to the high SNR value. Then, the RB allocation will select more users in order to have the highest CQI. This contributes to the distribution of RB allocation being made equal. Comparison results can be seen in Figure 6, which shows that the fairness enhancement depresses the standard deviation. It shows that the new scheduler can produce a better fairness than the combination of *Round Robin* and *Best CQI* with random user selection.

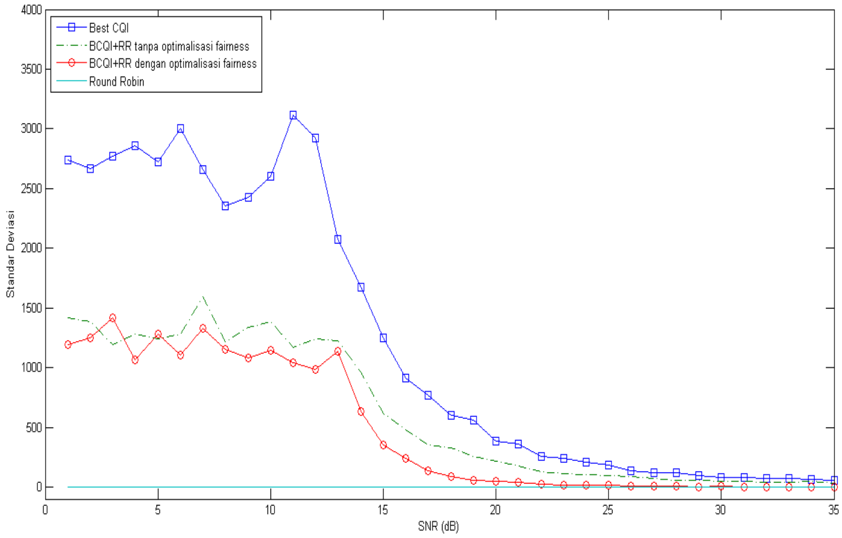

Figure 6 Comparison of standard deviation for each scheduler

3.3. Average Queuing Delay Comparison

Figure 7 shows a comparison of average queuing delay for the number of users by using the new scheduler. From the graph, it can be seen that waiting time for each user increases proportionally with the large number of active users in the future. When we compare the new scheduler with the waiting time of *Round Robin*, each user gains the RB allocation for every 0.5ms. This waiting time occurs when the number of users is less than RB allocation per TTI. The average delay for the new scheduler is slightly worse than that for the *Round Robin* scheduler, but the proposed scheduler's average queuing delay is much better than that of the *Best CQI* scheduler.

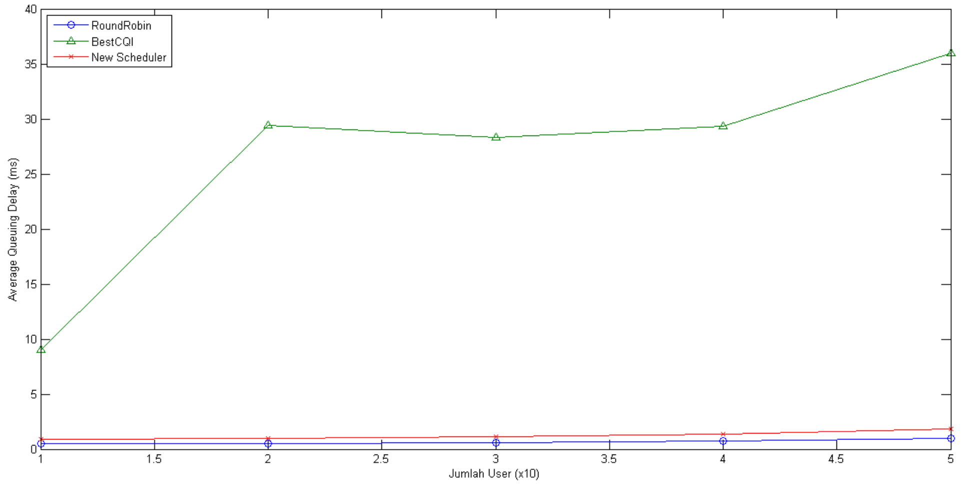

Figure 7 Comparison of average queuing delay for *Round Robin, Best CQI,* and the new scheduler

The large difference between the new scheduler and the *Best CQI* scheduler waiting time is due to the optimization at the new scheduler in the second time slot. This is the time slot where the RB allocations are distributed to the user who has the fewest RB allocations of the overall previous TTI. Using the priority ranking at the second time slot will lead to a better queuing delay than that for *Best CQI*.

Table 2 Average queuing delay comparison

Scheduler	Average Queuing Delay(ms)				
	10 users	20 users	30 users	40 users	50 users
Round Robin	0.5	0.5	0.6	0.75	1
Best CQI	9.02	29.38	28.31	29.33	35.97
New scheduler	0.873	0.94	1.13	1.37	1.84

4. CONCLUSION

The proposed new scheduler in this paper has been compared with pre-existing schedulers. The comparisons for throughput are generated at 15dB SNR and 20MHz bandwidth. This proposed model results in 61.2Mbps for *Best CQI*, 48Mbps for the new scheduler, and 32.3Mbps for *Round Robin*. These values indicate that the new scheduler gives a better throughput than the *Round Robin* algorithm but still has a smaller throughput with respect to *Best CQI*. In the comparison of fairness based on its minimum and maximum range, standard deviation of RB allocation, and Jain's fairness index, the new scheduler yields a better fairness value than *Best CQI*. Furthermore, the scheduler is created by combining the *Best CQI* and *Round Robin* schedulers without fairness optimization. The average queuing delay is slightly worse than that for *Round Robin* but is much better than that for *Best CQI*.

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