Wireless Communications and Networking – Fall 2020

Final Project- 5G Simulation in MATLAB

Modified Proportional Fairness Scheduling (MPF-BCQI) Algorithm with Best CQI

ECGR 6120/8120

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Project Objective:

To have an algorithm which performs better than the already existing scheduling algorithms and to compare them with each other.

The proposed scheduling algorithm is:

Modified Proportional Fair – Best CQI algorithm (MPF-BCQI)

The algorithm tries to satisfy both the average throughput and the fairness enhanced with new averaging methods.

The first is the modification of PF based on changing the method used to compute the average throughput for the user. These methods are: Median, Range and Geometric Mean methods.

The second is calculating the metric for each UE as a combination of PF and best CQI metric in order to achieve better channel allocation for the user while satisfying the fairness between users.

These are the ideas based on Mai Ali Ibrahim, Nada et al, "A Proposed Modified Proportional Fairness Scheduling (MPF-BCQI) Algorithm with Best CQI Consideration for LTE-A Networks", 2018 13th International Conference on Computer Engineering and Systems (ICCES)

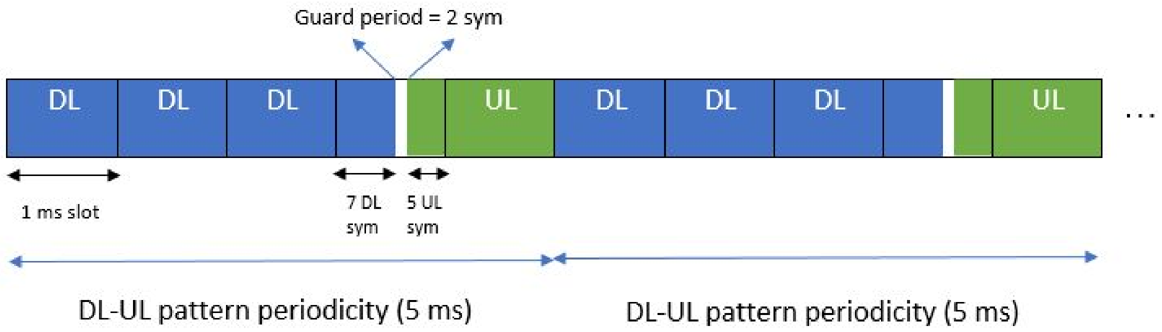
Introduction:

Brief description of scheduling:

Scheduling is a key Radio Resource Management (RRM) mechanism for realizing Quality of Service (QoS) requirements and optimizing system performance. Symbol/Slot based scheduling of resources allows shorter transmission durations spanning a few symbols in the slot. Some of the famous scheduling algorithms are Best Channel Quality Indicator (BestCQI), Round Robin (RR) and Proportional Fair (PF).

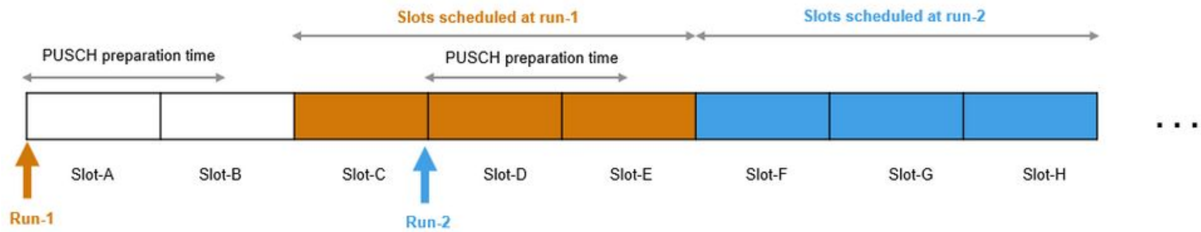
1. NR TDD Symbol Based Scheduling Performance Evaluation:

In time division duplexing (TDD) mode to assign uplink (UL) and downlink (DL) resources and evaluate the network performance. You can also switch to slot based scheduling. In TDD mode, physical uplink shared channel (PUSCH) and physical downlink shared channel (PDSCH) transmissions are scheduled in the same frequency band with separation in time domain. Scheduling strategy used in the example can be customized to evaluate the performance. A passthrough physical (PHY) layer without any physical layer processing is used, which adopts a probability-based approach to model packet reception failures. The performance of the scheduling strategy is evaluated in terms of achieved throughput and the fairness in resource sharing.



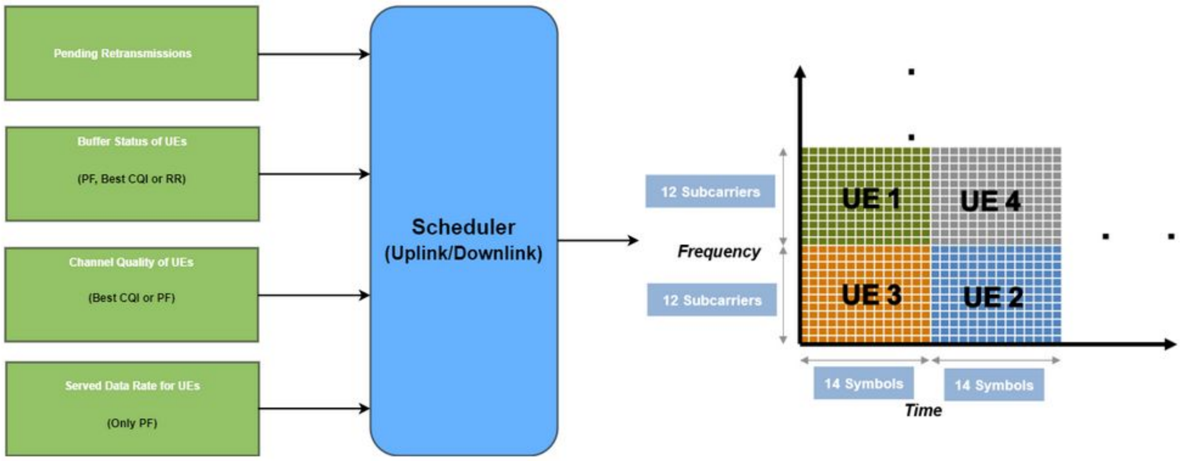
2. NR FDD Based Scheduling:

Frequency division duplexing (FDD) mode with medium access control (MAC) logical channel prioritization (LCP) functionality and evaluates the network performance. Scheduling strategy controls the downlink (DL) and uplink (UL) scheduling of resources and can be customized to evaluate the performance. The example shows the functionality of the radio link control (RLC) layer in unacknowledged mode (UM) with LCP to serve multiple logical channels. The performance of the scheduling strategy is evaluated in terms of achieved throughput and the fairness in resource sharing.



3. NR PUSCH FDD Scheduling:

This example evaluates the throughput and resource share fairness performance of an uplink (UL) scheduling strategy in frequency division duplexing (FDD) mode with radio link control (RLC) layer integrated. The UL scheduling strategy assigns the physical uplink shared channel resources (PUSCH) resources to a set of user equipment (UEs) connected to a gNB. The example uses unacknowledged mode (UM) of RLC layer and a passthrough physical (PHY) layer. The passthrough PHY layer does not involve any physical layer processing and adopts a probability-based approach to model packet reception failures. The example logs the events in the simulation and also shows the run time visualizations to observe the network performance.



Types of popular Scheduling Algorithms:

1. **Proportional Fairness:**

   Proportional Fairness (PF) algorithm is one of the standard uplink scheduling algorithm that aims to maximize fairness between users and also giving an acceptable performance in terms of average throughput, spectral efficiency and average system energy by calculating a priority value for each user on each RB and choose the highest value based on a priority function. Best Channel Quality Indicator (CQI) is also known as channel aware scheduling algorithm. It assigns RB to the user that has the best channel quality. This scheduler aims to maximize the average throughput and spectral efficiency and also give an acceptable value of fairness.

$$K^* = \arg\max_k \left(\frac{r_{k,n}}{(t_c - 1)\,T_k + \sum_{n=1}^{N} P_{k,n} r_{k,n}} \right)$$

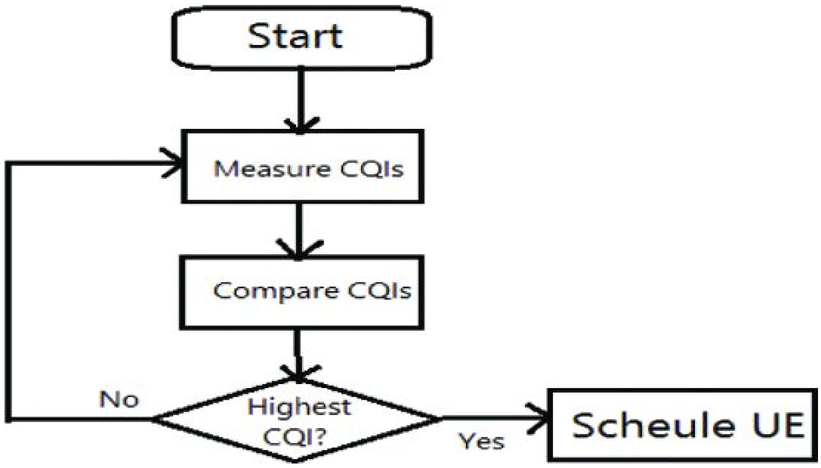
$$T_k\,(t+1) = \begin{cases} \left(1 - \frac{1}{t_c}\right) T_{k,n}\,(t) + \frac{1}{t_c} R_k\,(t)\,, & \mathrm{K} = \mathrm{K}^* \\ \left(1 - \frac{1}{t_c}\right) T_{k,n}\,(t) & \mathrm{K} \neq \mathrm{K}^* \end{cases}$$

2. **Round Robin:**

   RR scheduling algorithm maintains a constant delay between two transmissions to the same user. This is an advantage for modern voice and video communications which have strict delay requirements. RR scheduling algorithm also has the advantage of reduced overhead, since the eNB does not need to sacrifice transmission time to inform the users in every block about their allocated slot positions.

3. **Best CQI:**

Best-CQIScheduler allocates the resource blocksto the UEs with highest CQI on RB during a TTI. The best CQI algorithm is efficient, but it is not fair to all users. The UEs, such as those at the cell edges, which face bad channel conditions, will always not get RBs allocated. Hence such users always starve of radio resources, which is practically not acceptable. So, fairness should also be taken into account along with focus on spectral efficiency.



Proposed Algorithm Design:

Modified Proportional Fair – Best CQI algorithm (MPF-BCQI):

A new scheduler that considers a tradeoff balance between throughput and fairness among users. The benefits of both Best CQI and Proportional Fair schedulers have been combined in this proposed scheduler with new averaging methods for computing the average throughput for PF scheduler. Such combination ensures fairness and meanwhile better results of average throughput, spectral efficiency and system energy.

Positive attributes of the new design:

Benefits of both Best CQI and Proportional Fair schedulers can be combined for computing the average throughput for PF scheduler and Better results of average throughput, spectral efficiency and system energy also with Compromised fairness.

Modifications made:

1. **First modification -** Changing the PF method used to compute the average throughput for the user. The method is: Range.
2. **Second modification -** Calculating the metric for each UE as a combination of PF and best CQI metric in order to achieve better channel allocation for the user.

Pseudocode:

Calculate the combinational Metric of PF and Best CQI

$$a_{k,n} = \arg\max_k \left(\frac{r_{k,n}}{(t_c - 1)T_k + \sum_{n=1}^{N} p_{k,n} r_{k,n}} + CQI_{k,n} \right)$$

Search element in Matrix array of the largest value row I of Matrix array

Set the elements on correspondent row I and Column j of array element=0

Assign the rest element of Matrix to form a new Matrix
Next I

End For
End

The above pseudocode shows that we are Calculating the metric for each UE as a combination of PF and best CQI metric in order to achieve better channel allocation for the user while satisfying the fairness between users.

Algorithm implementation:

```
% Calculate UE weightage as per PF strategy
pfWeightage = achievableDataRate/pastDataRate;
% Get CQI values for the RBs of the resource block
% group and calculate average CQI for the whole RBG.
cqiRBG = schedulerInput.cqiRBG(i, :);
cqiAvg = floor(mean(cqiRBG));
if(pfWeightage > maxPFWeightage && cqiAvg > bestAvgCQI)
    % Update the UE with maximum weightage and also
    % Update the best CQI value till now.
    maxPFWeightage = pfWeightage;
    bestAvgCQI = cqiAvg;        %modified by also including BestCQI
    selectedUE = schedulerInput.eligibleUEs(i);
    mcsIndex = schedulerInput.mcsRBG(i, 1);
end
```

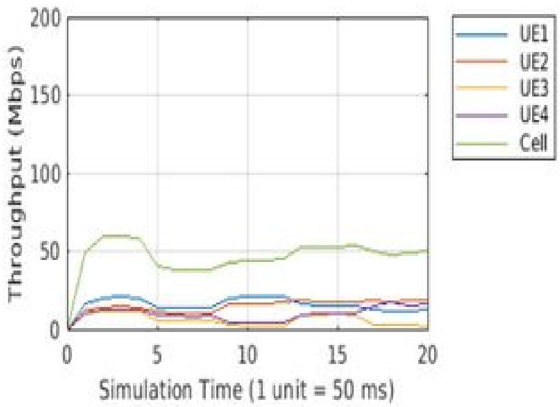
Using Range to compute average throughput in PF algorithm:

Range method is defined: Assume Rk1, Rk2….Rk,n are the throughputs of UE after k of TTI. We first find the maximum and minimum assigned throughput values to the user, then the average throughput is computed by:

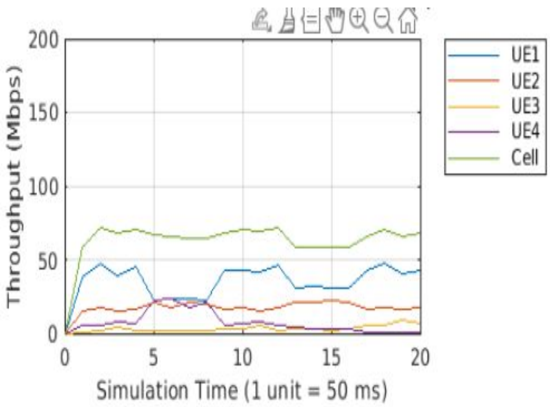
$$T_k(N+1) = \max(R_k(N)) - \min(R_k(N))$$

Comparison with various traditional scheduling algorithms:

Comparison 1: with PF Throughput



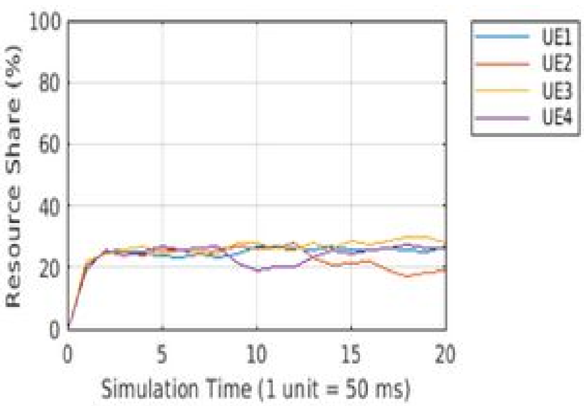
FDD - PF



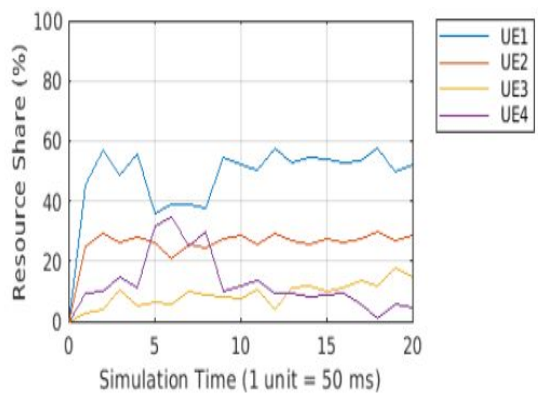
FDD MPF-BCQI

The above has the traditional PF on the left for FDD and on the right is my implemented algorithm that is the Modified Proportional Fairness(MPF-BCQI) and we can see that the throughput in the right is much better since we have altered the PF algorithm with a combinational metric of both PF + BestCQI. Hence the better throughput.

Comparison 2: with PF Resource Sharing



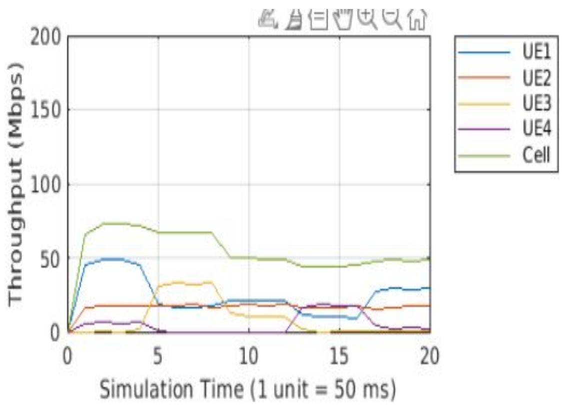
FDD - PF



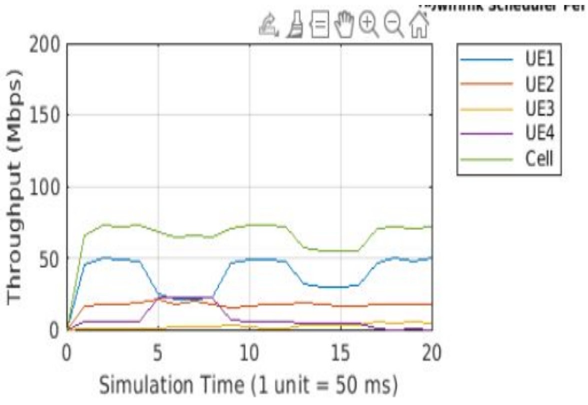
FDD MPF-BCQI

The above has the traditional PF Fairness on the left for FDD and on the right is my implemented algorithm that is the Modified Proportional Fairness(MPF-BCQI) Fairness and we can see that the fairness in the left is much better since we have altered the PF algorithm with a combinational metric of both PF + BestCQI, the Fairness is not much compromised for and has users with different priorities and have also left some starved. This can be tried to compensate by using other averaging methods like the geometric mean in the future.

Comparison 3: with BCQI Throughput



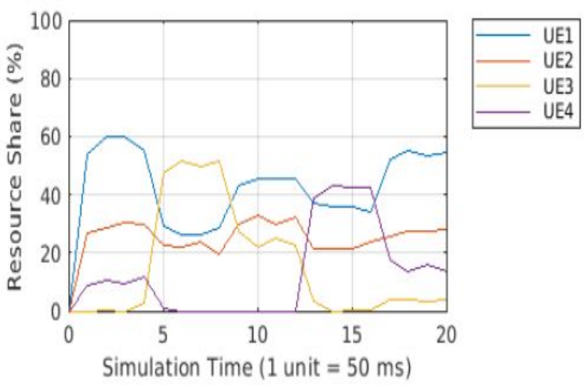
FDD BCQI



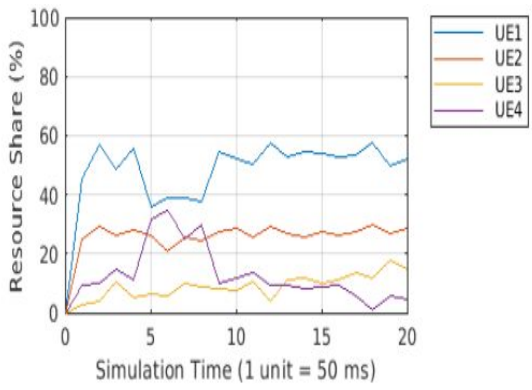
FDD MPF-BCQI

The Modified Proportional Fairness(MPF-BCQI) for BCQI comparison provides a much better throughput than the traditional BCQI since we have altered the PF algorithm with a combinational metric of both PF + BestCQI.

Comparison 4: with BCQI Resource Sharing



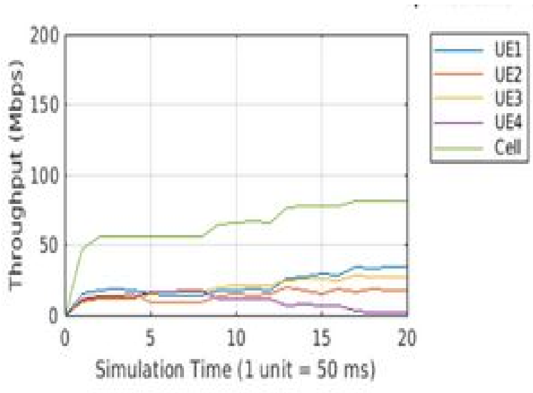
FDD BCQI

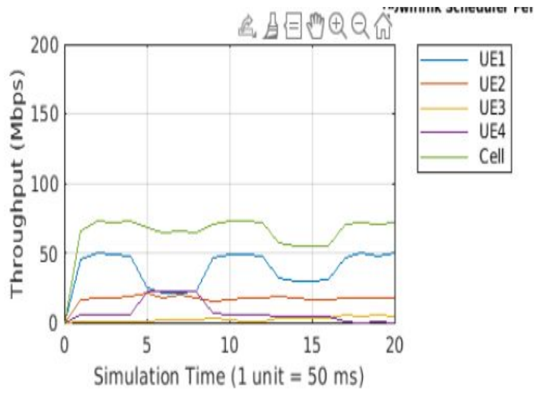


FDD MPF-BCQI

The Modified Proportional Fairness (MPF-BCQI) for BCQI Resource sharing comparison provides a much similar results to the traditional BCQI since we have altered the PF algorithm with a combinational metric of both PF + BestCQI and which thus retains the CQI capability of the fairness.

Comparison 5: with RR Throughput

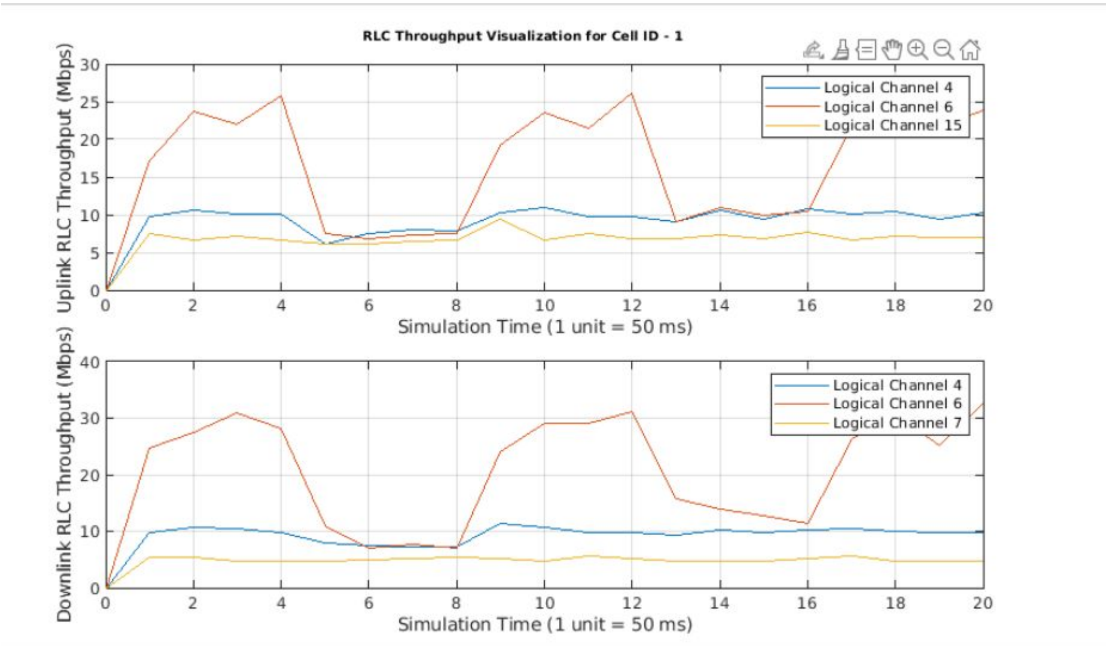


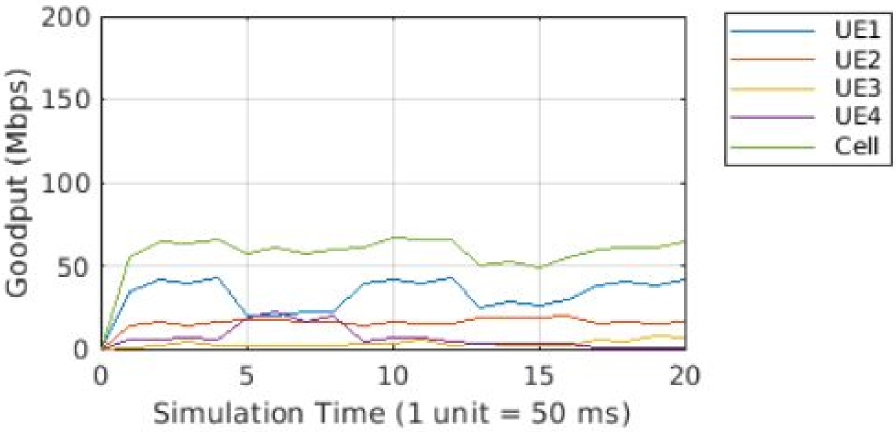


FDD RR FDD MPF-BCQI

The Modified Proportional Fairness(MPF-BCQI) for RR comparison provides a much better throughput than the traditional RR since we have altered the PF algorithm with a combinational metric of both PF + BestCQI and also altered the PF by averaging through range method.

Other Notable Simulation results:





Final Observations :

1. **MPF-BCQI vs Traditional PF :**
   Has the ability to provide fairness even though it starves some users in the channel. But with CQI part of the scheduling algorithm, it guarantees higher throughput than traditional PF.

2. **MPF-BCQI vs Traditional BestCQI :**
   Selects the user with the highest CQI value that means better channel condition in order to get the RB allocation for each time, although some of the fairness is not preserved and can be improved by geometric mean method.

Conclusion:

The Growth of mobile communication technologies offers many opportunities and challenges in satisfying the QoS requirements for the new real-time applications such as streaming multimedia and online gaming. The main feature of it is QoS supporting many application types. To achieve strong support for QoS, 5G needs a high performance packet scheduling algorithm. In this approach, a new scheduling algorithm is proposed based on changing the average throughput computational equation in PF algorithm and on the combination of PF and Best CQI metrics. Using the simulation evaluation of the proposed algorithms, the proposed modified PF algorithm, compared to others showed promising results. Moreover, the proposed MPF-BCQI scheduling algorithm compared to the original PF and the Best CQI Schedulers shows a good compromise between fairness and throughput and in future can also be improvised using other averaging methods.

Reference:

Mai Ali Ibrahim, Nada et al, “A Proposed Modified Proportional Fairness Scheduling (MPF-BCQI) Algorithm with Best CQI Consideration for LTE-A Networks”, *2018 13th International Conference on Computer Engineering and Systems (ICCES).*