Wireless Communications and Networking – Fall 2020

5G Simulation in MATLAB

ECGR 6120/8120

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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. The development process as well as the results obtained (in terms of throughput and fairness) through the evaluation of Maximum Rate (MR), Round Robin (RR), Proportional Fair (PF) are presented.

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.

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.

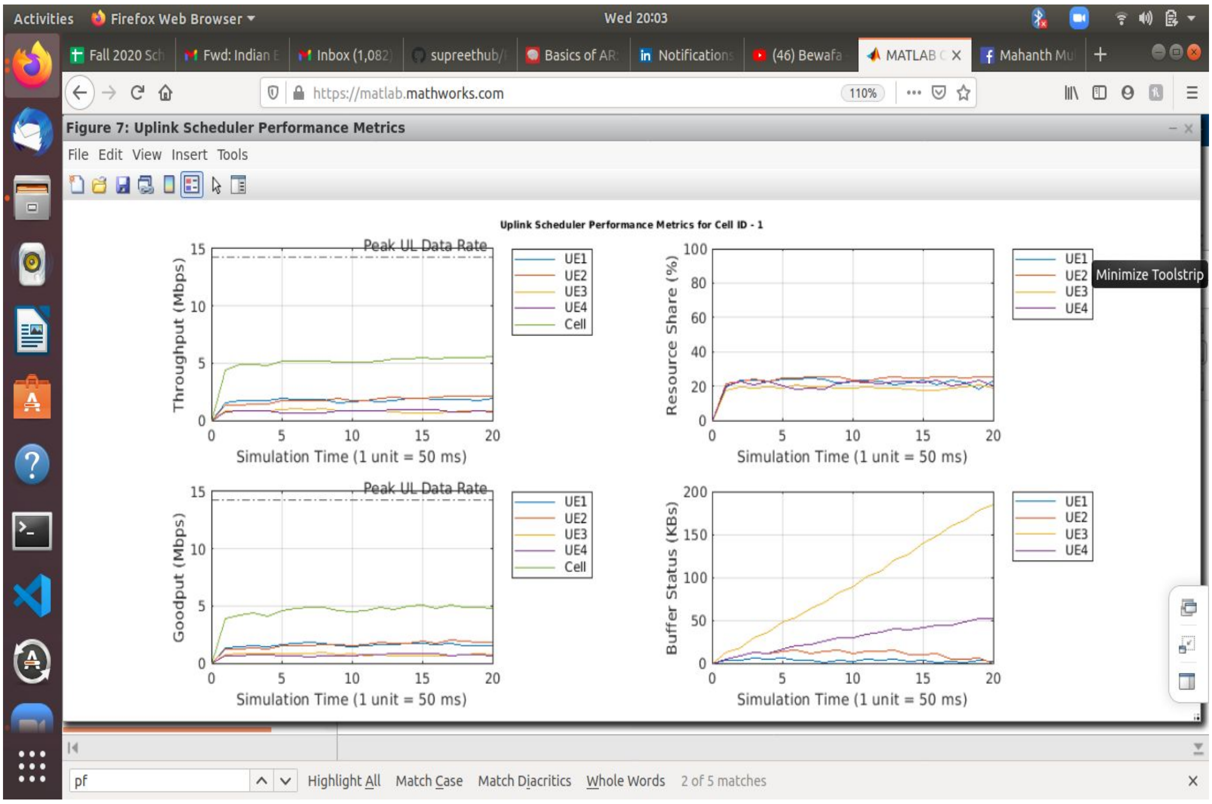


Figure 7: Uplink Scheduler Performance Metrics
Uplink Scheduler Performance Metrics for Cell ID - 1
Peak UL Data Rate
Throughput (Mbps)
Simulation Time (1 unit = 50 ms)
Resource Share (%)
Goodput (Mbps)
Buffer Status (KBs)
UE1
UE2
UE3
UE4
Cell
Minimize Toolstrip
https://matlab.mathworks.com
Highlight All
Match Case
Match Diacritics
Whole Words
2 of 5 matches

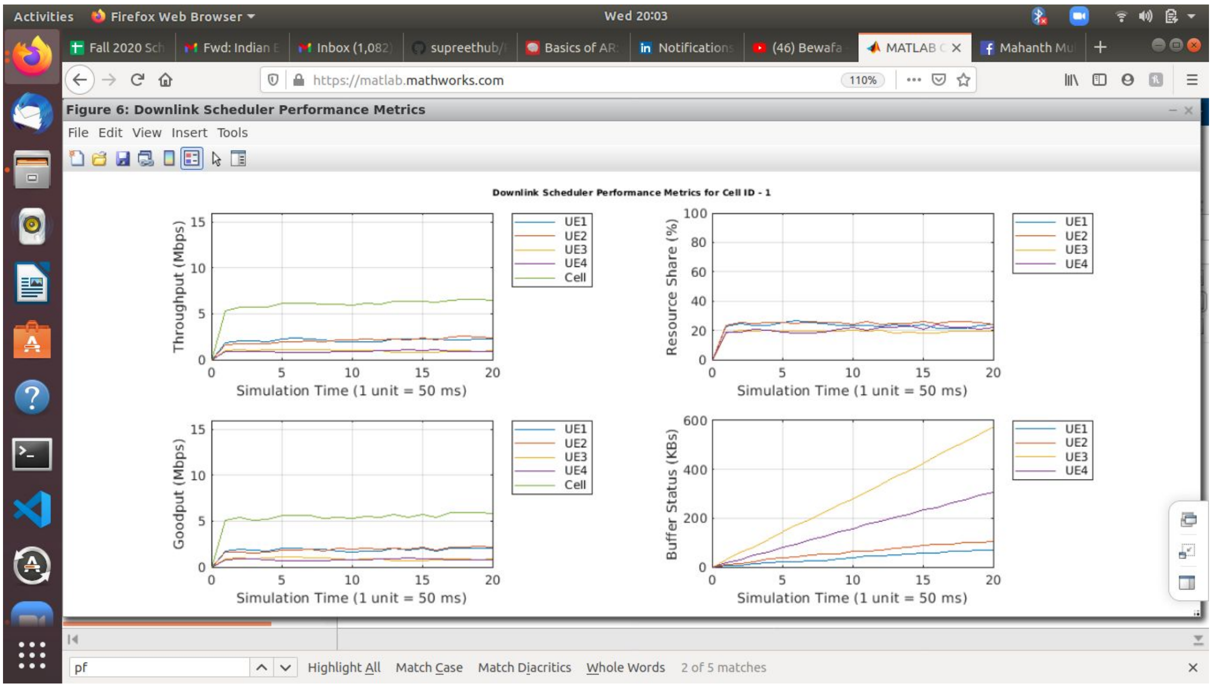


Figure 6: Downlink Scheduler Performance Metrics
Downlink Scheduler Performance Metrics for Cell ID - 1
Throughput (Mbps)
Resource Share (%)
Goodput (Mbps)
Buffer Status (KBs)
Simulation Time (1 unit = 50 ms)
UE1
UE2
UE3
UE4
Cell

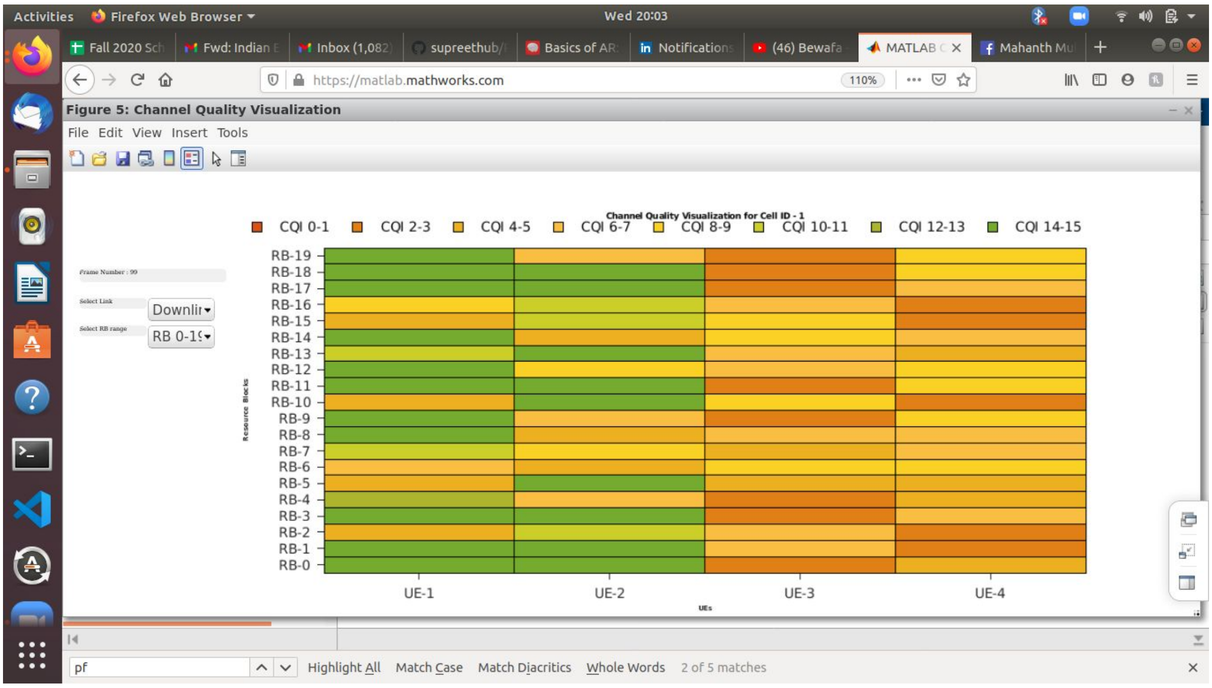
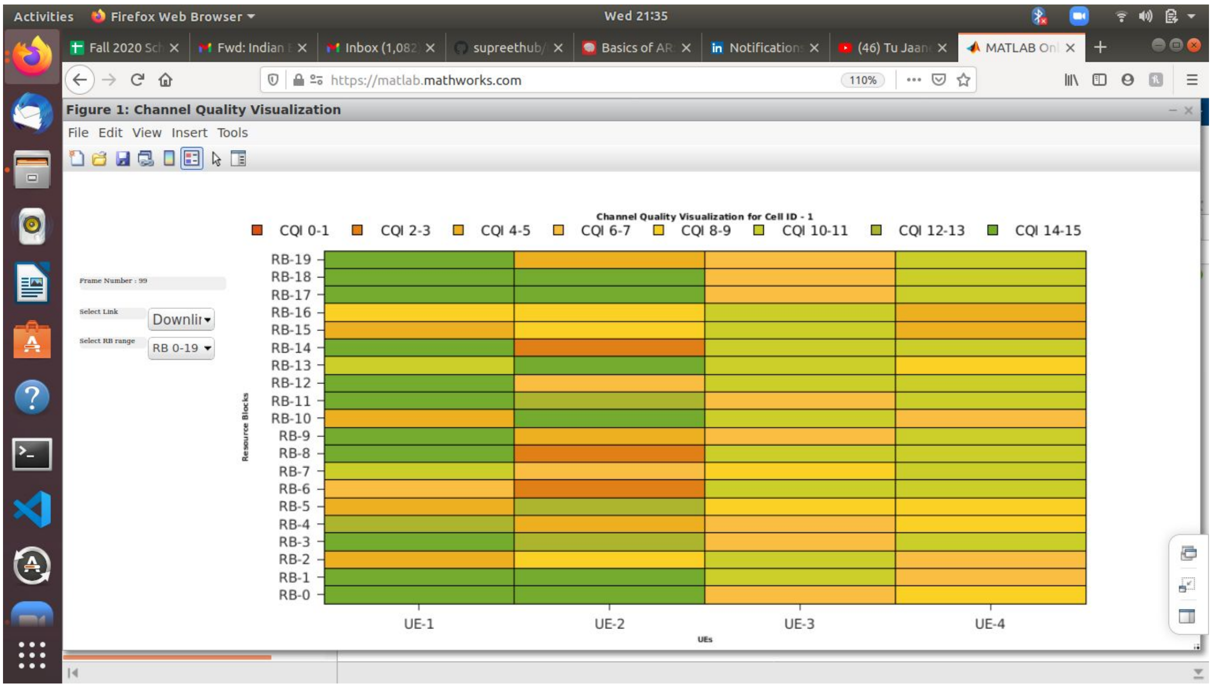
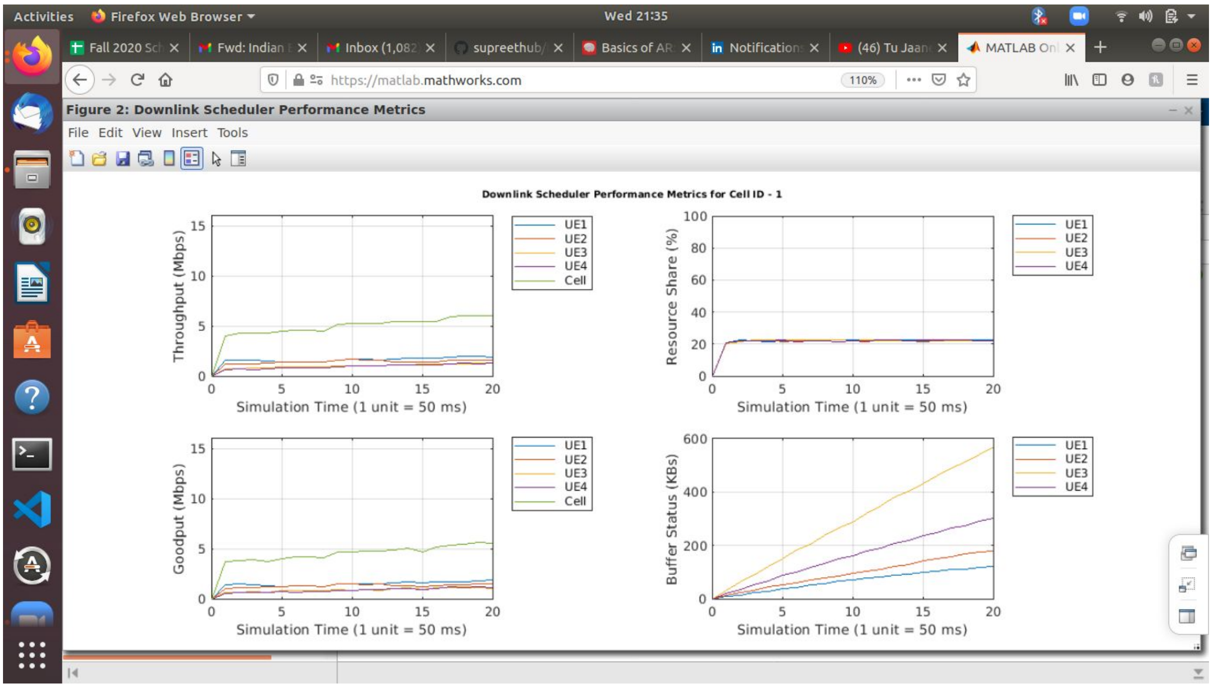


Figure 5: Channel Quality Visualization
Channel Quality Visualization for Cell ID - 1
CQI 0-1
CQI 2-3
CQI 4-5
CQI 6-7
CQI 8-9
CQI 10-11
CQI 12-13
CQI 14-15
Resource Blocks
UE-1
UE-2
UE-3
UE-4
UEs

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





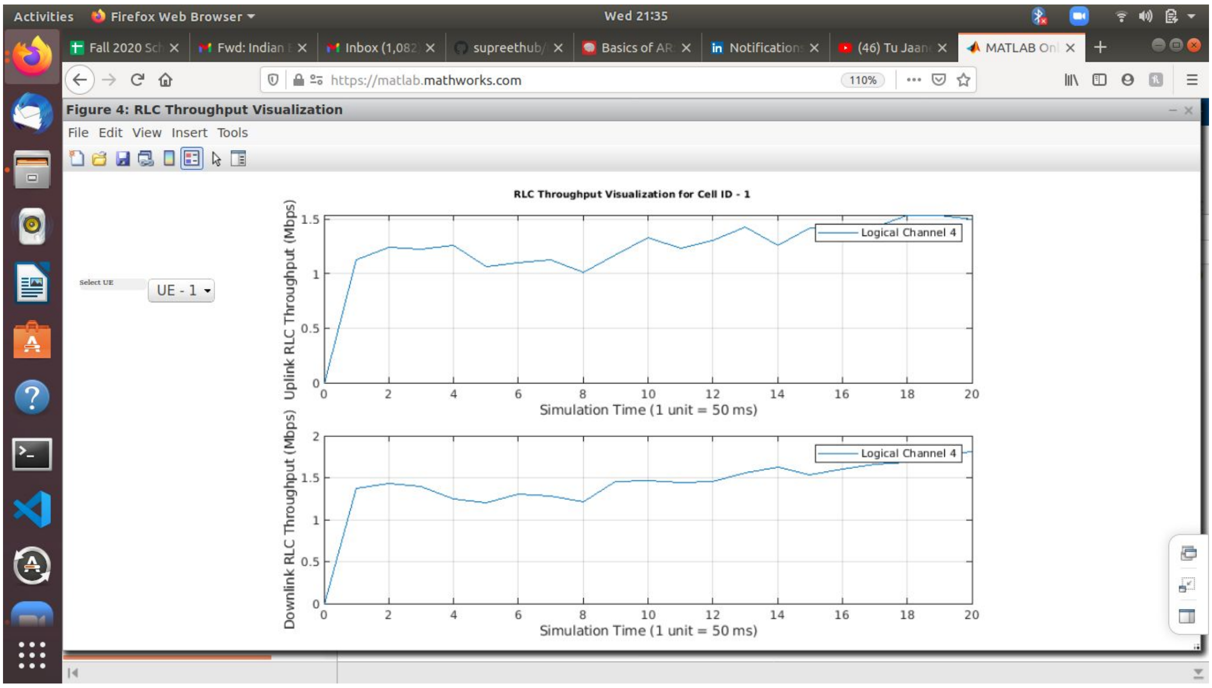


Figure 4: RLC Throughput Visualization
File Edit View Insert Tools
RLC Throughput Visualization for Cell ID - 1
Select UE
UE - 1
Uplink RLC Throughput (Mbps)
Logical Channel 4
Simulation Time (1 unit = 50 ms)
Downlink RLC Throughput (Mbps)
Logical Channel 4
Simulation Time (1 unit = 50 ms)

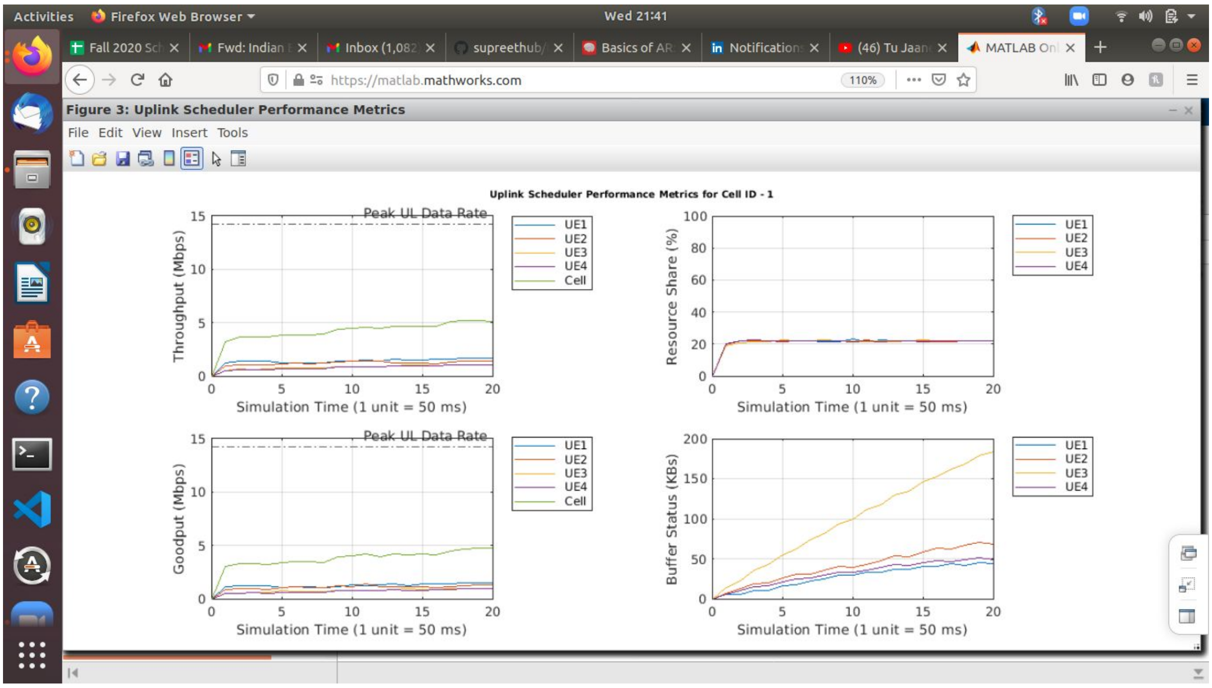
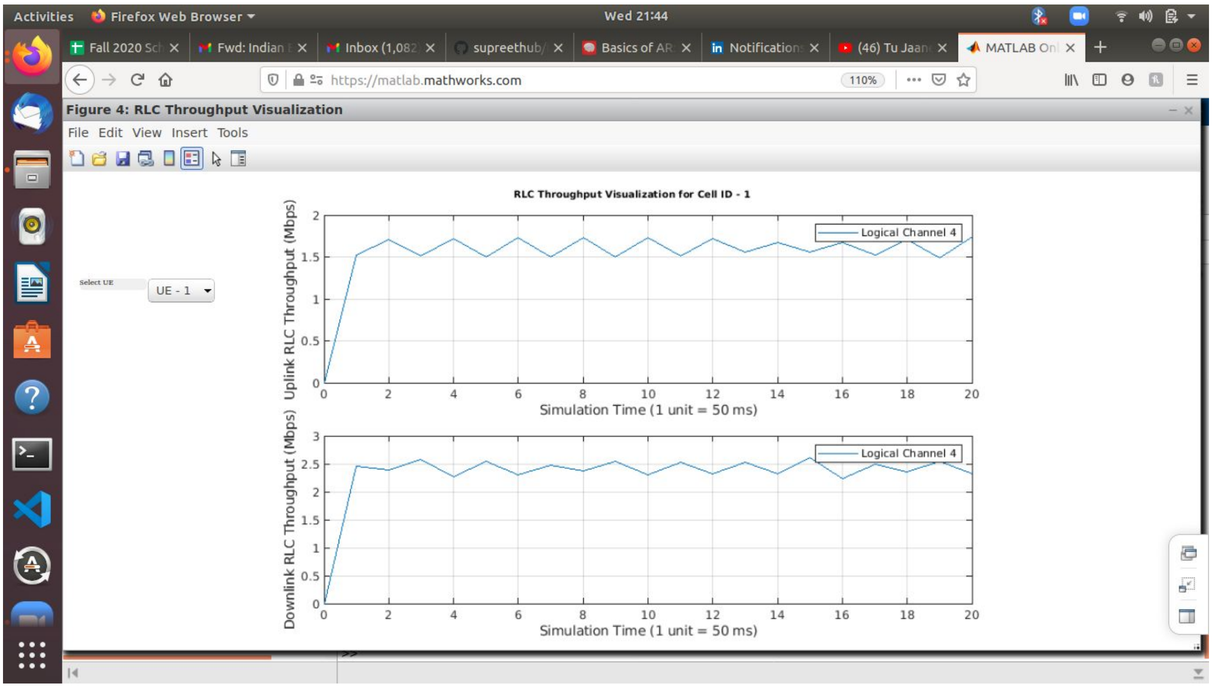
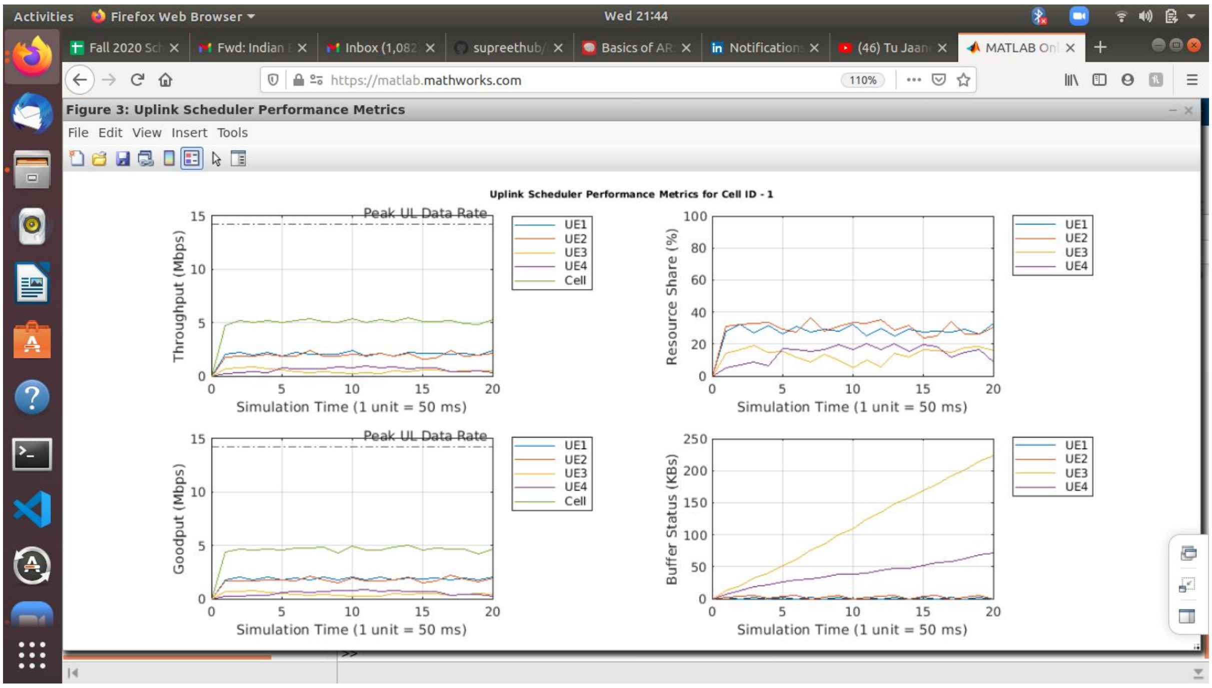


Figure 3: Uplink Scheduler Performance Metrics
File Edit View Insert Tools
Uplink Scheduler Performance Metrics for Cell ID - 1
Peak UL Data Rate
Throughput (Mbps)
UE1
UE2
UE3
UE4
Cell
Simulation Time (1 unit = 50 ms)
Resource Share (%)
Simulation Time (1 unit = 50 ms)
Peak UL Data Rate
Goodput (Mbps)
Simulation Time (1 unit = 50 ms)
Buffer Status (KBs)
Simulation Time (1 unit = 50 ms)

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.





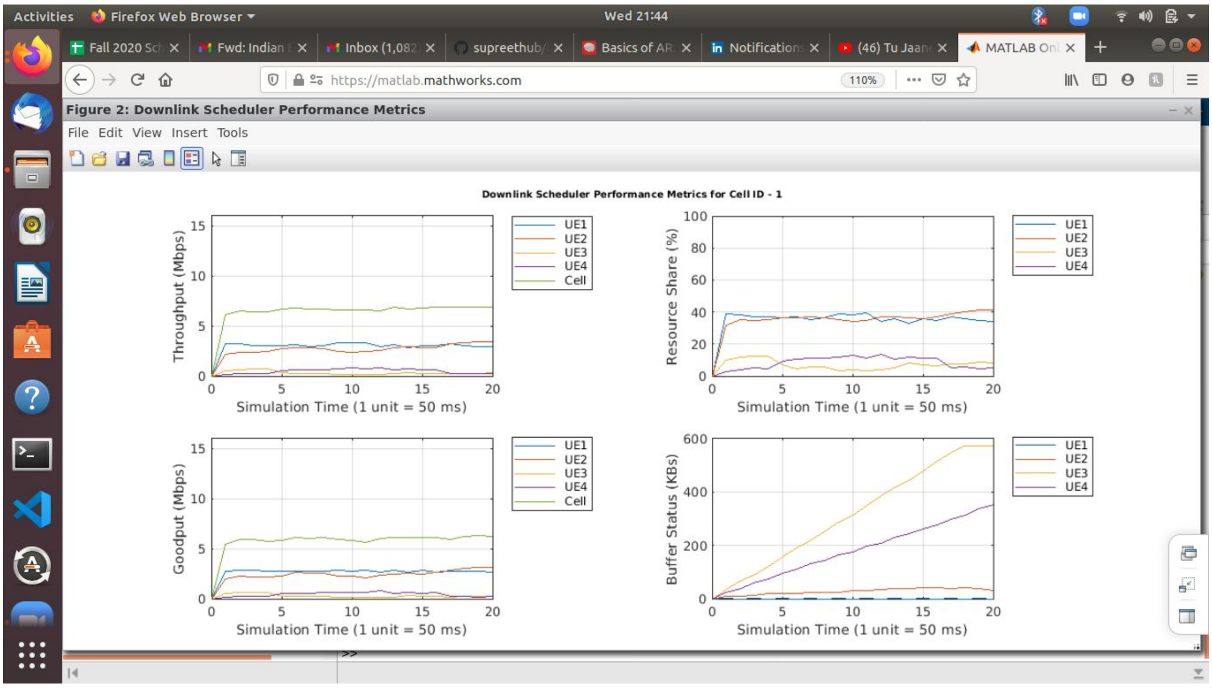


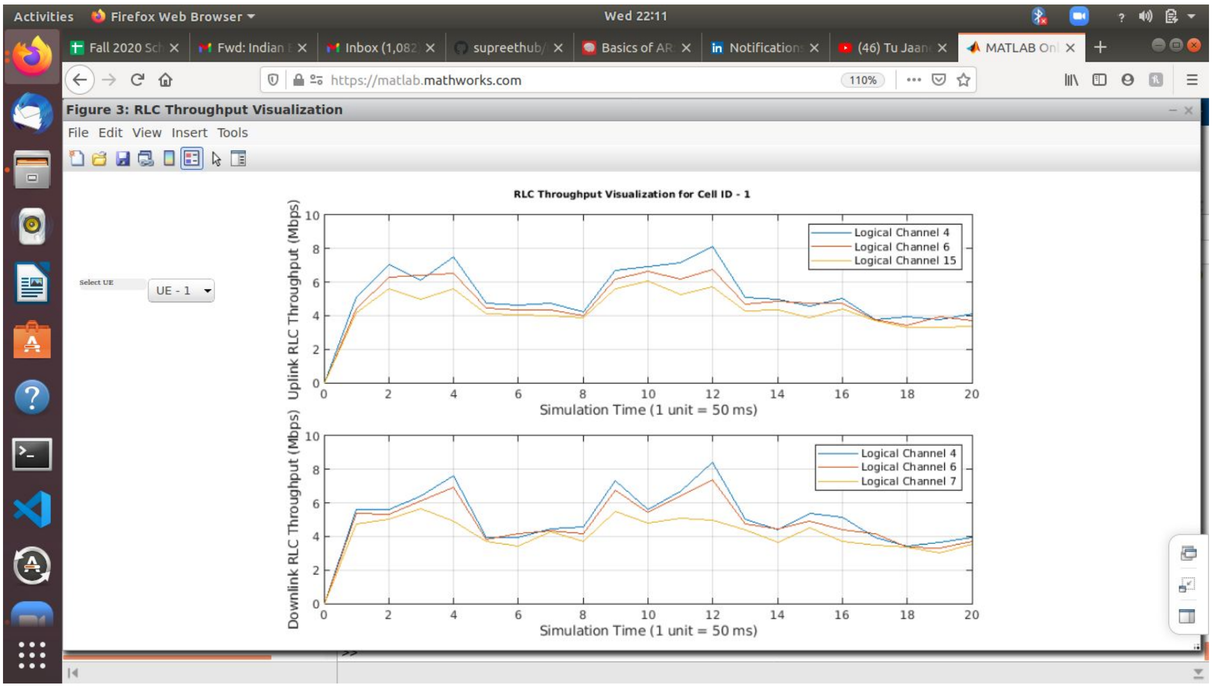
Figure 2: Downlink Scheduler Performance Metrics
Downlink Scheduler Performance Metrics for Cell ID - 1
Throughput (Mbps)
Resource Share (%)
Goodput (Mbps)
Buffer Status (KBs)
Simulation Time (1 unit = 50 ms)
UE1
UE2
UE3
UE4
Cell

Figure 1: Channel Quality Visualization
Channel Quality Visualization for Cell ID - 1
CQI 0-1
CQI 2-3
CQI 4-5
CQI 6-7
CQI 8-9
CQI 10-11
CQI 12-13
CQI 14-15
Select Link
Downlink
Select RB range
RB 0-19
Resource Blocks
UE-1
UE-2
UE-3
UE-4
UEs

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.

Proportional Fairness:



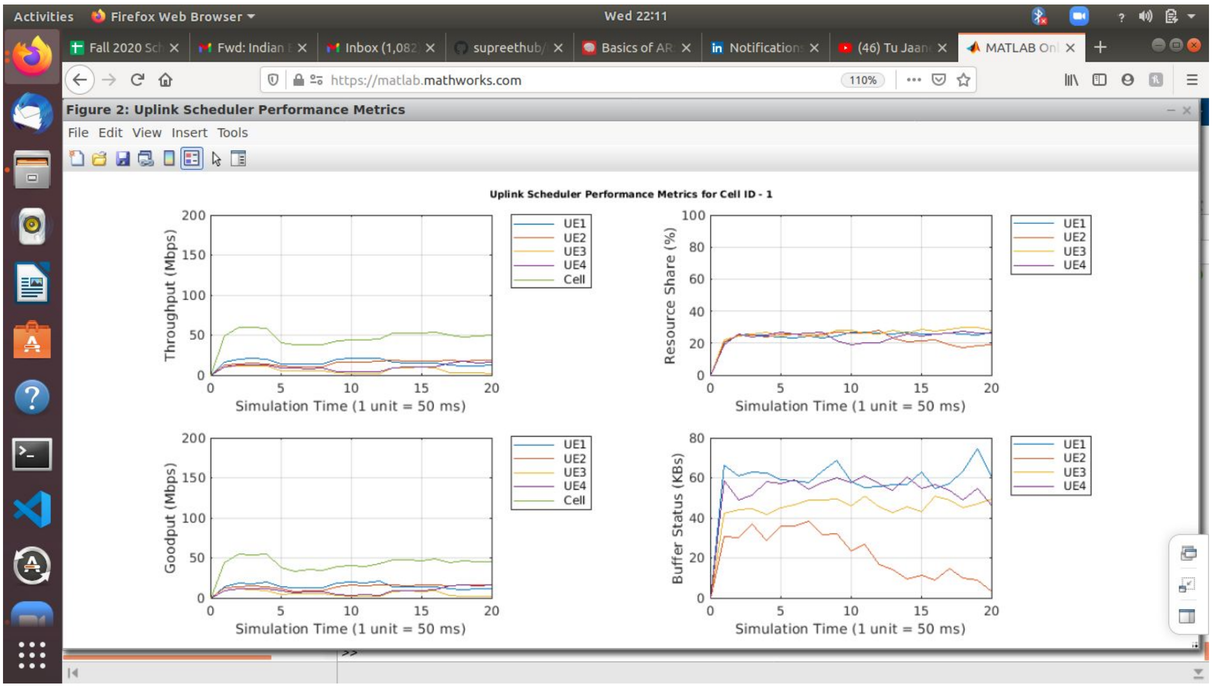
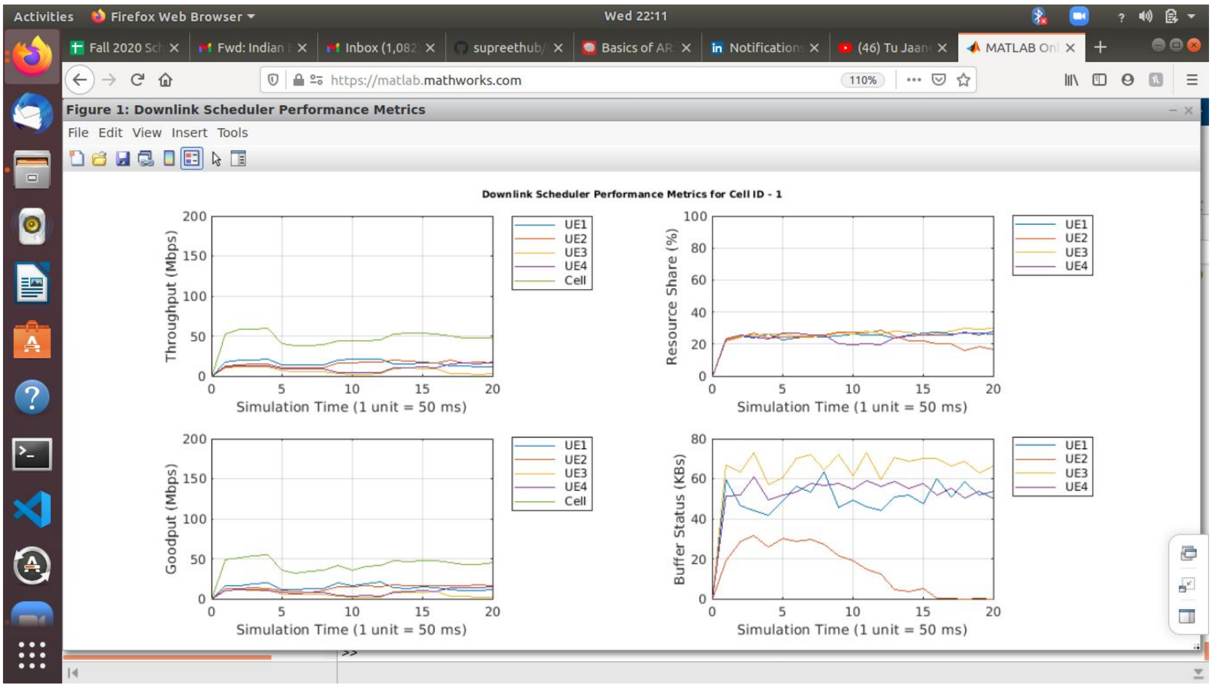


Figure 2: Uplink Scheduler Performance Metrics
Uplink Scheduler Performance Metrics for Cell ID - 1
Throughput (Mbps)
Resource Share (%)
Goodput (Mbps)
Buffer Status (KBs)
Simulation Time (1 unit = 50 ms)
UE1
UE2
UE3
UE4
Cell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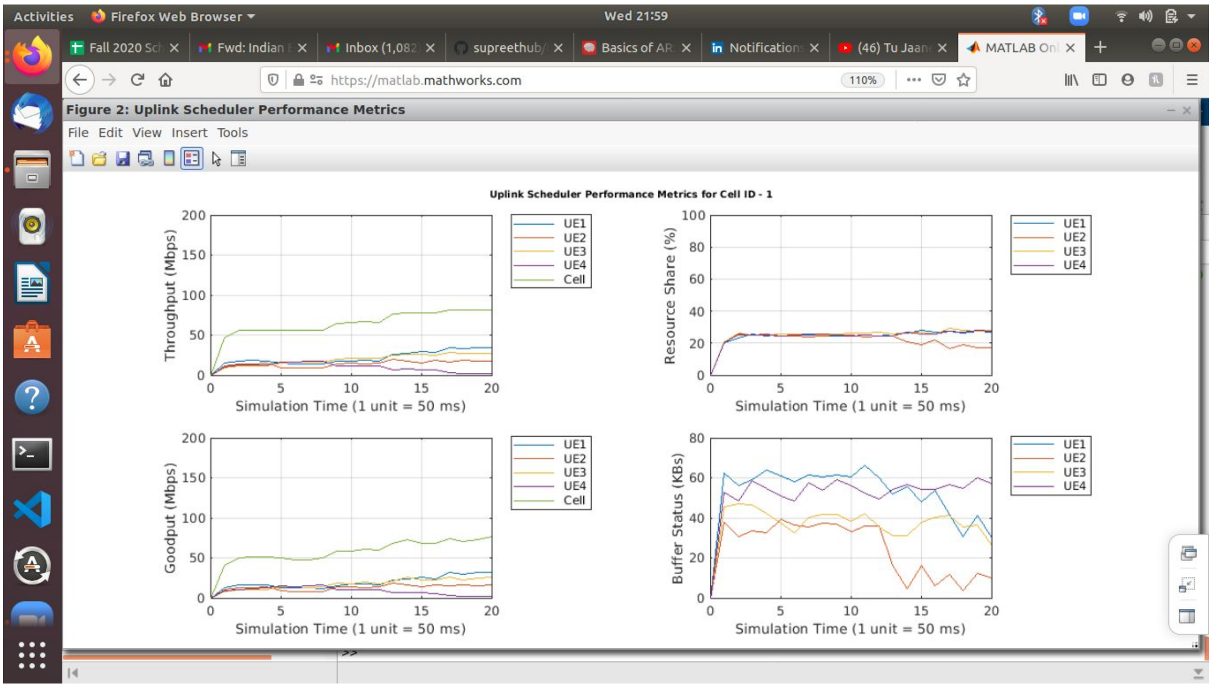
Downlink Scheduler Performance Metrics for Cell ID - 1
Throughput (Mbps)
Resource Share (%)
Goodput (Mbps)
Buffer Status (KBs)
Simulation Time (1 unit = 50 ms)
UE1
UE2
UE3
UE4
Cell

Round Robin:


Activities
Firefox Web Browser
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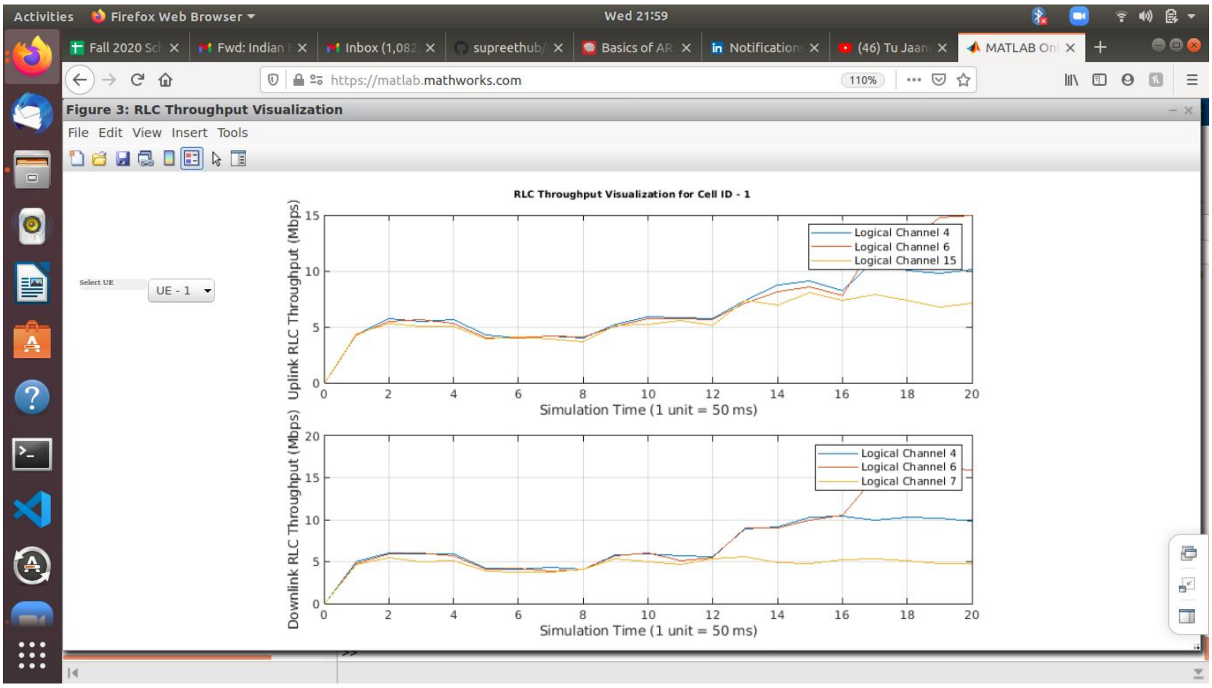
https://matlab.mathworks.com
Figure 2: Uplink Scheduler Performance Metrics
File Edit View Insert Tools
Uplink Scheduler Performance Metrics for Cell ID - 1
Throughput (Mbps)
Resource Share (%)
Goodput (Mbps)
Buffer Status (KBs)
Simulation Time (1 unit = 50 ms)
UE1
UE2
UE3
UE4
Cell


Activities
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https://matlab.mathworks.com
Figure 3: RLC Throughput Visualization
File Edit View Insert Tools
RLC Throughput Visualization for Cell ID - 1
Select UE
UE - 1
Uplink RLC Throughput (Mbps)
Downlink RLC Throughput (Mbps)
Simulation Time (1 unit = 50 ms)
Logical Channel 4
Logical Channel 6
Logical Channel 15
Logical Channel 7

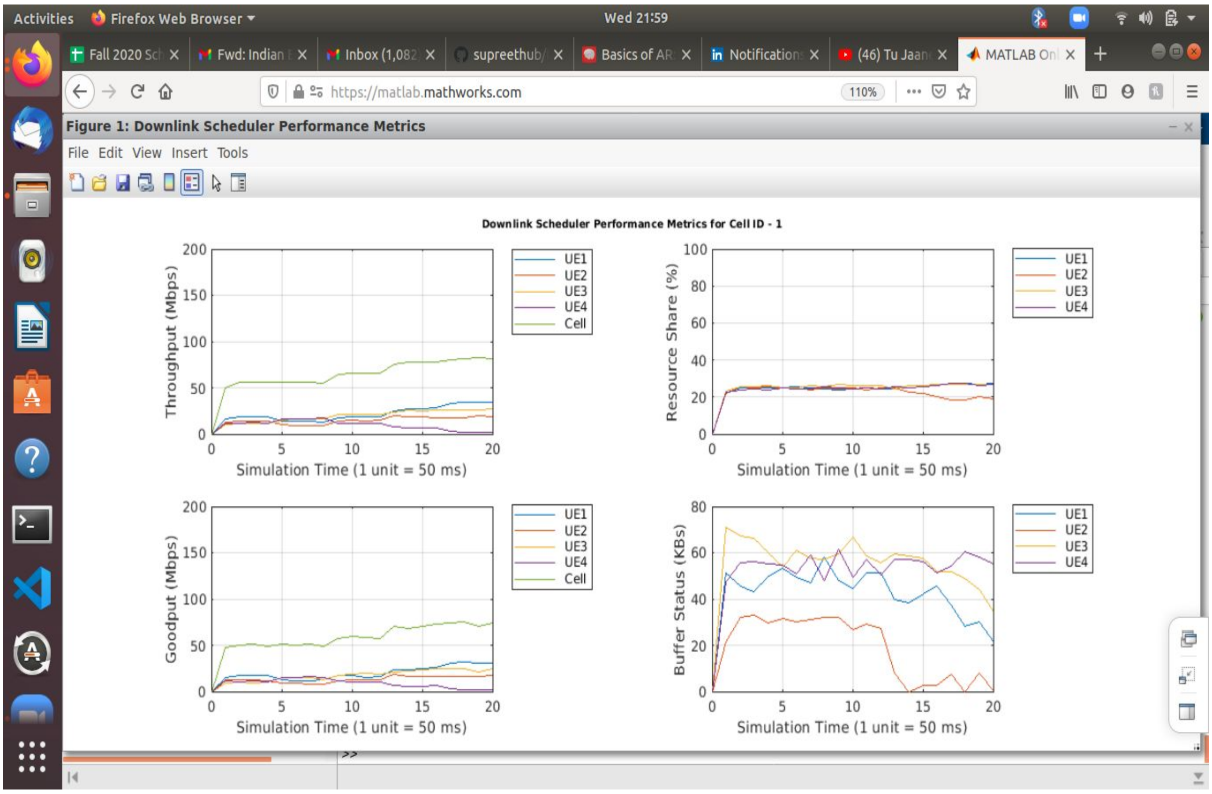
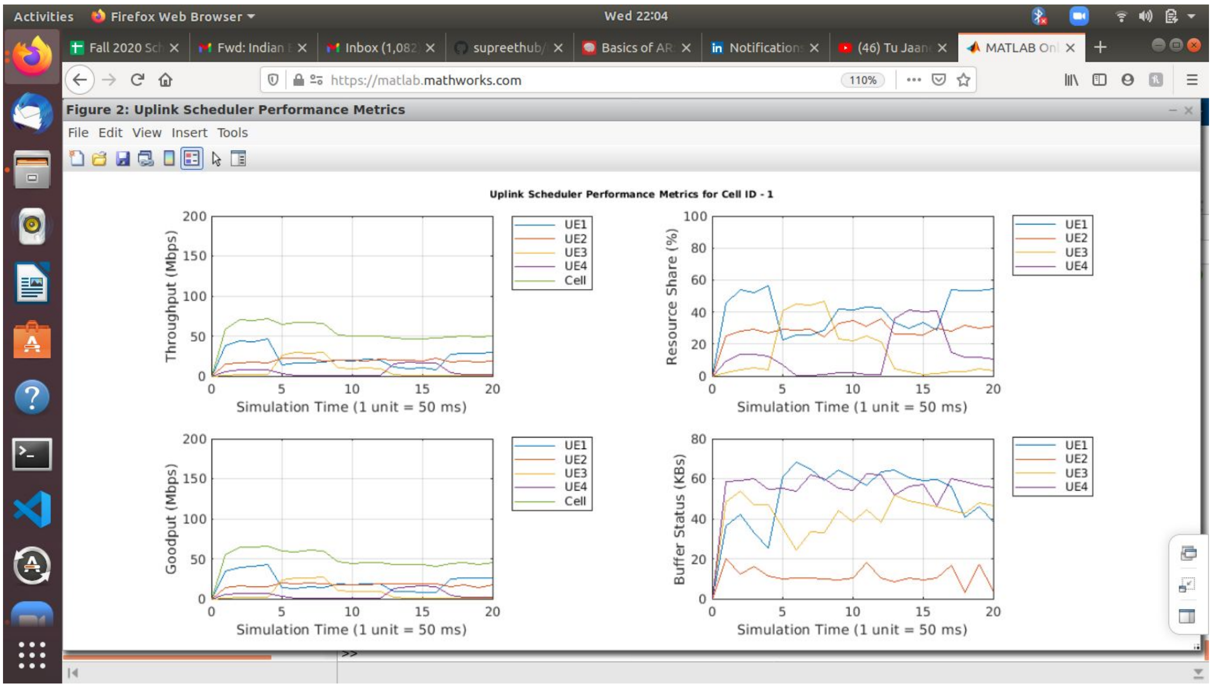
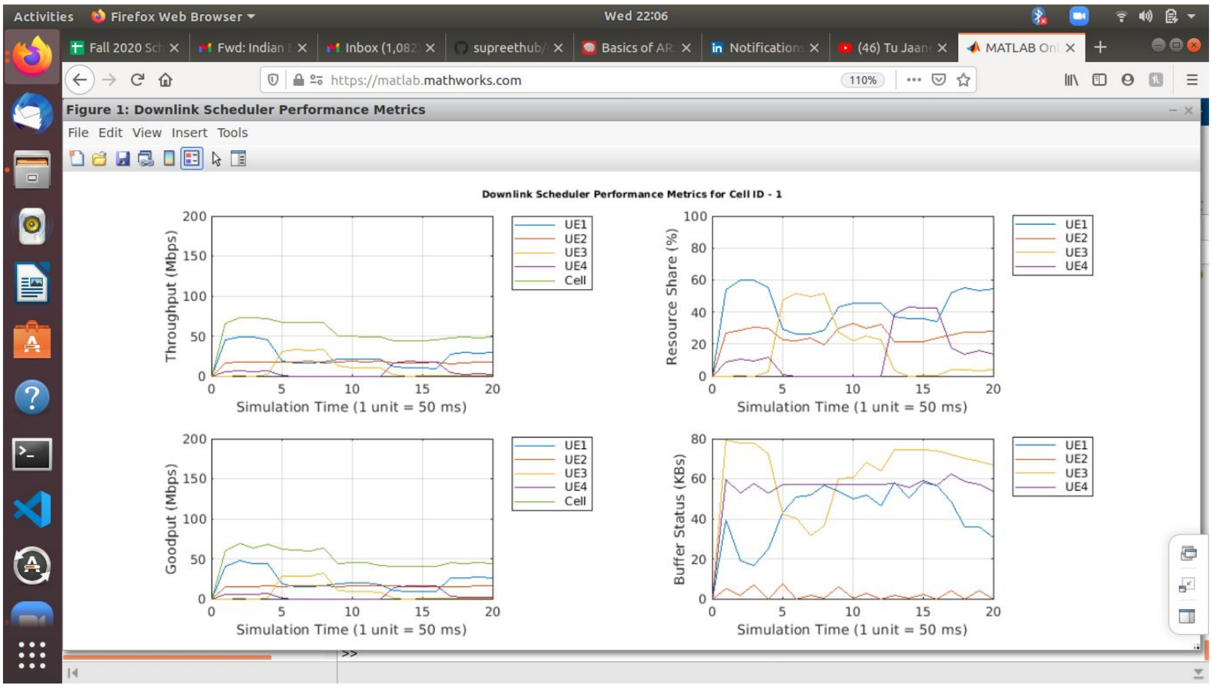


Figure 1: Downlink Scheduler Performance Metrics
File Edit View Insert Tools
Downlink Scheduler Performance Metrics for Cell ID - 1
Throughput (Mbps)
Resource Share (%)
Goodput (Mbps)
Buffer Status (KBs)
Simulation Time (1 unit = 50 ms)
UE1
UE2
UE3
UE4
Cell

Best CQI:

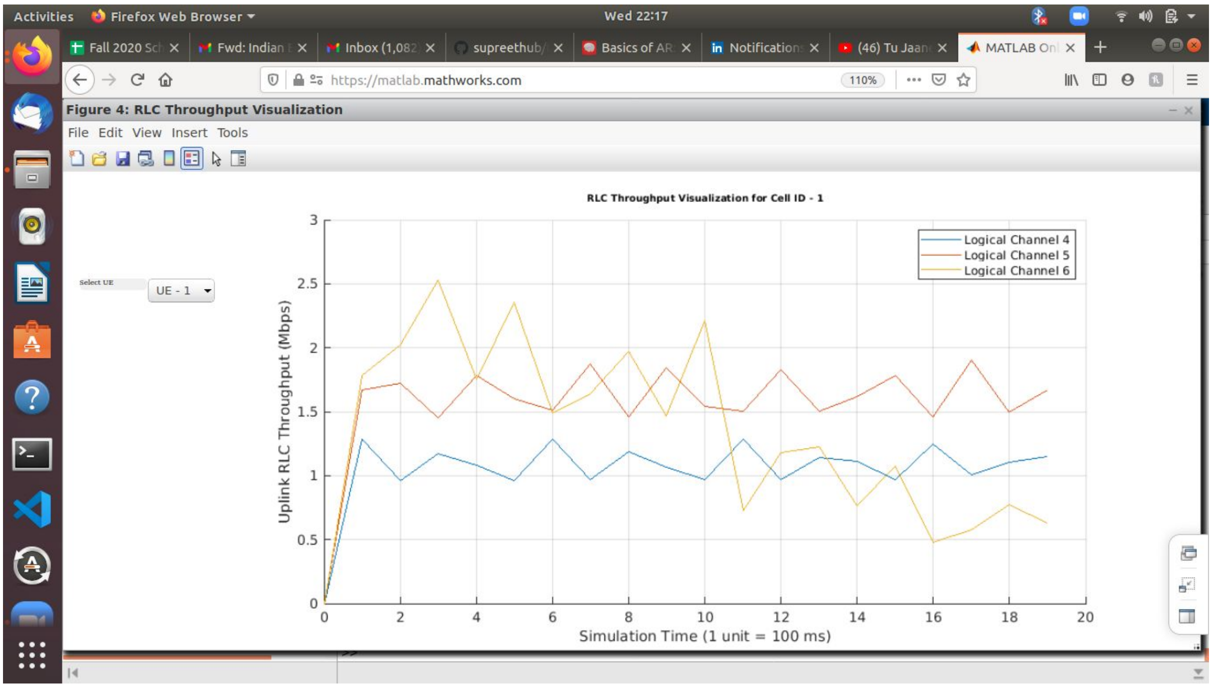


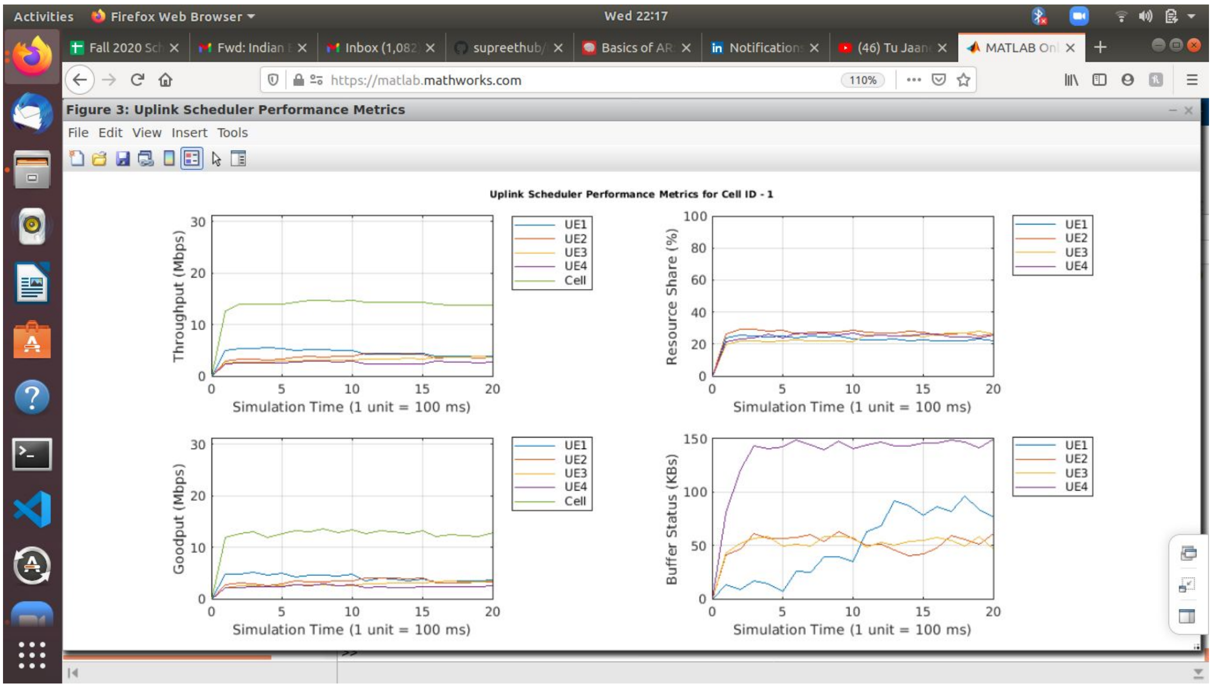


3. NR PUSCH FDD Scheduling:

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.

Proportional Fairness:





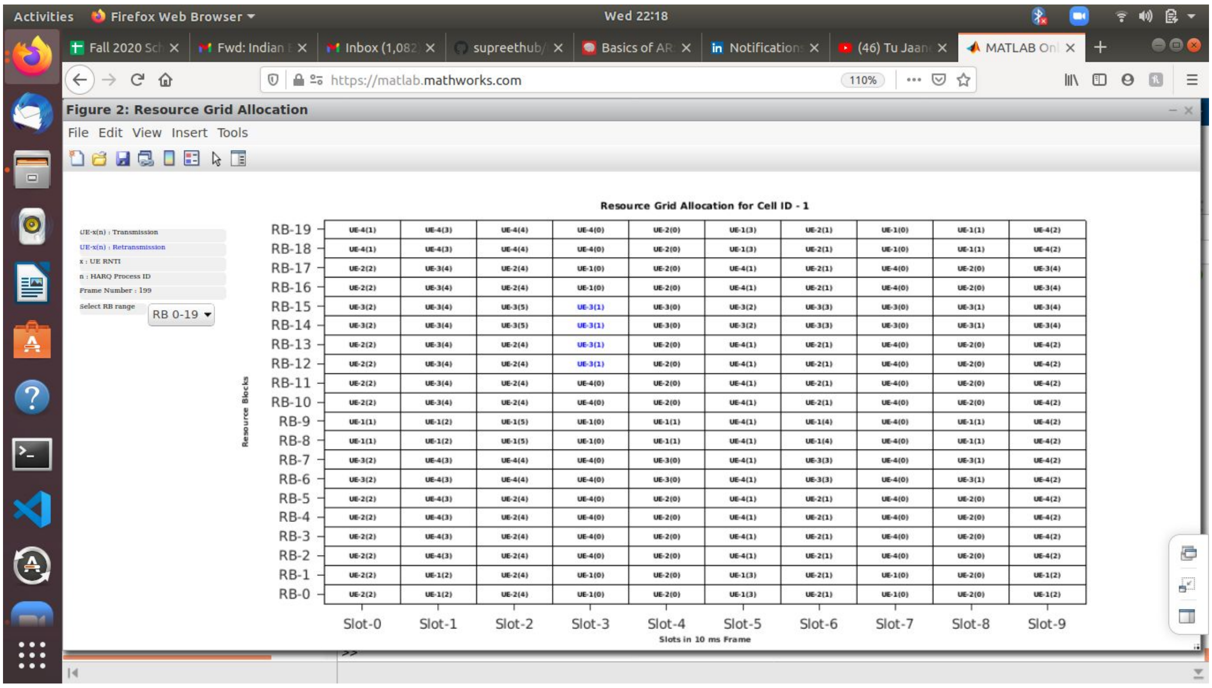


Figure 2: Resource Grid Allocation
File Edit View Insert Tools
Resource Grid Allocation for Cell ID - 1
Select RB range
RB 0-19
Resource Blocks
RB-19
RB-18
RB-17
RB-16
RB-15
RB-14
RB-13
RB-12
RB-11
RB-10
RB-9
RB-8
RB-7
RB-6
RB-5
RB-4
RB-3
RB-2
RB-1
RB-0
Slot-0 Slot-1 Slot-2 Slot-3 Slot-4 Slot-5 Slot-6 Slot-7 Slot-8 Slot-9
Slots in 10 ms Frame

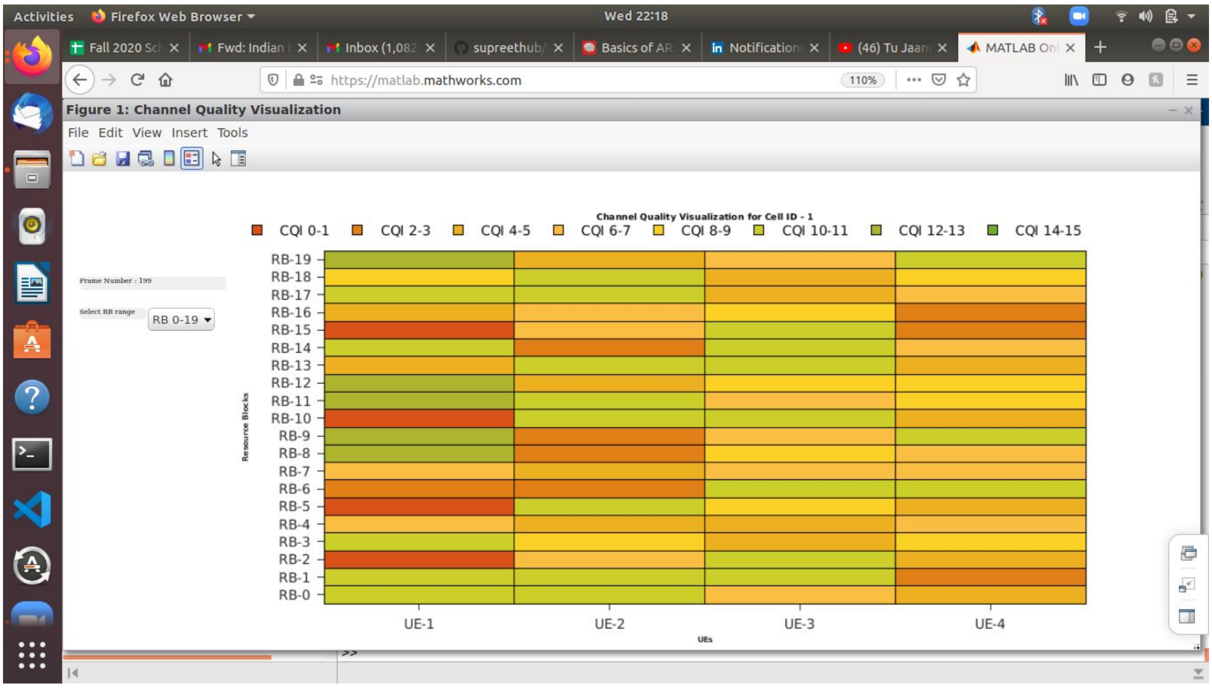


Figure 1: Channel Quality Visualization
File Edit View Insert Tools
Channel Quality Visualization for Cell ID - 1
CQI 0-1 CQI 2-3 CQI 4-5 CQI 6-7 CQI 8-9 CQI 10-11 CQI 12-13 CQI 14-15
Frame Number : 199
Select RB range
RB 0-19
Resource Blocks
RB-19
RB-18
RB-17
RB-16
RB-15
RB-14
RB-13
RB-12
RB-11
RB-10
RB-9
RB-8
RB-7
RB-6
RB-5
RB-4
RB-3
RB-2
RB-1
RB-0
UE-1 UE-2 UE-3 UE-4
UEs

Round Robin:

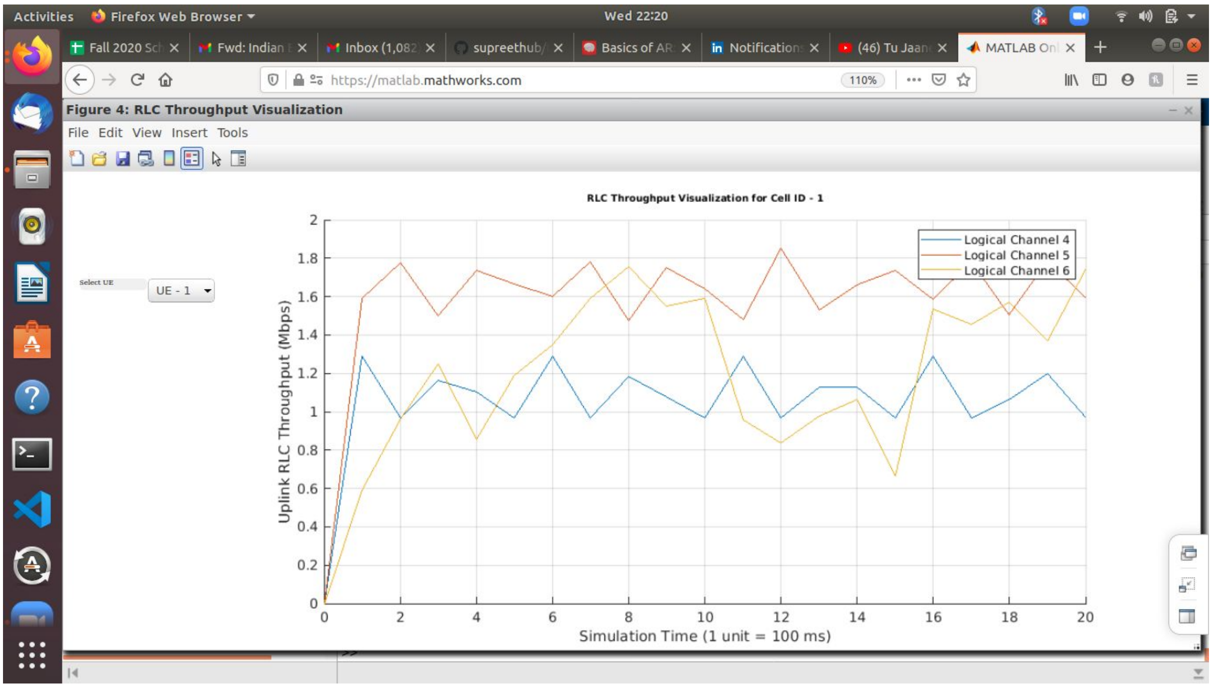

Activities
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Figure 4: RLC Throughput Visualization
File Edit View Insert Tools
RLC Throughput Visualization for Cell ID - 1
Select UE
UE - 1
Logical Channel 4
Logical Channel 5
Logical Channel 6
Uplink RLC Throughput (Mbps)
Simulation Time (1 unit = 100 ms)

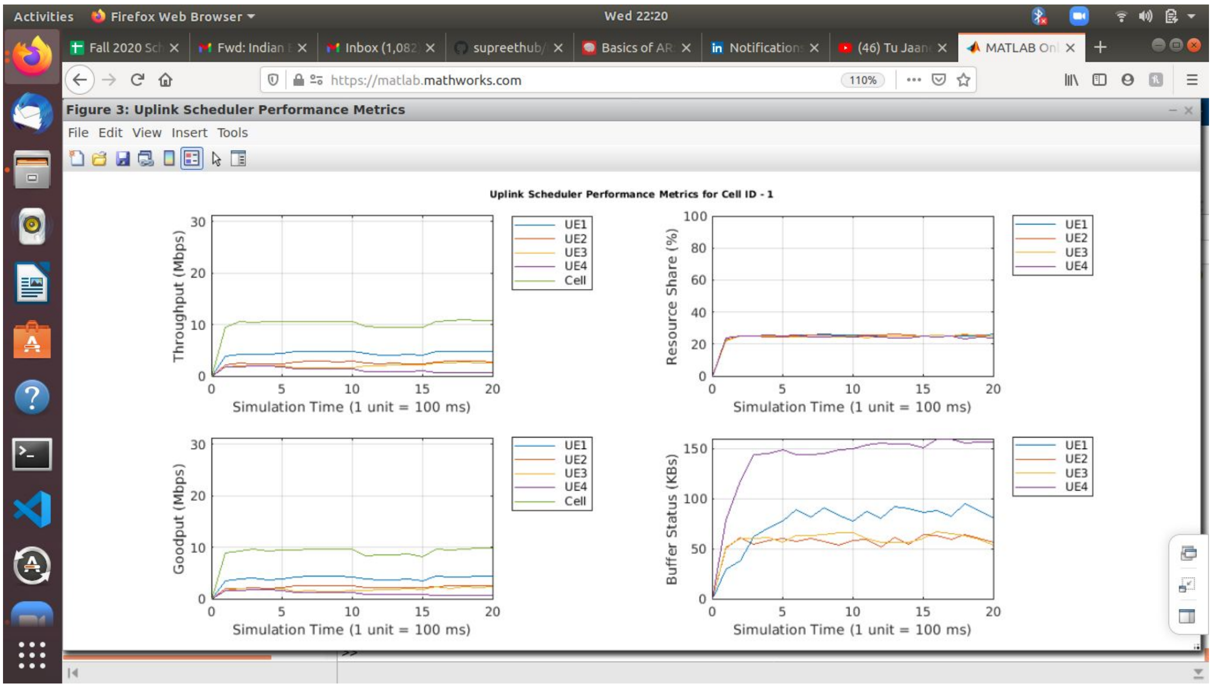
Activities
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Figure 3: Uplink Scheduler Performance Metrics
File Edit View Insert Tools
Uplink Scheduler Performance Metrics for Cell ID - 1
Throughput (Mbps)
UE1
UE2
UE3
UE4
Cell
Resource Share (%)
Goodput (Mbps)
Buffer Status (KBs)
Simulation Time (1 unit = 100 ms)

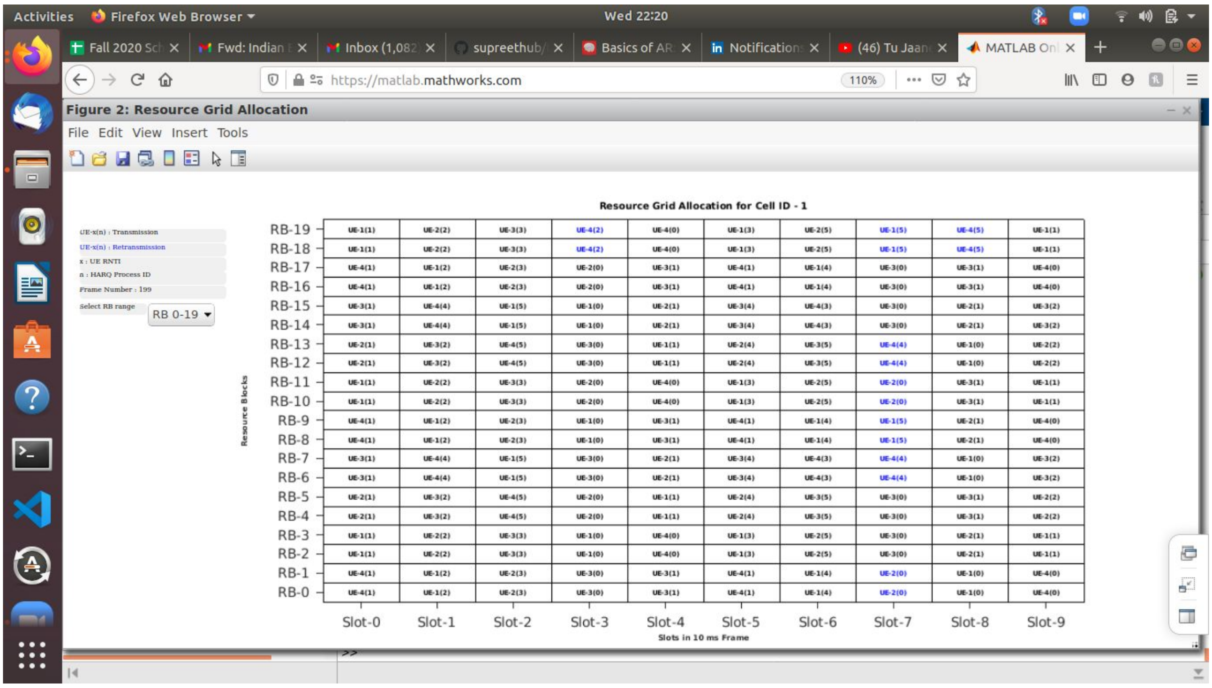
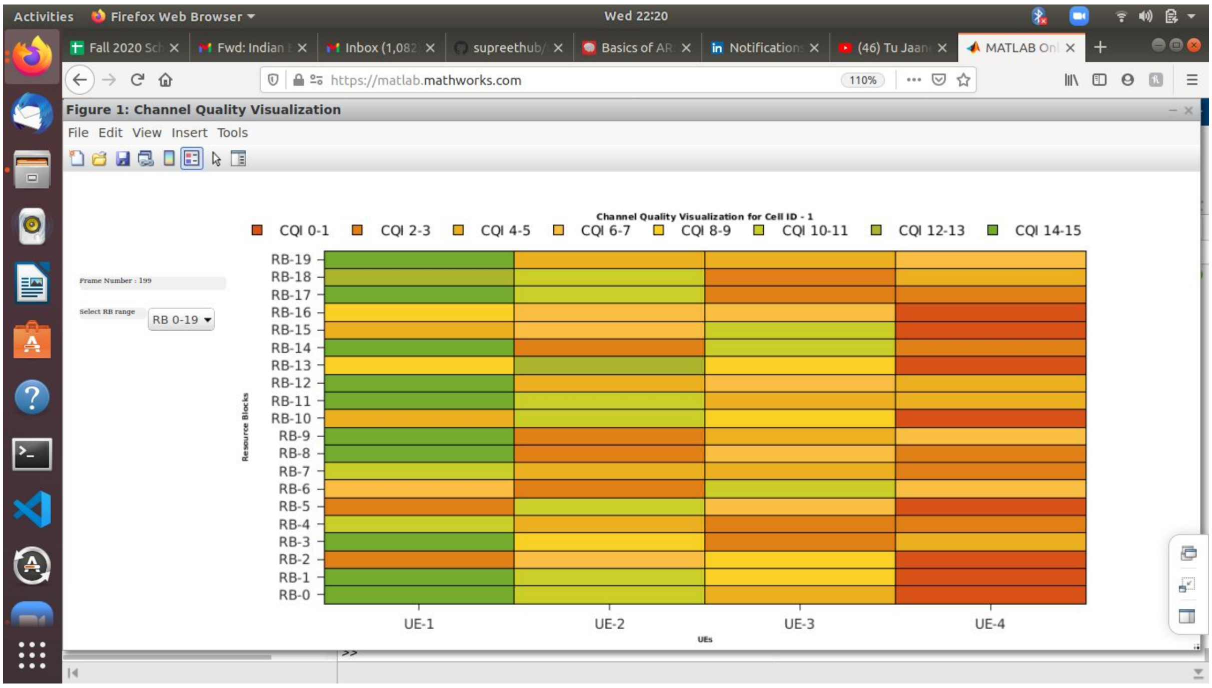


Figure 2: Resource Grid Allocation
Resource Grid Allocation for Cell ID - 1
UE-x(n) : Transmission
UE-x(n) : Retransmission
x : UE RNTI
n : HARQ Process ID
Frame Number : 199
Select RB range
RB 0-19
Resource Blocks
Slot-0
Slot-1
Slot-2
Slot-3
Slot-4
Slot-5
Slot-6
Slot-7
Slot-8
Slot-9
Slots in 10 ms Frame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CQI 2-3
CQI 4-5
CQI 6-7
CQI 8-9
CQI 10-11
CQI 12-13
CQI 14-15
Frame Number : 199
Select RB range
RB 0-19
Resource Blocks
UE-1
UE-2
UE-3
UE-4
UEs

Best CQI:

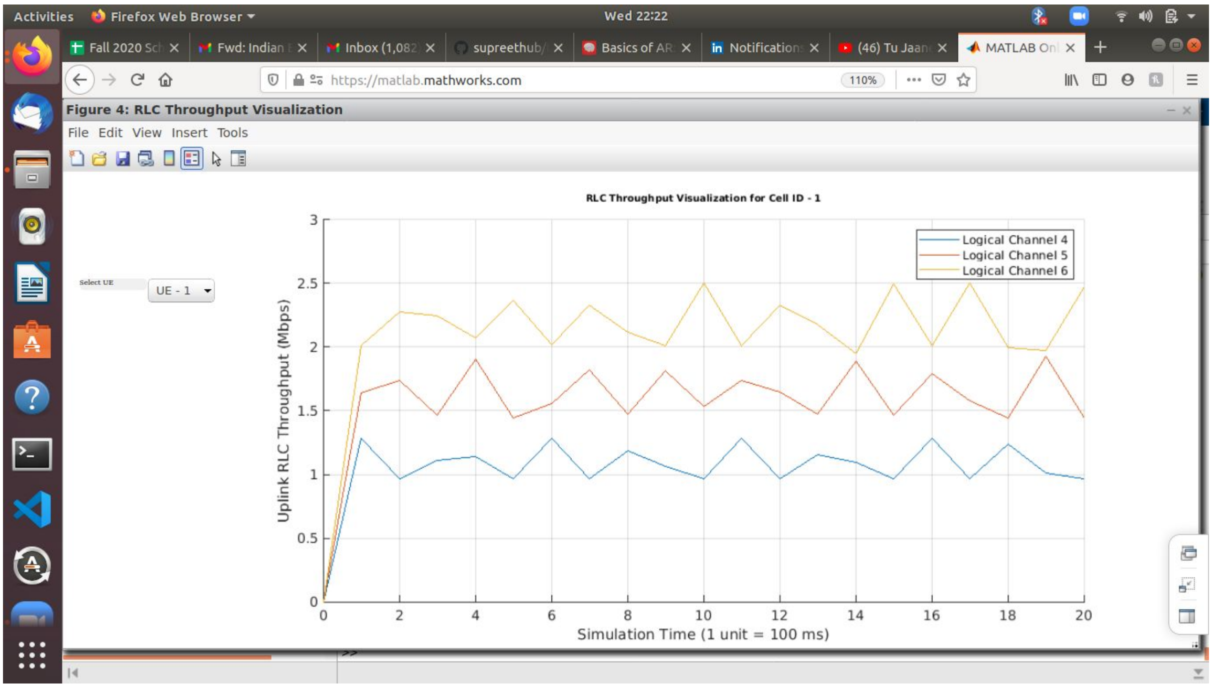
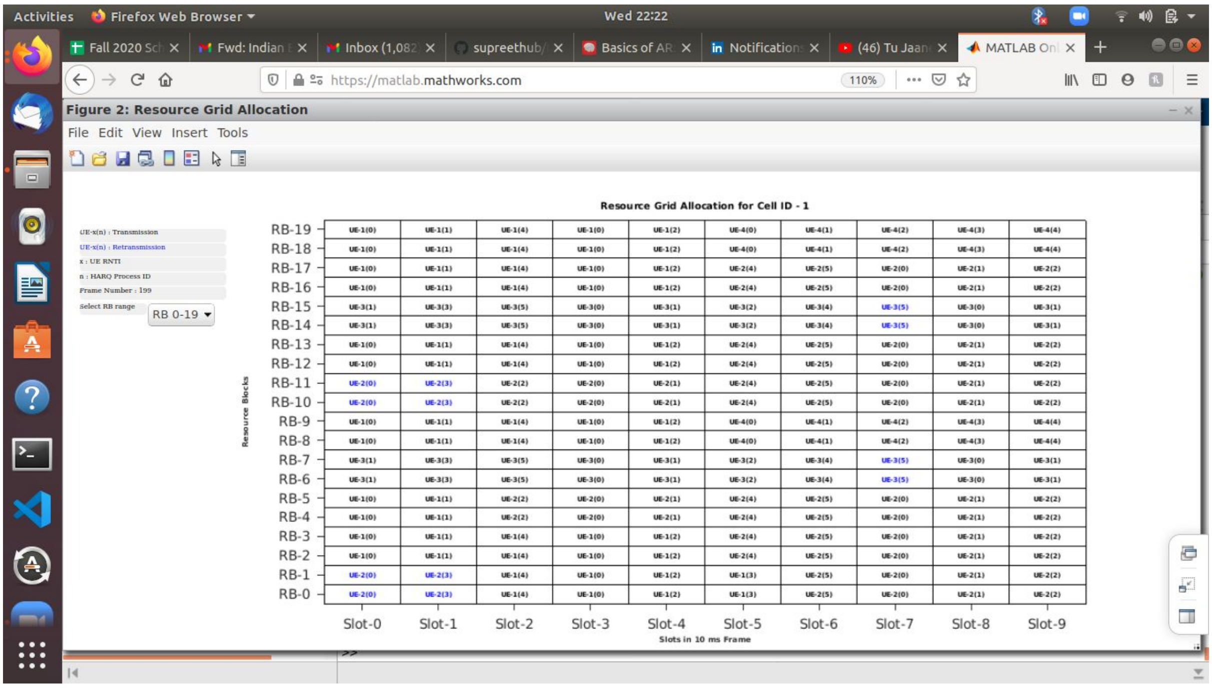


Figure 4: RLC Throughput Visualization
File Edit View Insert Tools
RLC Throughput Visualization for Cell ID - 1
Select UE
UE - 1
Logical Channel 4
Logical Channel 5
Logical Channel 6
Uplink RLC Throughput (Mbps)
Simulation Time (1 unit = 100 ms)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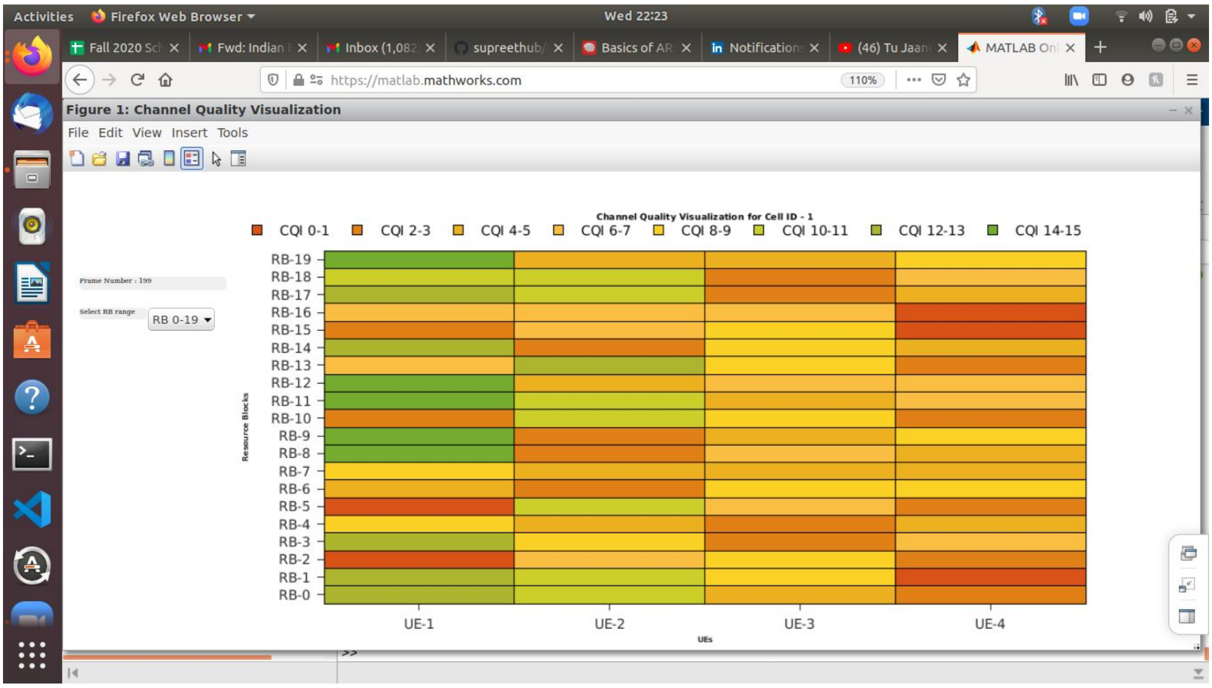
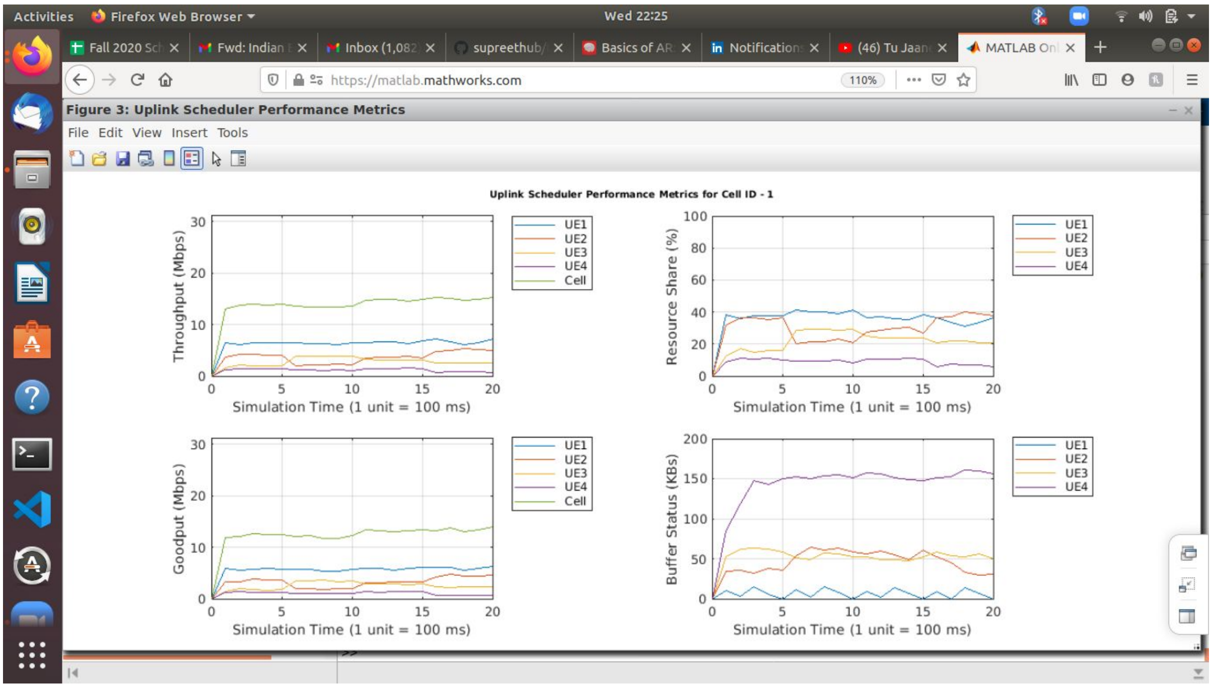
RB 0-19
Resource Blocks
Slots in 10 ms Frame





Observation , Comparison and Analysis:

- Quality of Service (QoS) requirements, such as fairness, average throughput and spectral efficiency, are a set of the important parameters that assess the performance of scheduling algorithms.
- The PF scheduling algorithm provides a good tradeoff between system throughput and fairness by selecting the user with the highest instantaneous data rate relative to its average data rate. However, in every block PF

scheduler informs the UEs about their allotted slot positions of radio resources thus increasing scheduler complexity and overhead.

- We can see that the RR scheduler promotes priority to fairness between all users regardless of system throughput. Unlike, Best CQI used to maximize the system capacity without considering the fairness among users. But, from the results obtained, it is also observed that the proportional fairness algorithm performs a compromise between system fairness and throughput.
- **Proportional Fair (PF) scheduling algorithms have proved to be the commonly used scheduling algorithms for their ability to provide fairness while Best Channel Quality Indicator (CQI) scheduling algorithm guarantees high throughput but also starves other users in the channel.**

Thus, I believe the results reveal that the performance of the proposed schedulers in PF algorithms would be the best possible algorithm.

Future idea/modification for final project:

I also believe that the benefits of both Best CQI and Proportional Fair schedulers can be combined **for my final project** 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.

- Why one algorithm is better than another