NWS Assignment 4 Report

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Introduction:
The objective of this assignment is to understand, evaluate and compare performance of different LTE Scheduling algorithms.

Experiment:
20 UDP applications send data to the same number of UEs which are spread across 4 ENBs from the Internet(Remote Host) connected to the PGW through a 1-Gbps Point-to-Point link.

The following are some parameters of this scenario:

1. Inter distance between eNBs : 1 KM.
2. eNB Tx Power : 30 dBm (1W).
3. # of RBs : 50 in DL and 50 in UL (LTE FDD).
4. UE attachment to eNB : Automatic based on received signal strength, so handovers may take place during mobility.

Schedulers in theory:

1. *Proportional Fair (PF) :*
   It works by scheduling a user when its instantaneous channel quality is high relative to its own average channel condition over time.

   The scheduler allocates more resources to a user, comparatively with better channel quality. This is done by giving each data flow a scheduling priority that is inversely proportional to its anticipated resource consumption.

2. *Round Robin (RR) :* The scheduler provides resources cyclically to the users without considering channel conditions into account. It's a simple procedure giving the best fairness. RR meets the fairness by providing an equal share of packet transmission time to each user. In Round Robin (RR) scheduling, the terminals are assigned the resource blocks in turn (one after another) without considering CQI. Thus the terminals are equally scheduled. However, throughput performance degrades significantly as the algorithm does not rely on the reported instantaneous downlink SNR values when determining the number of bits to be transmitted.

   It is probably the simplest scheduler. It works by dividing the available resources among the active flows, i.e., those logical channels which have a non-empty RLC queue.

   If the number of RBGs is greater than the number of active flows, all the flows can be allocated in the same subframe.

   If the number of active flows is greater than the number of RBGs, not all the flows can be scheduled in a given subframe; then, in the next subframe the allocation will start from the last flow that was not allocated.

3. *Max Throughput (MT) :*
   The scheduler aims to maximize the overall throughput of the UE. It allocates each RB to the user that can achieve the maximum achievable rate in the current TTI.

   In TDMT, every TTI, MAC scheduler selects one UE which has highest achievable rate calculated by wideband CQI. Then scheduler allocates all RBGs to this UE in current TTI.

4. *Blind Average Throughput Schedulers (BATS) :*
   Frequency domain blind average throughput (FD-BET), for every TTI, the scheduler first selects one UE with lowest pastAverageThroughput (largest priority metric).

   Then scheduler assigns one RBG to this UE, it calculates expected throughput of this UE and uses it to compare with past average throughput of other UEs. The scheduler continues to allocate RBG to this UE until its expected throughput is not the smallest one among past average throughput of all UE.

   Then the scheduler will use the same way to allocate RBG for a new UE which has the lowest past average throughput until all RBGs are allocated to UEs.

NOTE:

Max Throughput (MT) : (ns3::TdMtFfMacScheduler)

It aims to maximize the overall throughput of the ENB. It allocates each RBG to the user that can achieve the maximum achievable rate in the current TTI. The scheduler selects one UE which has highest achievable rate calculated by wideband CQI and allocates all RBGs to this UE.

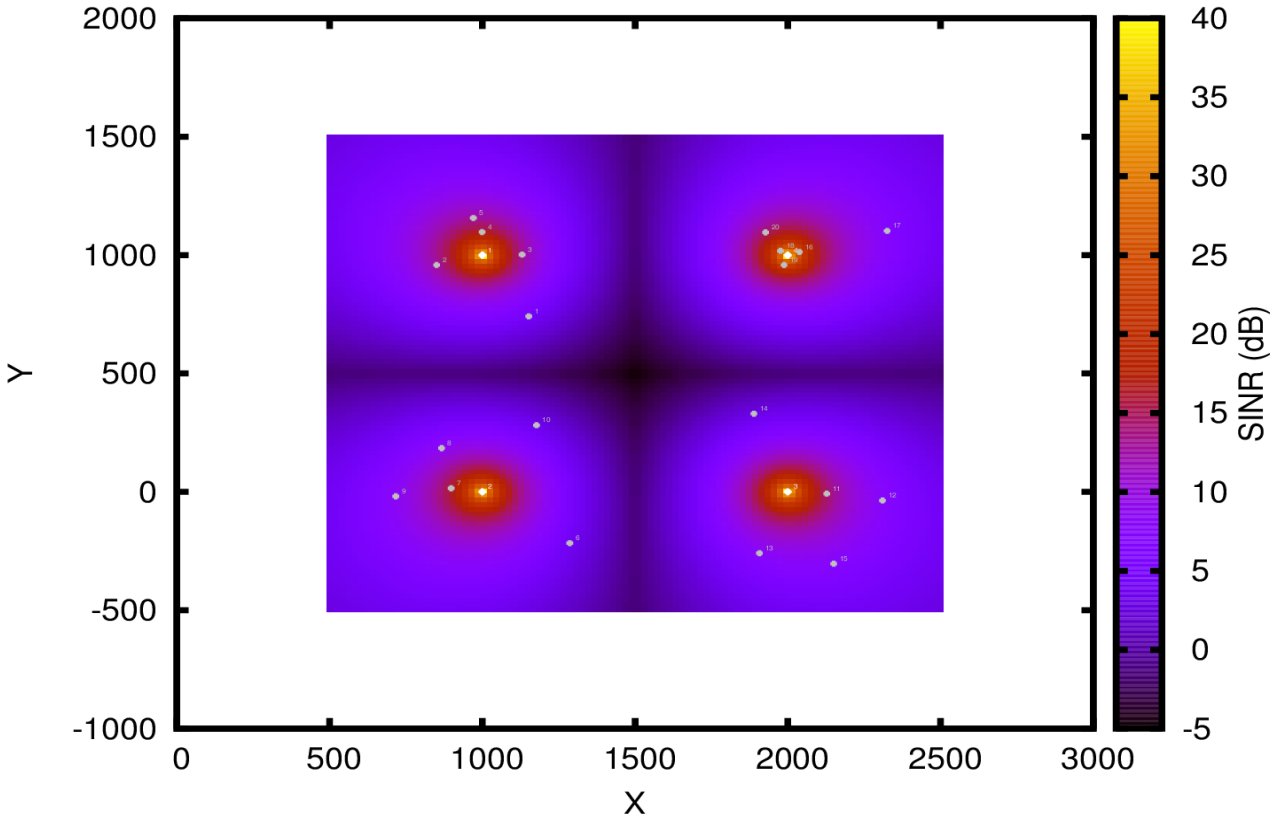
Due to this other Ues are not allocated any RBGs during that TTI. Hence, the following observation in the DlRlcStats.txt while executing the code for this scheduler.

% start	end	CellId	IMSI	RNTI	LCID	nTxPDUs	TxBytes	nRxPDUs	RxBytes	delay	min	max
0.5	0.75	1	4	2	3	250	389000	0.003	0.003	1556	1556	
0.5	0.75	2	7	2	3	250	389000	0.003	0.003	1556	1556	
0.5	0.75	3	11	3	3	250	389000	0.003	0.003	1556	1556	
0.5	0.75	4	16	1	3	250	389000	0.003	0.003	1556	1556	
0.75	1	1	4	2	3	250	389000	0.003	0.003	1556	1556	
0.75	1	2	7	2	3	250	389000	0.003	0.003	1556	1556	
0.75	1	3	11	3	3	250	389000	0.003	0.003	1556	1556	
0.75	1	4	16	1	3	250	389000	0.003	0.003	1556	1556	
1	1.25	1	4	2	3	250	389000	0.003	0.003	1556	1556	
1	1.25	2	7	2	3	250	389000	0.003	0.003	1556	1556	
1	1.25	3	11	3	3	250	389000	0.003	0.003	1556	1556	
1	1.25	4	16	1	3	250	389000	0.003	0.003	1556	1556	
1.25	1.5	1	4	2	3	250	389000	0.003	0.003	1556	1556	
1.25	1.5	2	7	2	3	250	389000	0.003	0.003	1556	1556	
1.25	1.5	3	11	3	3	250	389000	0.003	0.003	1556	1556	
1.25	1.5	4	16	1	3	250	389000	0.003	0.003	1556	1556	
1.5	1.75	1	4	2	3	250	389000	0.003	0.003	1556	1556	
1.5	1.75	2	7	2	3	250	389000	0.003	0.003	1556	1556	
1.5	1.75	3	11	3	3	250	389000	0.003	0.003	1556	1556	
1.5	1.75	4	16	1	3	250	389000	0.003	0.003	1556	1556	
1.75	2	1	4	2	3	250	389000	0.003	0.003	1556	1556	
1.75	2	2	7	2	3	250	389000	0.003	0.003	1556	1556	
1.75	2	3	11	3	3	250	389000	0.003	0.003	1556	1556	
1.75	2	4	16	1	3	250	389000	0.003	0	1556	1556	

Graphs:

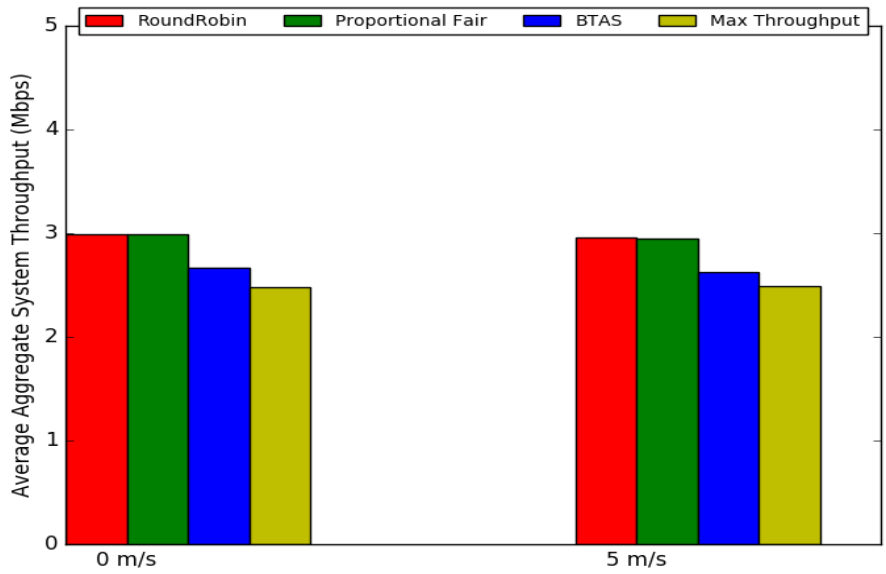
1. SINR Radio Environment Map (REM) **(Graph I)** :

It shows 20 UEs uniformly distributed among 4 ENBs alongwith the SINR values around each ENB.



ENBs are placed at locations (1000, 1000), (1000, 0), (2000, 0) and (2000, 1000) respectively. All the Ues are placed with in a radius of 500 meters of the ENB in its region.

2. Average Aggregate System throughput.
(Graph II) Full Buffer Scenario:



Observations:
1. Different Schedulers:

a. When averaged for every UE over the span of simulation time, RoundRobin(RR) and Propotional Fair(PF) Throughputs are similar but will be different for a particular UE under consideration. (analysed later).

b. Blind Average Throughput does not perform better than the above two as it aims to improve the UE with lowest pastAverageThroughput. It keeps on improving the the lowest UE by providing minimum level of service to each and every UE.

c. Max Throughput is worst because it aims to maximize the overall throughput of the UE. It allocates each RB to the user that can achieve the maximum achievable rate in the current TTI. Hence, the other Ues are effected because of this scheduler biasness.
For the selected Ue, Throughput will be maximum, thus affecting others and brining down the overall average. (Reasoning done above)

2. Different Speeds:

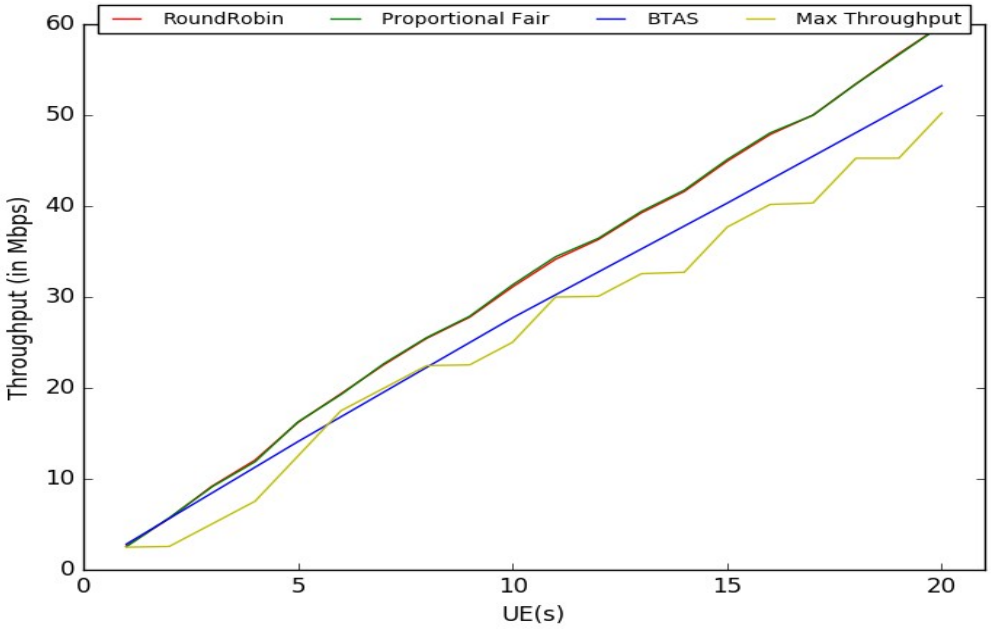
a. RoundRobin scheduling algorithm provides same Throughput irrespective of the speed because of the fairness of the algorithm.

b. There is a minute slip in Proportional Fair and BTAS at 5m/s compared to 0 m/s because of the mobility of the Ues (at a very slow speed).

c. Max Throughput value has dropped slightly depending on when the scheduler finds the UE to give priority RGBs. This value can be random over different runs.

3. Throughput CDF plot ***(Graph III)***

(a). At 0 m/sec speed.

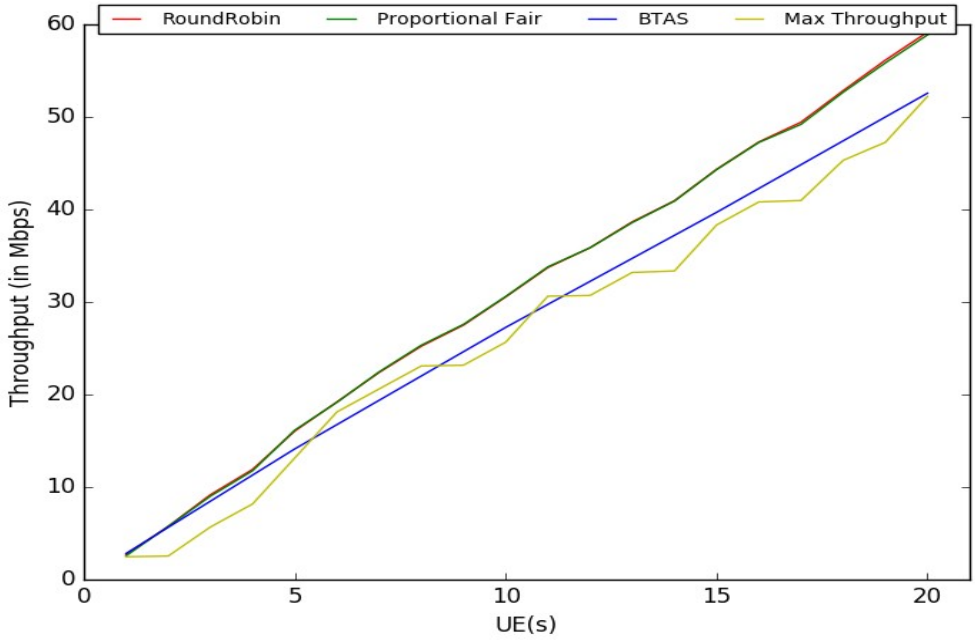


Observations:
1. Different Schedulers:
a. Proportional Fair is slightly better than RoundRobin (notice PF mostly on top of RR in the graph) by allocating more resources to a user, comparatively with better channel quality increasing the Throughput of the UE. Thus, this scheduling may be the best option.

b. Blind Average Throughput(BTAS) increases linearly indicating that it aims to provide a minimum level of service to all the Ues by allocating RGBs to the UE will the lowest average throughput during each iteration.

c. Maximum Throughput: As it is baised towards the Ues for whom it predicts that they can have maximum achievable rate in the current TTI by allocating all the RGBs, effecting the other Ues. Notice, the portions with 0-slope in the curve, as it indicates those Ues are effected because of the scheduler's baisness.

(b). At 5 m/sec speed.



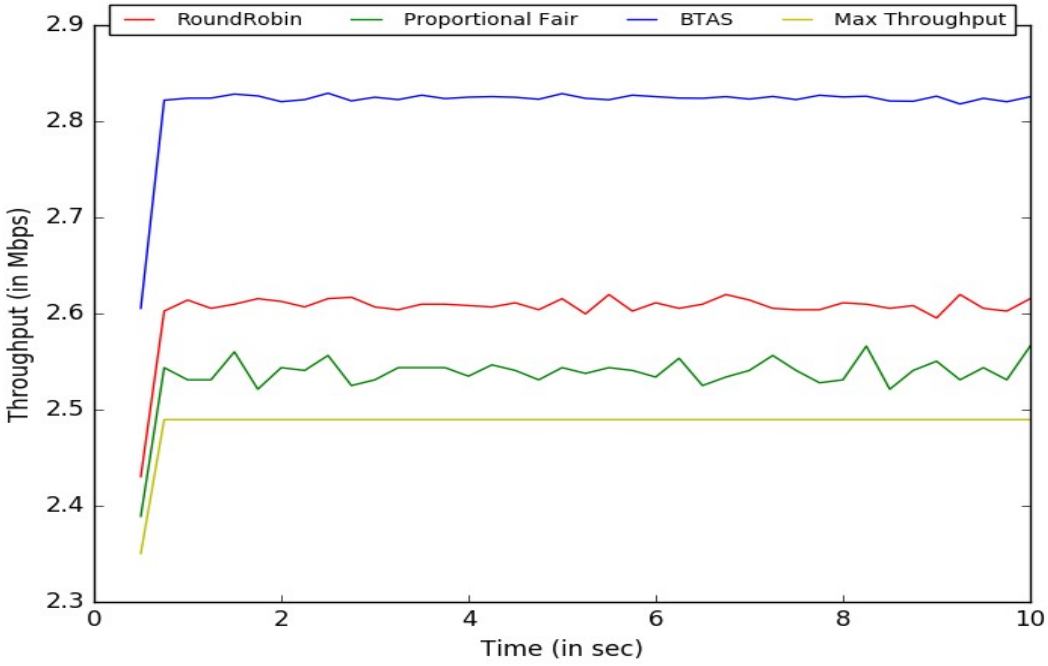
Observations:
1. Different Schedulers:
a. Proportional Fair and RoundRobin are more or less similar, as PF scheduler is affected by the mobility of the Ues. But for Ues 17,18,19 & 20 it is more evident as RR dominates over PF.

b. Blind Average Throughput(BTAS) : Same as above.
w.r.t - 0 m/sec : The overall throughput is slightly less as compared to 0 m/sec.
(Closely observe the two graphs to notice the difference).

c. Maximum Throughput: Same as above.
w.r.t. 0 m/sec : Slightly better than 0 m/s in the hope that some Ues moved closer to the ENB and those got selected for the scheduler's priority algorithm. (Plot will be mostly random over different runs).

4a. *Instantaneous throughput values for UE 0 (IMSI-1)* ***(Graph-IV)***

Speed 0 m/sec:



Observations:
1. Different Schedulers:

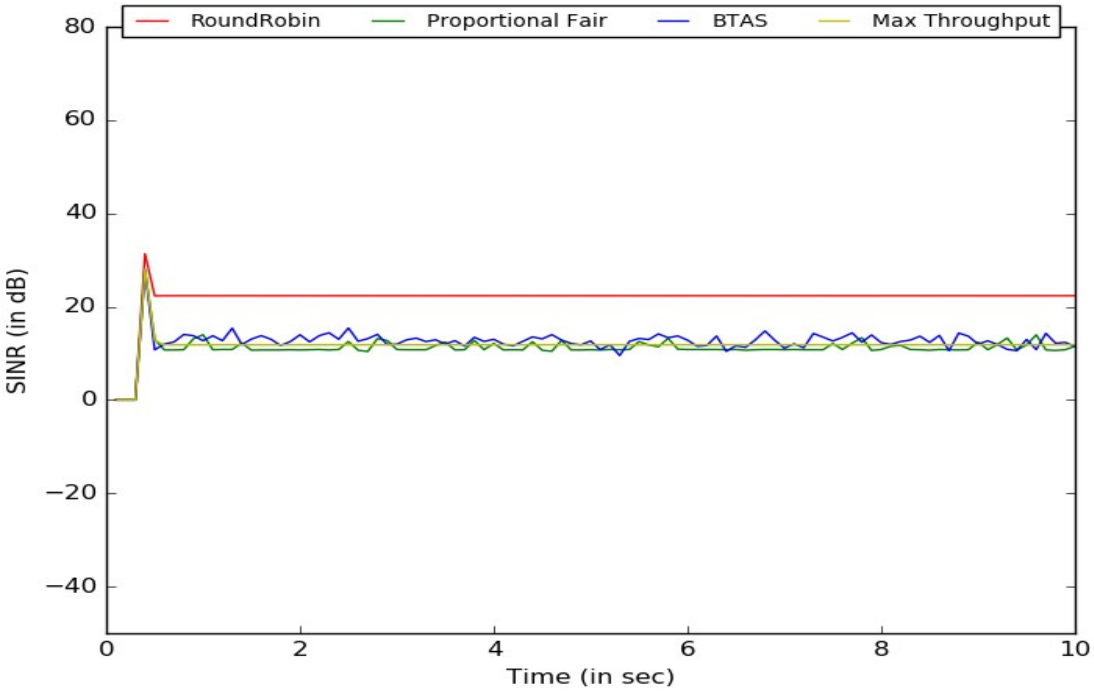
a. Blind Average Throughput(BTAS): It provides minimum level of throughput(service) to all the Ues by allocating RGBs to the UE will the lowest average throughput during each iteration, here the position of the Ues does matter, as the closer Ues will get less RBGs compared to the far away Ues. Thus, maintaing a uniform service(throughput) for all the Ues.

b. RoundRobin: Due to its fairness policy, all the RBGs are equally distributed among the Ues (across a span of iterations) irrespective of their positions. Hence, it has lower throughput for UE-0 as compared to BTAS.

c. Proportional Fair: It depends on the distance of the UEs from the ENB as it allocates more resources to a user, comparatively with better channel quality. This baisedness has efffected UE-0.

d. Max Throughput: UE-0 is selected by the scheduler for priority (allocating all RBGs), hence a constant throughput for the UE. Across different Runs, this UE may not be selected always.

4b. *SINR values for UE 0 (IMSI-1) (**Graph-IV** contd.)*



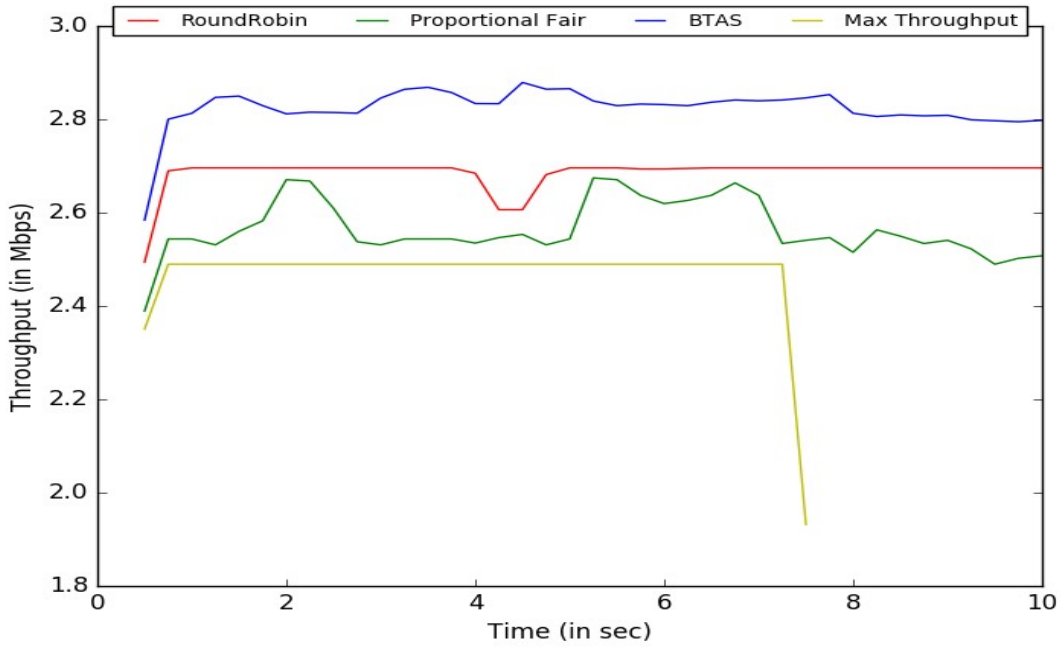
Observations:
1. Different Schedulers:

a. RoundRobin(RR): It remains constant throughout the lifetime of the UE because all the Ues are static and RBGs are fairly allocated by this scheduler irrespective of the distance of the UE from the ENB.

b. Other Schedulers: It varies because of the different allocation schemes of RBGs to the Ues at different time intervals. Also, the SINR is less as compared RoundRobin.

*5a. Instantaneous throughput values for UE 0 (IMSI-1) (**Graph-V**)*

Speed 5 m/sec:



Observations:
1. Different Schedulers:

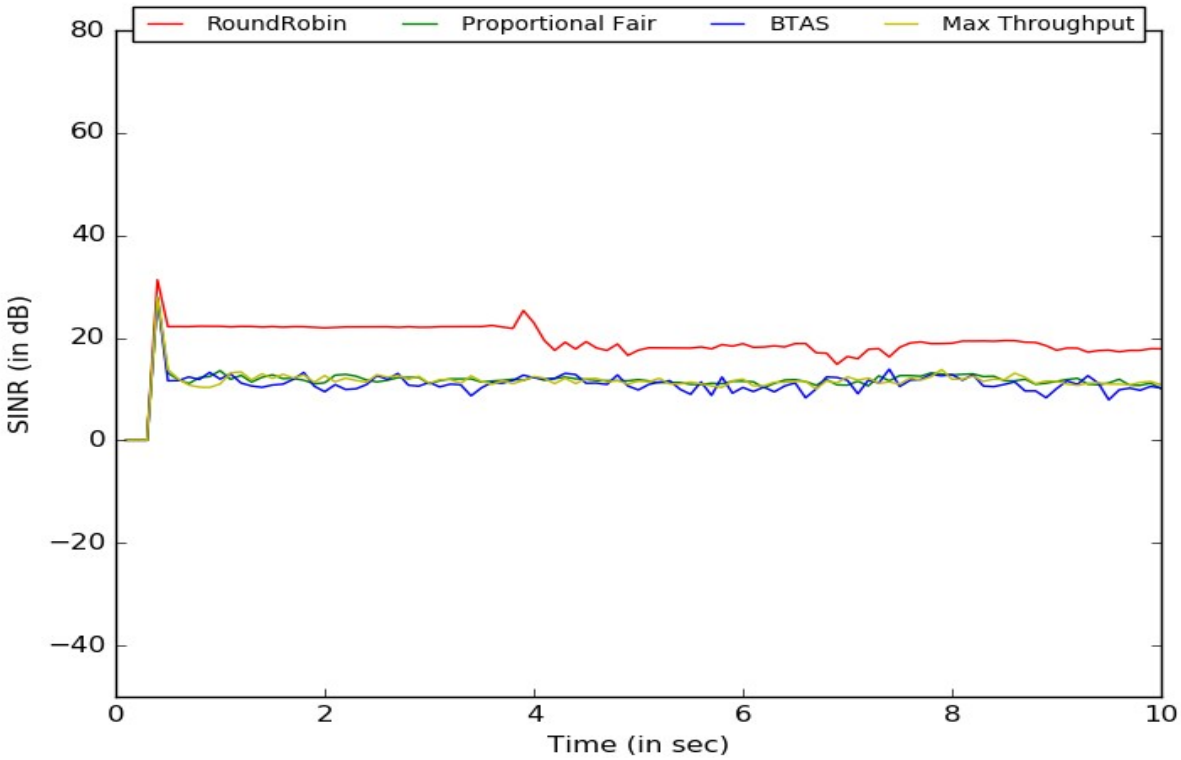
a. Blind Average Throughput(BTAS): Same as above.
w.r.t. 0 m/sec: Due to the mobility of the Ue, the throughput is slightly uneven.

b. RoundRobin:
w.r.t. 0 m/sec: Mobility of the UE did matter as evident by a dip in the middle of the curve.

c. Proportional Fair: Same as above.
*w.r.t. 0 m/sec:*Due to mobility of the UE, scheduler is considering the UE for short intervals of time by allocating it more resources in that TTI.

d. Max Throughput: UE-0 is selected by the scheduler for priority (allocating all RBGs), hence a constant throughput for the UE till time 7 sec, *after that the scheduler selects some other UE, thus discarding UE-0.* This could only be observed because of the mobility of the Ues.

5b. *SINR values for UE 0 (IMSI-1) (**Graph-V** contd.)*

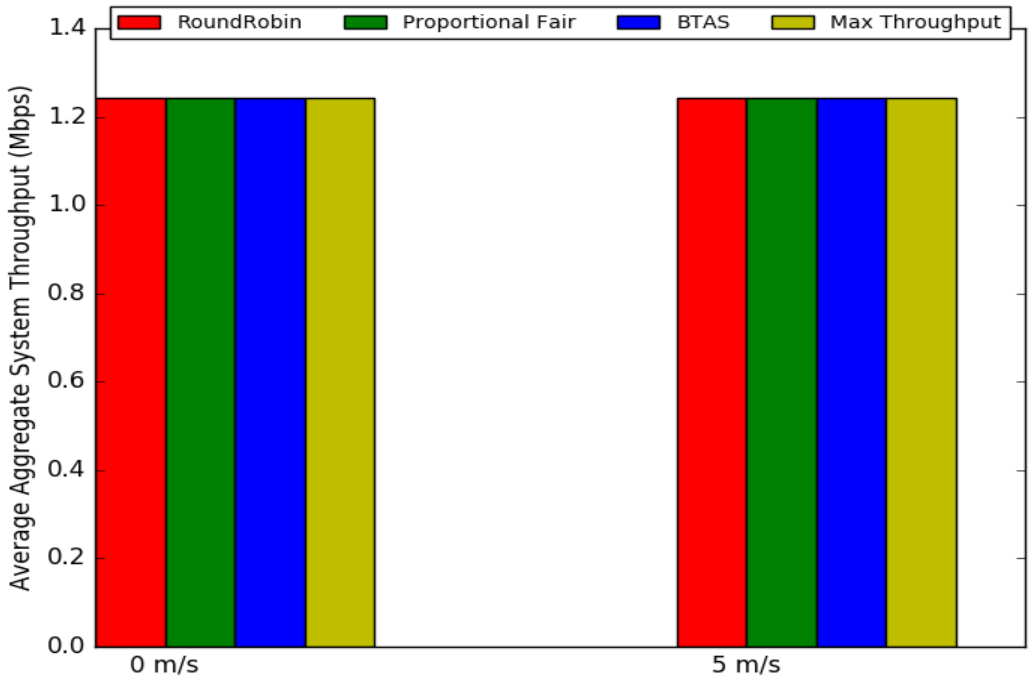


Observations:
1. Different Schedulers:

a. RoundRobin(RR): Similar to above.
w.r.t. 0 m/sec : The mobility of the Ues effects the SINR from 4 sec onwards. The UE may have moved closer to the UE and away from other Ues, hence less SINR value.

b. Others: Same as above.
w.r.t. 0 m/sec : The SINR is more as compared to 0 m/s because of mobility.
(Closely observe the two graphs to notice the difference).

5. Average Aggregate System throughput.
(Graph VI) Half Buffer Scenario:



Observation:
1.Different Schedulers:
None of the scheduling algorithms have any impact as the data for each application is coming at intervals of 10 ms and each sub-frame of LTE is 1 ms duration and 50 DL resource blocks are sufficient for data transfer.

2. Different Speed:
DlRlcStats are logged for every interval of 0.25 seconds, which is enough to send the data to the UEs irrespective of the (slow) mobility of the Ues.

3. Compared with Full Buffer Scenario:
The throughput is less because of the high packet interval between incoming packets.

Changes:
Different shedulers may be considered depending upon the requirements of the system and the conditions of the environment.

References:
1. *ns3/ns-allinone-3.25/ns-3.25/src/lte/doc/lte-design.rst

NOTE:
1. Used final Slip Day for this Assignment.
2. Individual submission as
Shamik Kundu (cs16mtech11015) has formed group with Gaurav Garg(Cs16mtech11020).