

Wireless Communications and Mobile Computing

Assignment 1: Understanding the impact of MAC scheduling algorithms, numerology, and mobility in 5G NR

Group ID: **6**

Group Members:

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Dear Dr. Giluka,

First of all, let me apologise for my mistake for simulating the entire data for the following UEs:

UE1: (1000.0, 0.0)

UE2: (-500, 0.0) :: This was supposed to be (-3000.0, 0.0)

UE3: (3000.0, 0.0)

UE4: (-1000.0, 0.0)

UE5: (10.0, 0.0)

UE6: (-10.0, 0.0)

I was testing different UE configurations, and accidentally simulated and plotted the results for the aforementioned positions. It is June 23, 22:51, as I'm typing this. and because of the deadline being in just an hour I'm unable to redo the entire simulation and plotting.

Hope you'd understand!

Regards,

Note: All the plots and data sheet can be found attached in the zip file, in appropriate location along with simulation results.

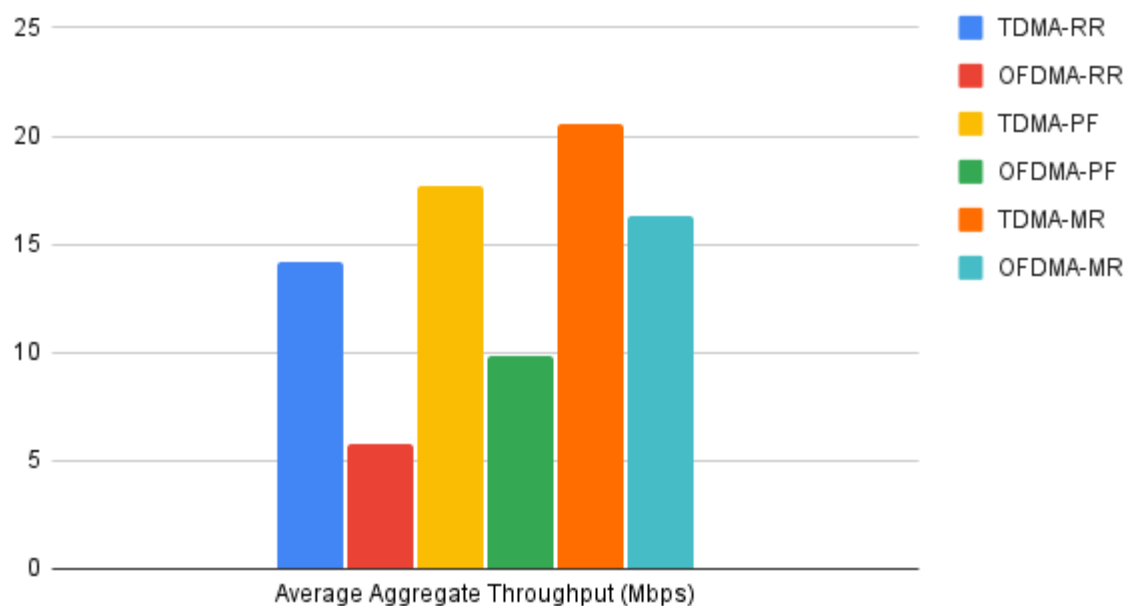
Task 1. Part A

Answer 1.

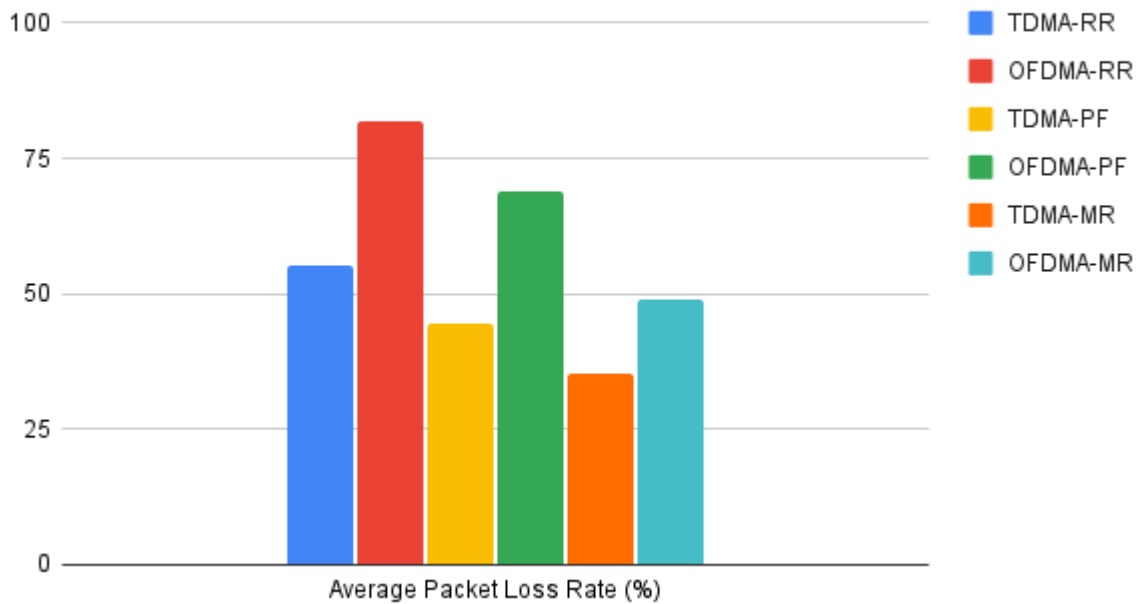
FULL BUFFER	Round Robin (RR)		Proportional Fair (PF)		Maximum Rate (MR)	
	TDMA-RR	OFDMA-RR	TDMA-PF	OFDMA-PF	TDMA-MR	OFDMA-MR
Average Aggregate Throughput (Mbps)	14.2227054	5.8160976	17.6760668	9.8555592	20.5284968	16.267699
Average Packet Loss Rate (%)	55.2772652	81.7115108	44.4183068	69.0095838	35.4489546	48.8468634
Average Packet Delay (ms)	1301.695774	2028.891066	1035.29442	1559.982059	306.3106924	530.6841438

The following are the absolute data plots for the full buffer case.

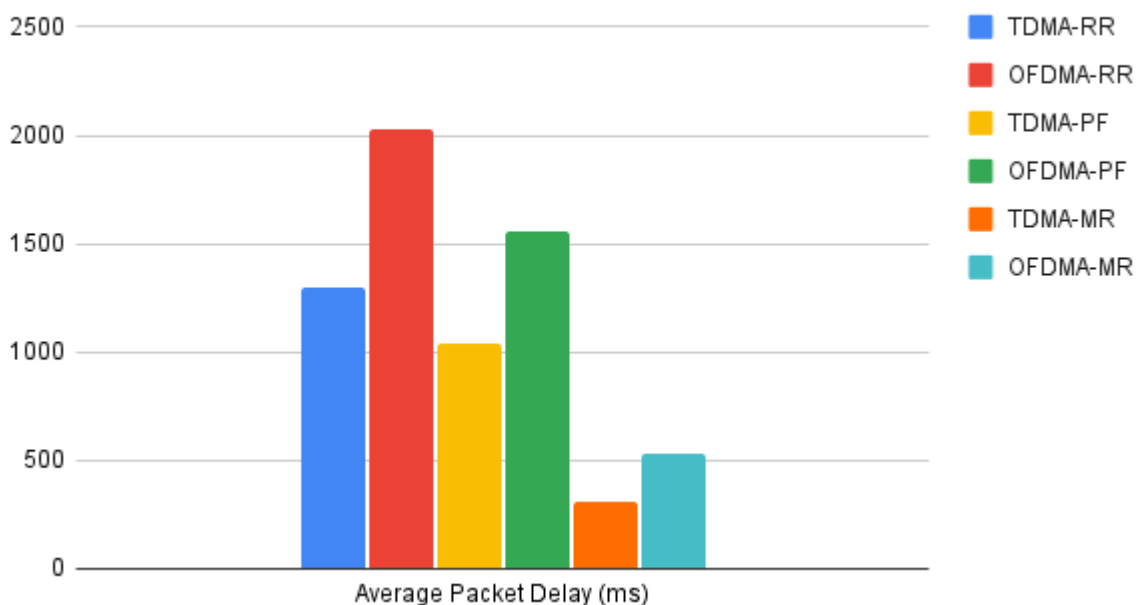
Task 1. Part A. Question 1 - Full Buffer Case (abs)



Task 1. Part A. Question 1 - Full Buffer Case (abs)



Task 1. Part A. Question 1 - Full Buffer Case (abs)

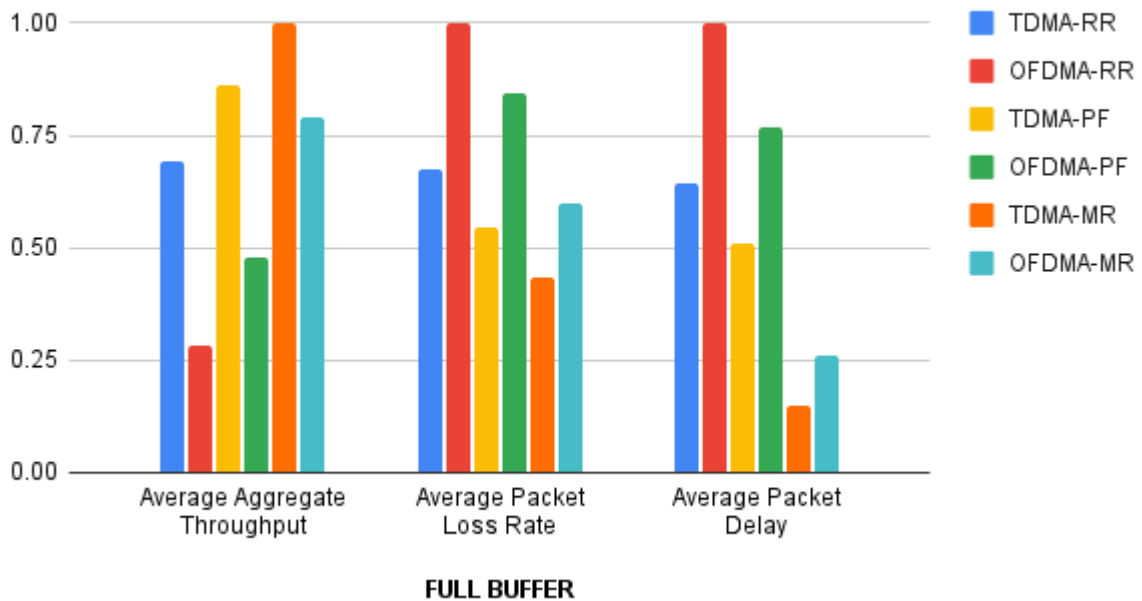


As we can see from these plots, **TDMA performs better than OFDMA** scheduler, in general for all the algorithms.

While for the same scheduler, **Maximum Rate (MR) performs the best** followed by Proportional Fair (PF) and Round Robin (RR) algorithm at last.

The aforementioned inference can further be established by plotting the relative value plot of all the parameters. (RVP, or relative value plot, is the plot where the absolute value is taken as the fraction of the maximum possible value).

Task 1. Part A. Question 1 - Full Buffer Case (rel)



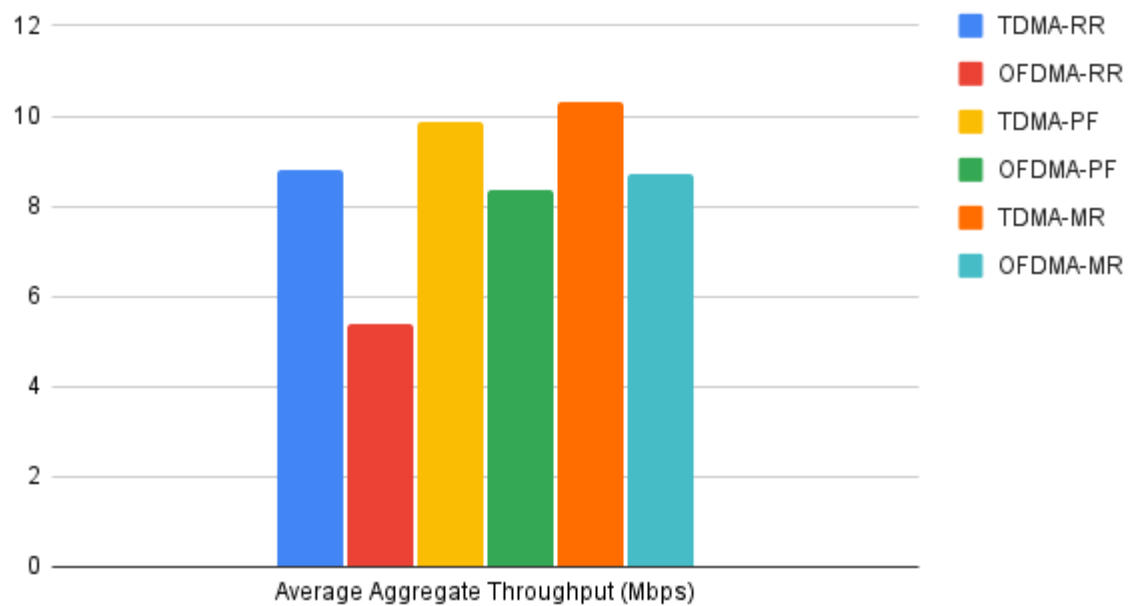
TDMA-MR scheduler-algorithm pair performs the best across all the categories.

Answer 2.

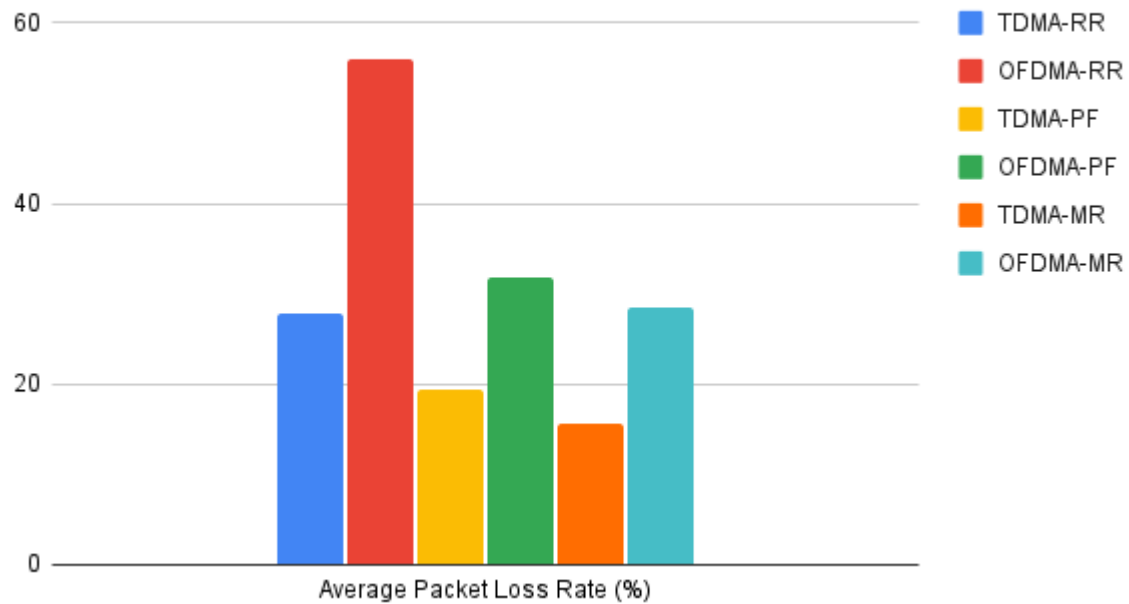
NON FULL BUFFER	Round Robin (RR)		Proportional Fair (PF)		Maximum Rate (MR)	
	TDMA-RR	OFDMA-RR	TDMA-PF	OFDMA-PF	TDMA-MR	OFDMA-MR
Average Aggregate Throughput (Mbps)	8.809022	5.379701	9.848388	8.3388054	10.3080918	8.7288324
Average Packet Loss Rate (%)	27.864531	55.9466132	19.3533532	31.7150482	15.5889222	28.5211876
Average Packet Delay (ms)	616.0573464	1388.895892	403.5855538	625.4659586	307.5317186	534.0768868

The following are the absolute data plots for the non-full buffer case.

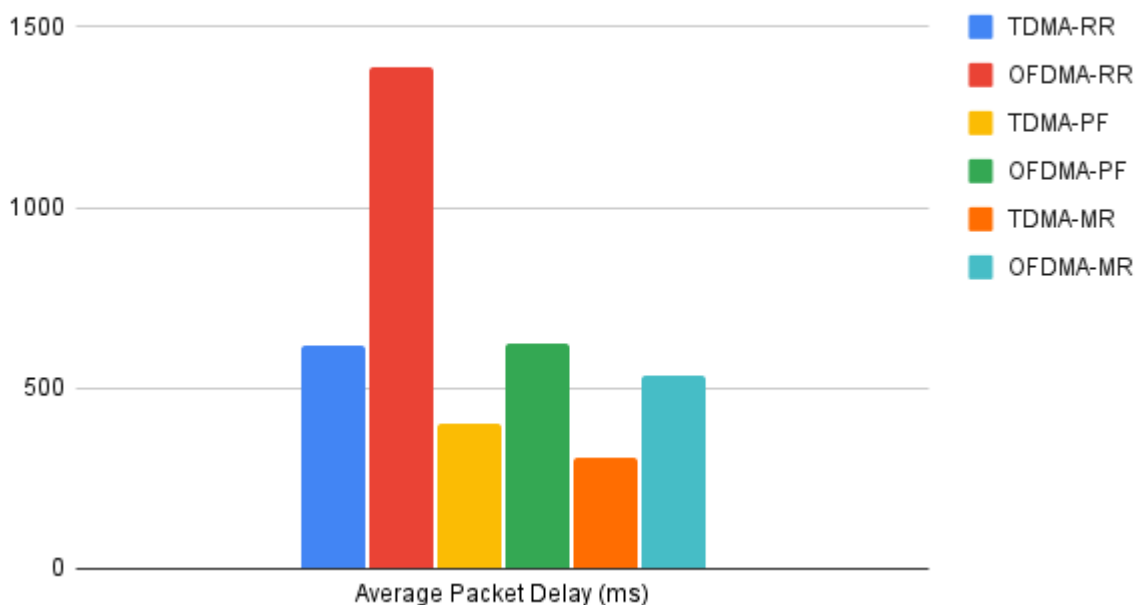
Task 1. Part A. Question 2 - Non Full Buffer Case (abs)



Task 1. Part A. Question 2 - Non Full Buffer Case (abs)



Task 1. Part A. Question 2 - Non Full Buffer Case (abs)

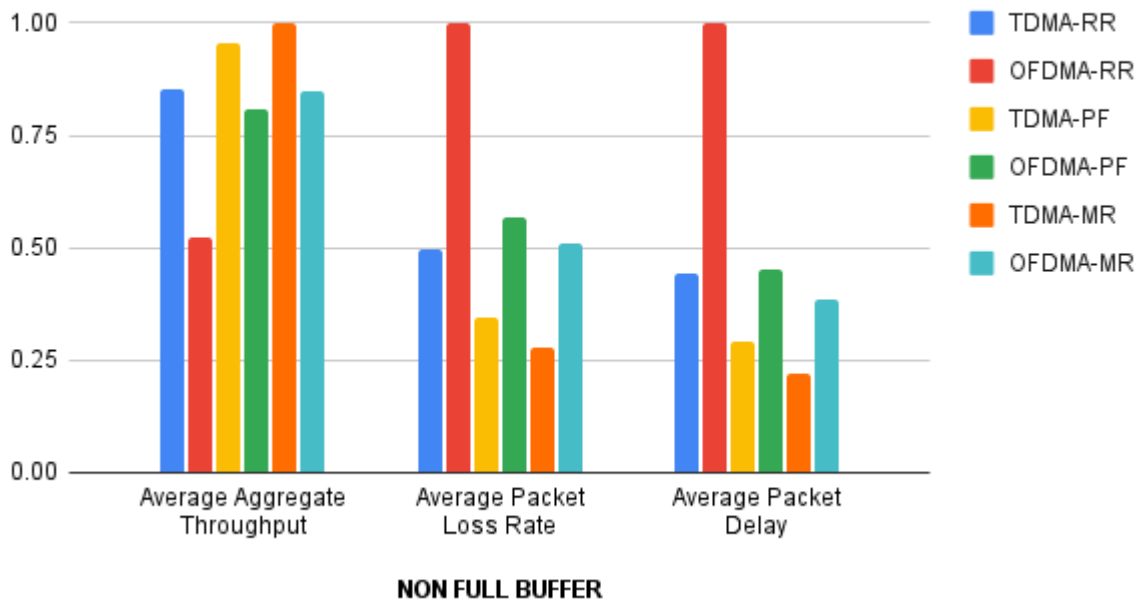


As we can see from these plots, **TDMA performs better than OFDMA** scheduler, in general for all the algorithms.

While for the same scheduler, **Maximum Rate (MR) performs the best** followed by Proportional Fair (PF) and Round Robin (RR) algorithm at last.

The aforementioned inference can further be established by plotting the relative value plot of all the parameters. (RVP, or relative value plot, is the plot where the absolute value is taken as the fraction of the maximum possible value).

Task 1. Part A. Question 2 - Non Full Buffer Case (rel)



Task 1. Part B.

Answer 3.

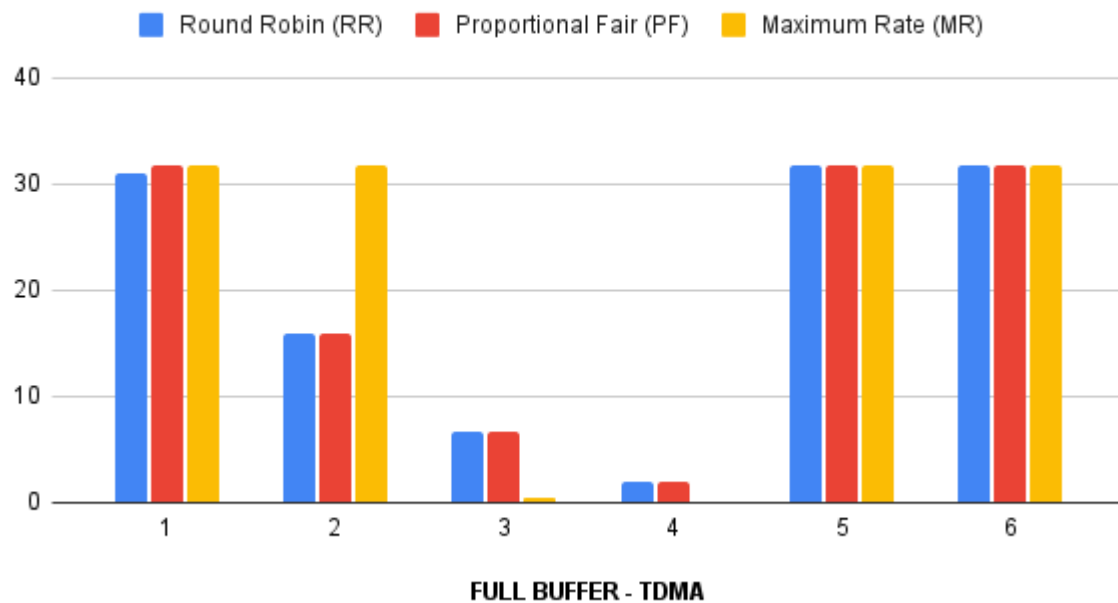
TDMA

FULL BUFFER TDMA	Round Robin (RR)		
	Throughput (Mbps)	Loss Rate (%)	Delay (ms)
1	31.056294	2.344711	59.68146
2	15.893645	50.023063	1250.728921
3	6.715866	78.882226	1971.526454
4	2.063411	93.511685	2337.088537
5	31.689498	0.353629	9.134189
6	31.687053	0.361316	9.205617

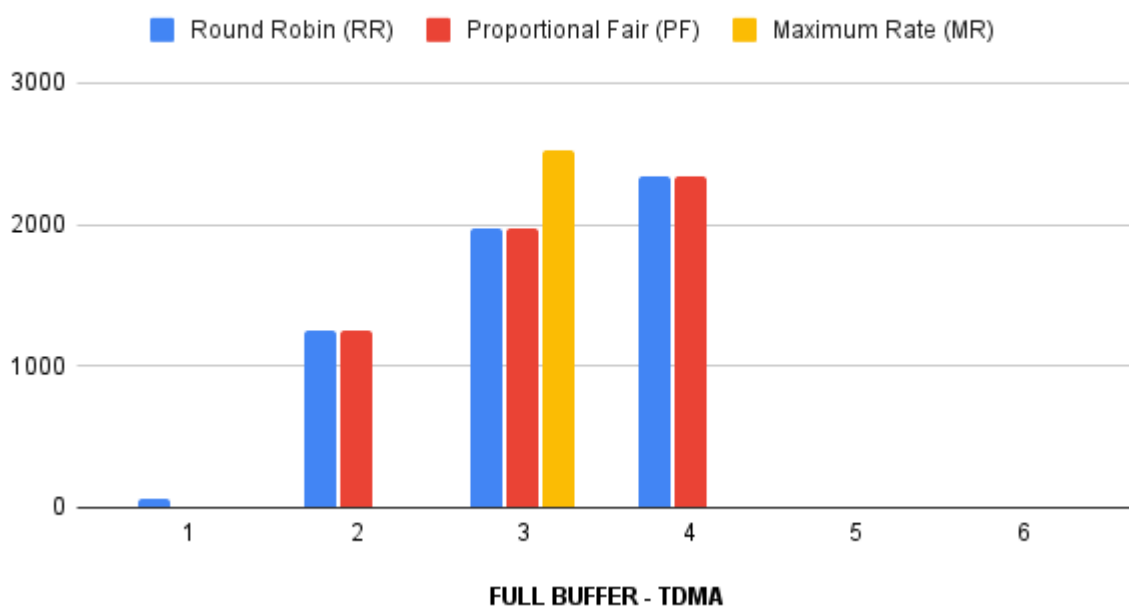
Proportional Fair (PF)		
Throughput (Mbps)	Loss Rate (%)	Delay (ms)
31.689498	0.353629	8.844871
15.827635	50.230627	1255.540445
6.659635	79.059041	1976.414473
2.01696	93.657749	2341.127659
31.689498	0.353629	9.138424
31.687053	0.361316	9.210053

Maximum Rate (MR)		
Throughput (Mbps)	Loss Rate (%)	Delay (ms)
31.691942	0.345941	8.49957
31.689498	0.353629	9.377685
0.405837	98.723862	2527.441482
0	100%	0
31.691942	0.345941	8.718766
31.689498	0.353629	8.823376

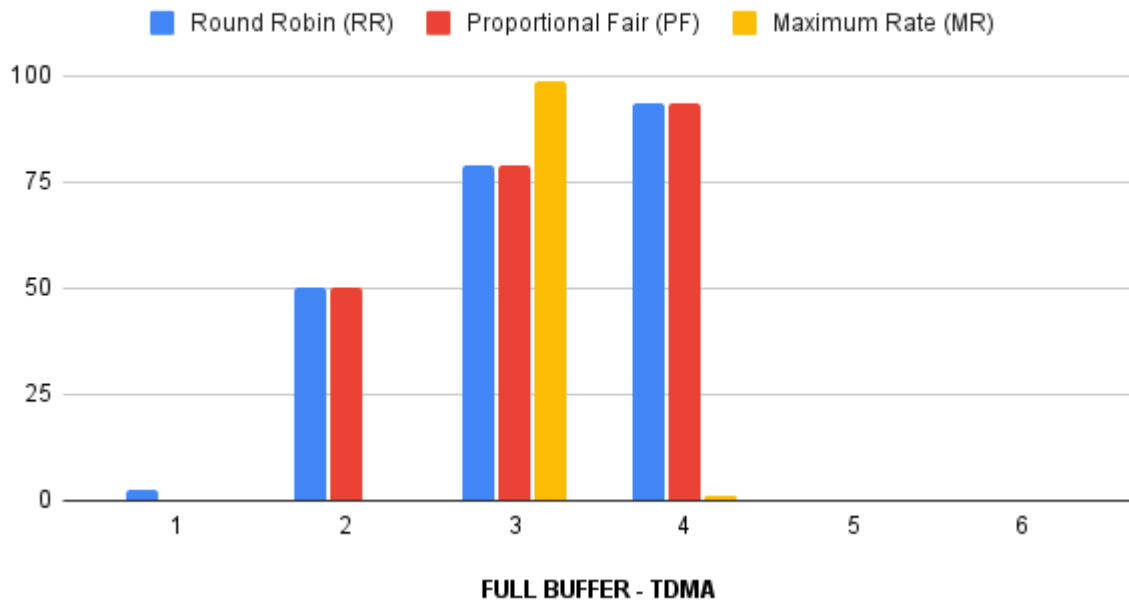
Task 1. Part B. Question 3a - Flow Throughput (Mbps)



Task 1. Part B. Question 3a - Packet Delay (ms)



Task 1. Part B. Question 3a - Packet Loss Rate (%)



By the means of the presented data and following plots, we can see that the transmission performs very well for short distance, e.g. +10, and -10, i.e. UE 5 and UE 6 respectively. The transmission is very poor for long distances like +3000, i.e. UE 3. It performs poorly.

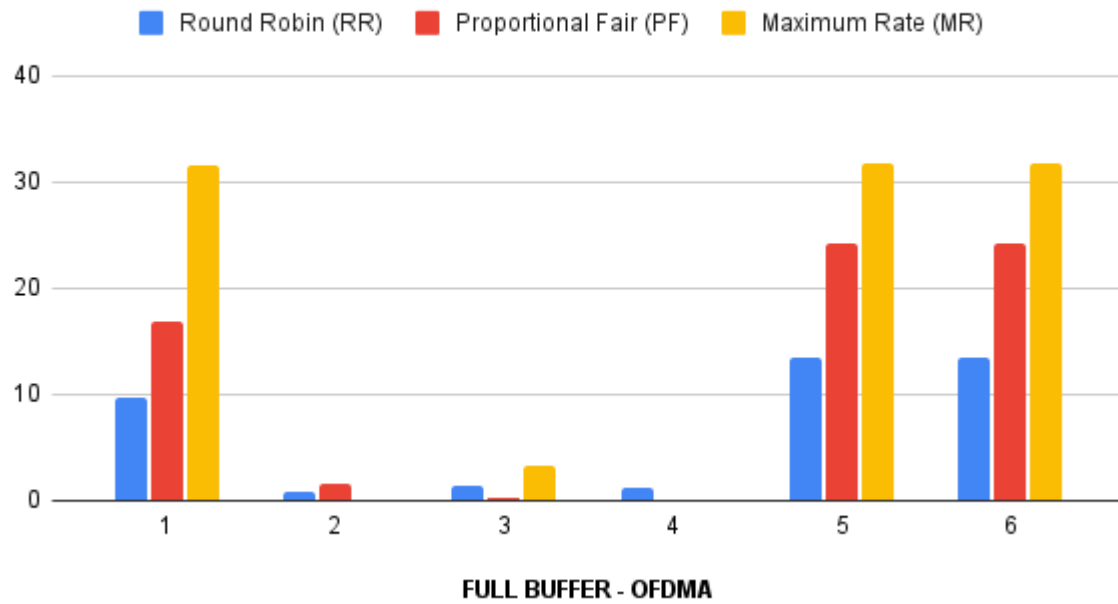
OFDMA

FULL BUFFER OFDMA	Round Robin (RR)		
	Throughput (Mbps)	Loss Rate (%)	Delay (ms)
1	9.786534	69.22663	1919.977488
2	0.858125	97.301661	2625.711565
3	1.486438	95.325953	1776.141989
4	1.149056	96.386839	1956.620071
5	13.414618	57.818266	1635.390151
6	13.414618	57.818266	1635.390151

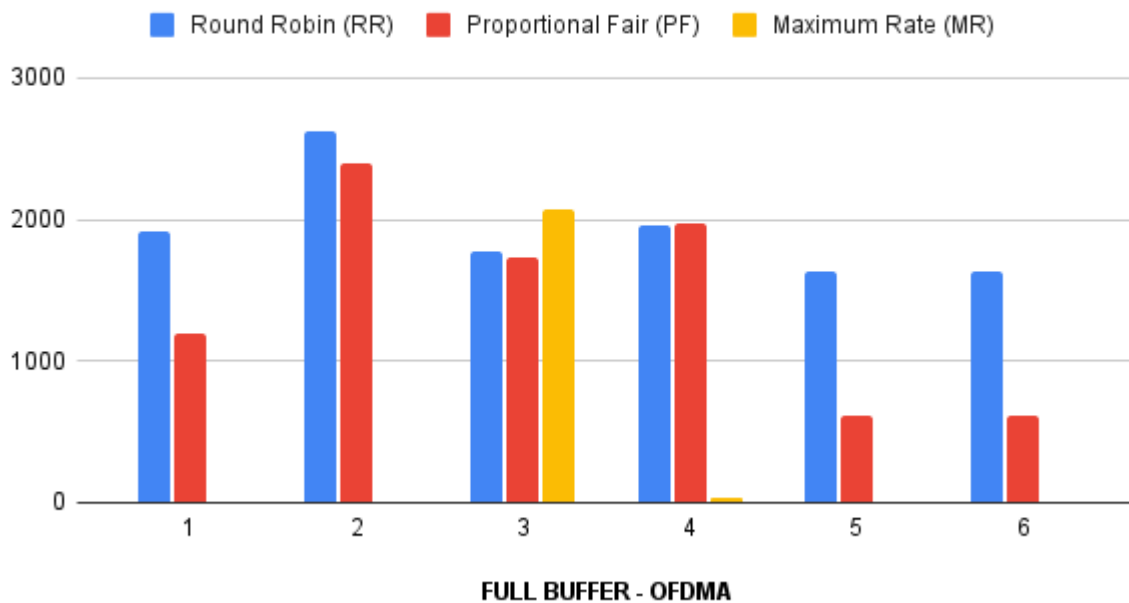
Proportional Fair (PF)		
Throughput (Mbps)	Loss Rate (%)	Delay (ms)
16.957133	46.678967	1191.897526
1.552448	95.118389	2402.741514
0.224922	99.292743	1725.743284
0.119795	99.623309	1977.415301
24.279309	23.654674	616.586806
24.279309	23.654674	616.648949

Maximum Rate (MR)		
Throughput (Mbps)	Loss Rate (%)	Delay (ms)
31.645491	0.492005	12.765605
0	100%	0
3.30537	89.606396	2071.301015
0.002445	99.992312	34.232281
31.684608	0.369004	10.216718
31.682163	0.376691	10.267936

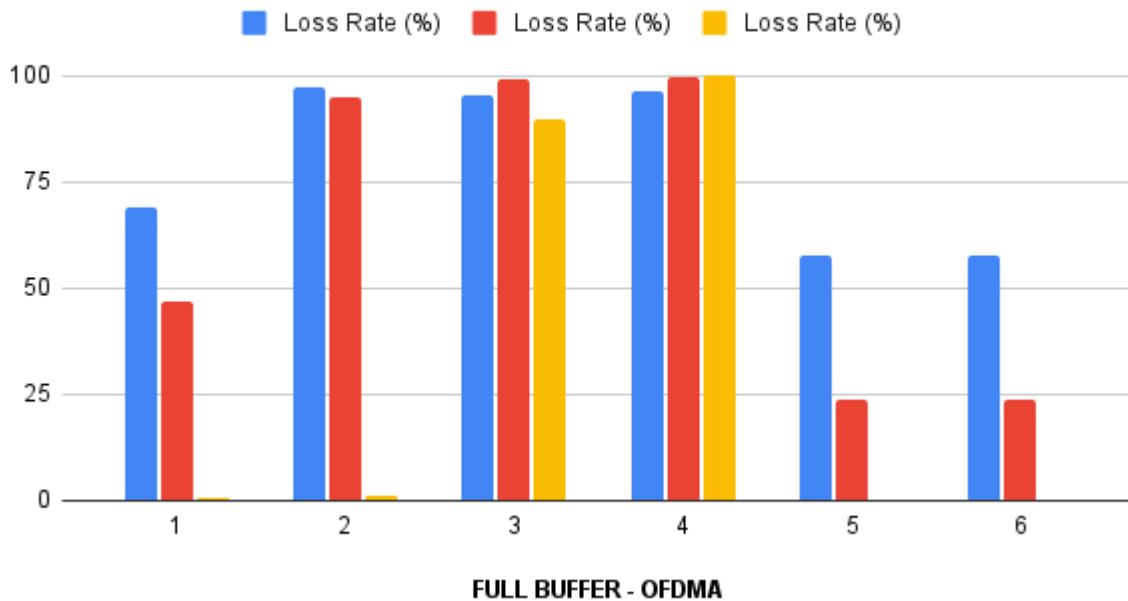
Task 1. Part B. Question 3b - Flow Throughput (Mbps)



Task 1. Part B. Question 3b - Packet Delay (ms)



Task 1. Part B. Question 3b - Packet Loss Rate (%)



By the means of the presented data and following plots, we can see that the transmission performs very well for short distance, e.g. +10, and -10, i.e. UE 5 and UE 6 respectively. The transmission is very poor for long distances like +3000, i.e. UE 3. It performs poorly.

As we can see from these plots, **TDMA performs better than OFDMA** scheduler, in general for all the algorithms.

While for the same scheduler, **Maximum Rate (MR) performs the best** followed by Proportional Fair (PF) and Round Robin (RR) algorithm at last.

Task 2. Part A

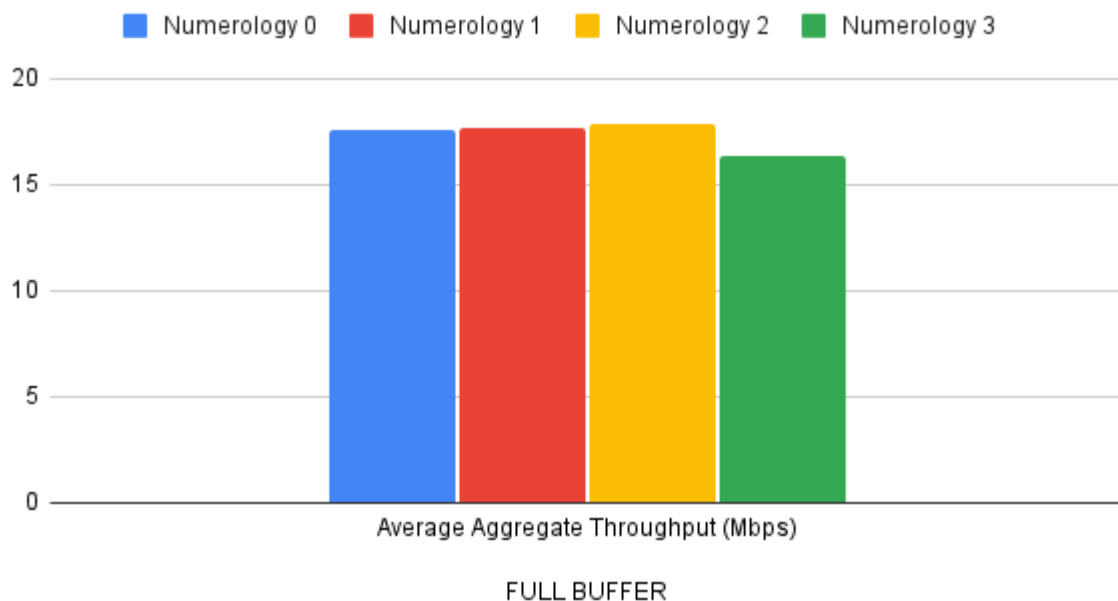
Answer 4.

FULL BUFFER TDMA-PF	Numerology 0	Numerology 1	Numerology 2	Numerology 3
Average Aggregate Throughput (Mbps)	17.5442106	17.6760668	17.844351	16.367284
Average Packet Loss Rate (%)	44.8329234	44.4183068	43.8891448	48.5337228
Average Packet Delay (ms)	1032.558421	1035.29442	1017.419247	803.5999778

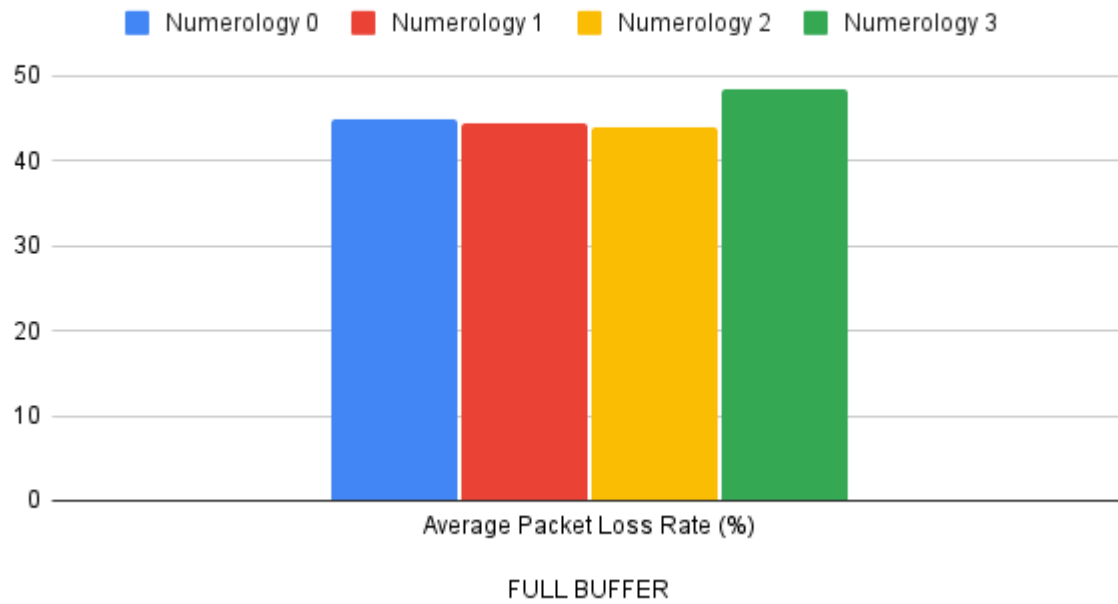
By the means of the following data, we can see that **Numerology 2 performs best** among all other numerologies with Numerology 1 and 0 following close by. But Numerology 3 lags far behind in Average Aggregate Throughput and also has comparatively higher Average Packet Loss Rate.

But, when considered for the **time-sensitive traffic**, **Numerology 3 is the best** providing the least Average Packet Delay.

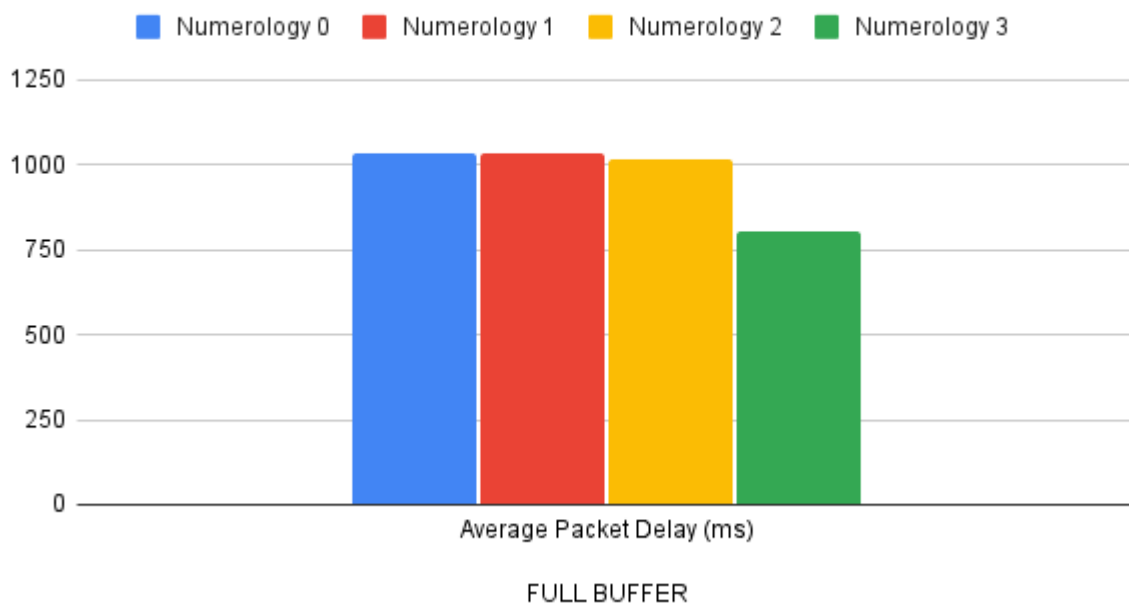
Task 2. Part A. Question 4 - Full Buffer TDMA-PF (abs)



Task 2. Part A. Question 4 - Full Buffer TDMA-PF (abs)

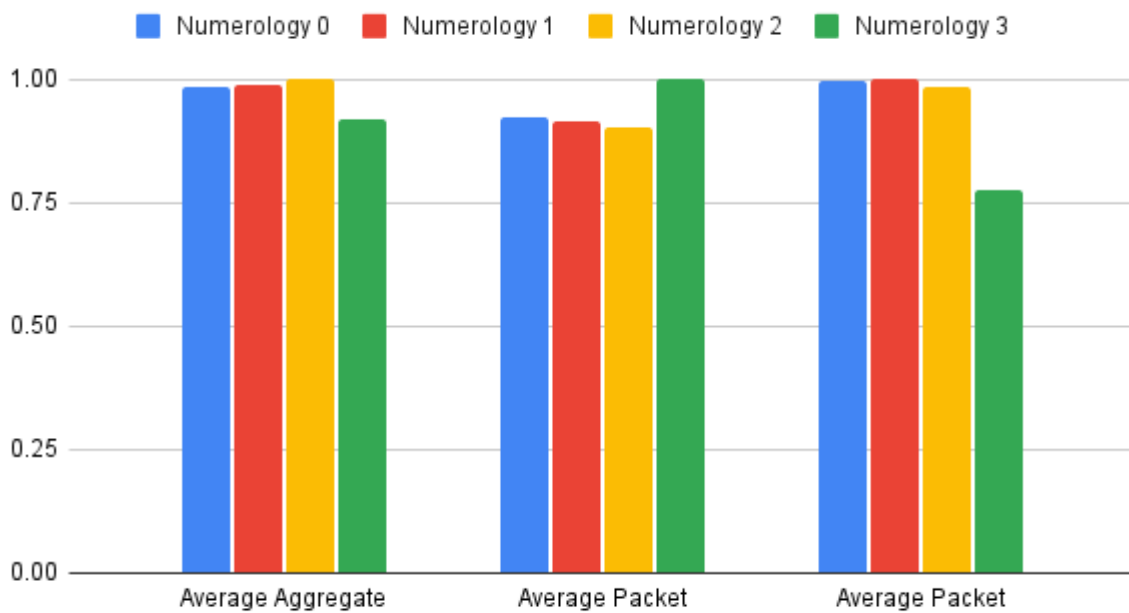


Task 2. Part A. Question 4 - Full Buffer TDMA-PF (abs)



When plotting the relative data we can see the minute difference between various numerologies.

Task 2. Part A. Question 4 - Full Buffer TDMA-PF (rel)



Task 2. Part B

Answer 5.

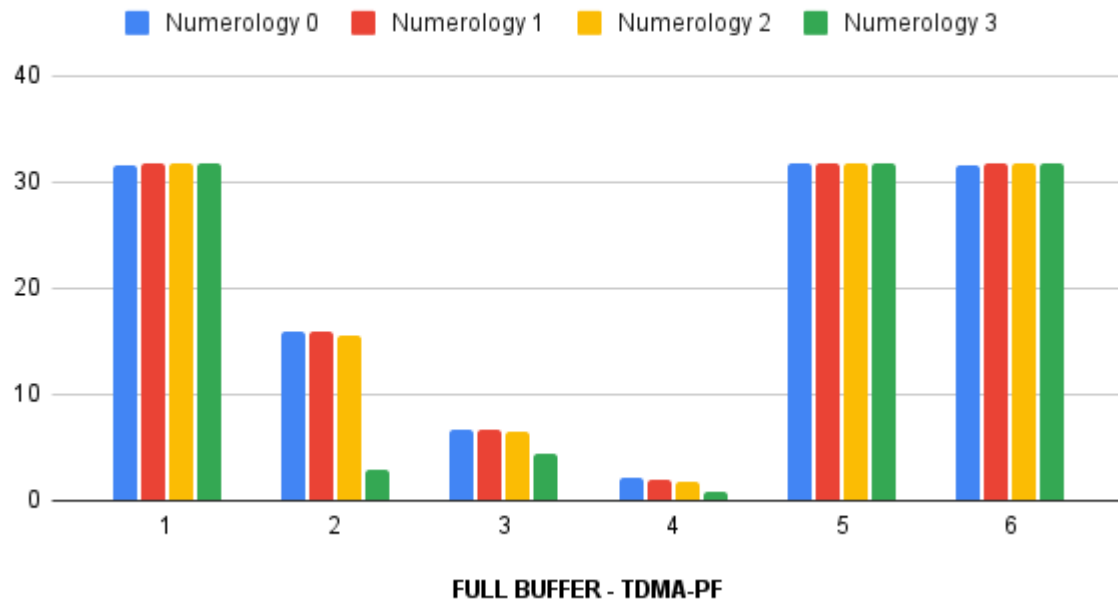
FULL BUFFER TDMA-PF	Numerology 0		
	Throughput (Mbps)	Loss Rate (%)	Delay (ms)
1	31.662605	0.438192	10.336001
2	15.864307	50.115314	1253.840261
3	6.730534	78.836101	1971.508826
4	2.095194	93.411747	2336.945633
5	31.66505	0.430504	10.904128
6	31.66016	0.445879	11.056102

Numerology 1		
Throughput (Mbps)	Loss Rate (%)	Delay (ms)
31.689498	0.353629	8.844871
15.827635	50.230627	1255.540445
6.659635	79.059041	1976.414473
2.01696	93.657749	2341.127659
31.689498	0.353629	9.138424
31.687053	0.361316	9.210053

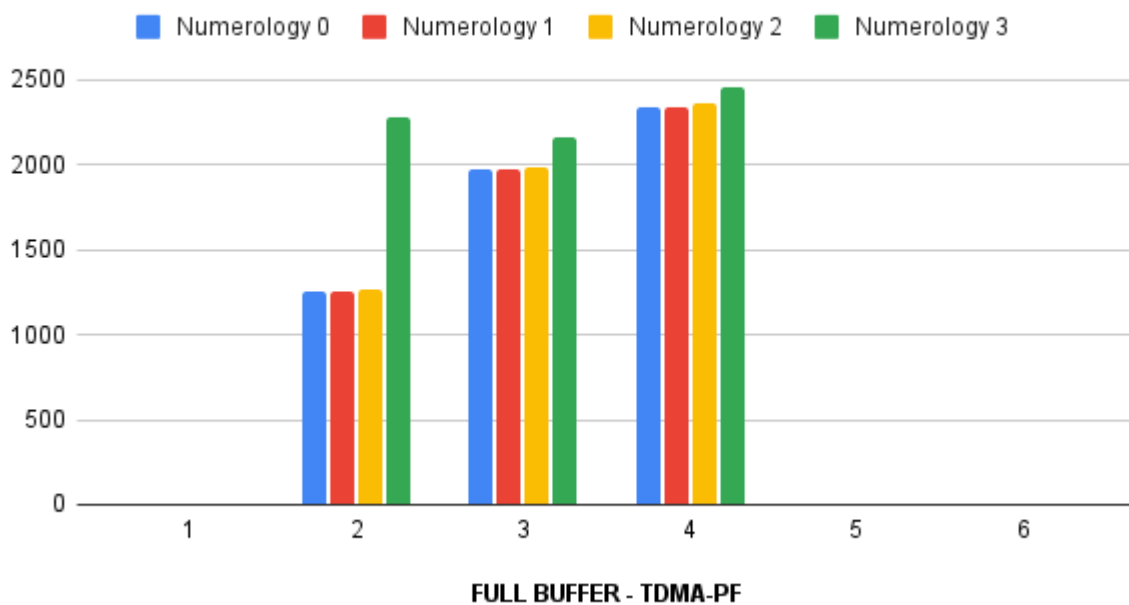
Numerology 2	Numerology 2	Numerology 2
Throughput (Mbps)	Loss Rate (%)	Delay (ms)
31.704166	0.307503	8.176706
15.634496	50.837946	1270.88359
6.498278	79.566421	1988.729109
1.823821	94.265068	2357.413653
31.704166	0.307503	8.321735
31.701722	0.315191	8.361662

Numerology 3	Numerology 3	Numerology 3
Throughput (Mbps)	Loss Rate (%)	Delay (ms)
31.709056	0.292128	9.432274
2.818854	91.136224	2280.709872
4.361523	86.285363	2157.860333
0.85568	97.309348	2456.264595
31.709056	0.292128	9.574685
31.706611	0.299815	9.60196

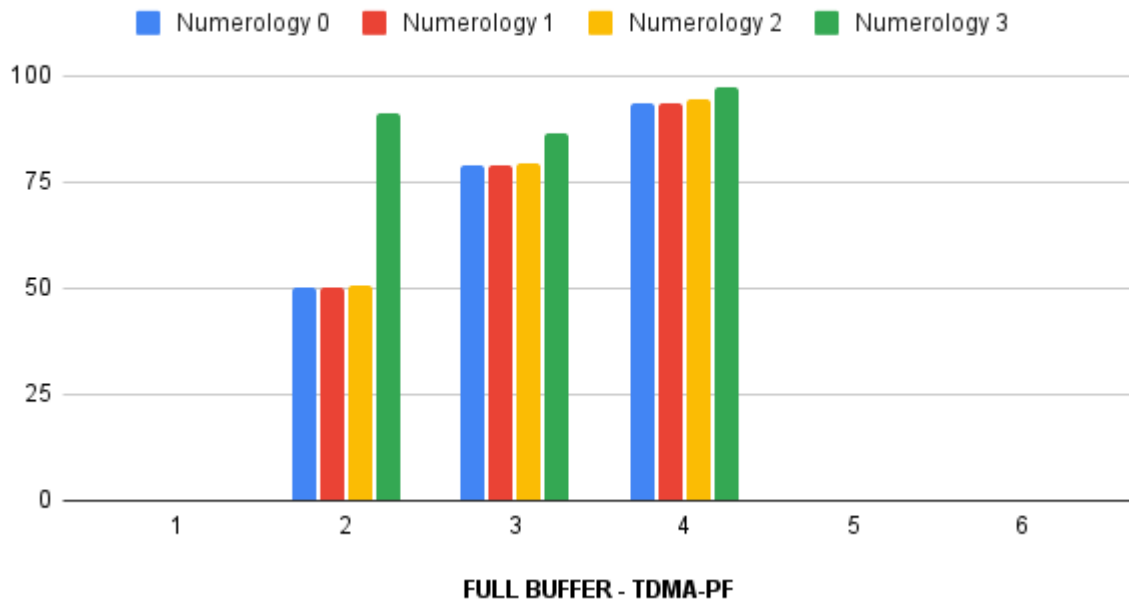
Task 2. Part B. Question 5 - Flow Throughput (Mbps)



Task 2. Part B. Question 5 - Packet Delay (ms)



Task 2. Part B. Question 5 - Packet Loss Rate (%)



Proportional Fair (PF) is generally fair among all the Numerologies, generating nearly consistent results. The results fall in the general direction of previously simulated results.

Task 3. Part A

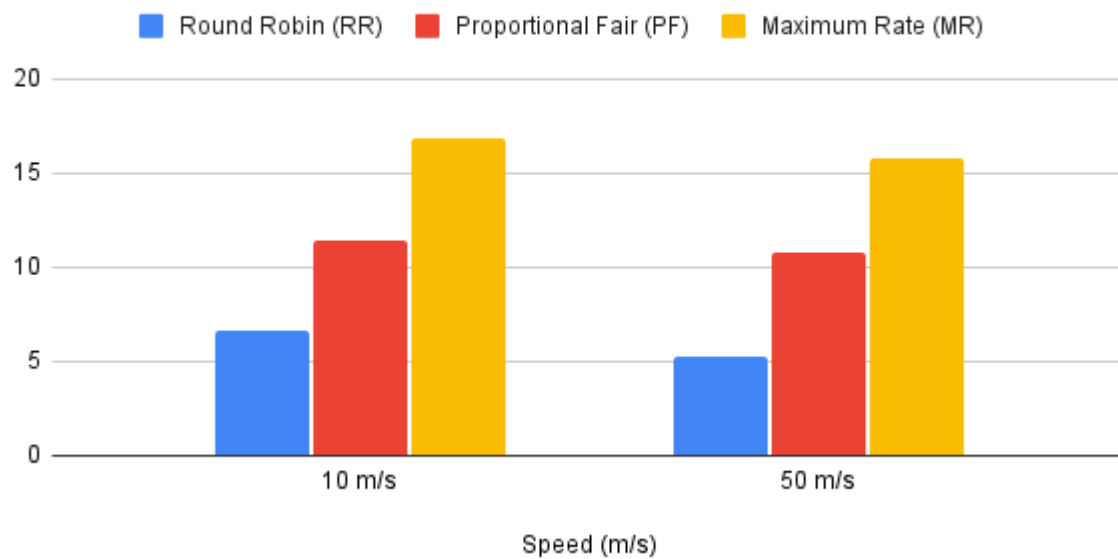
Answer 6.

Average Aggregate Throughput (Mbps)			
Speed (m/s)	Round Robin (RR)	Proportional Fair (PF)	Maximum Rate (MR)
10 m/s	6.5921996	11.4217592	16.7976302
50 m/s	5.2973114	10.77513	15.765965

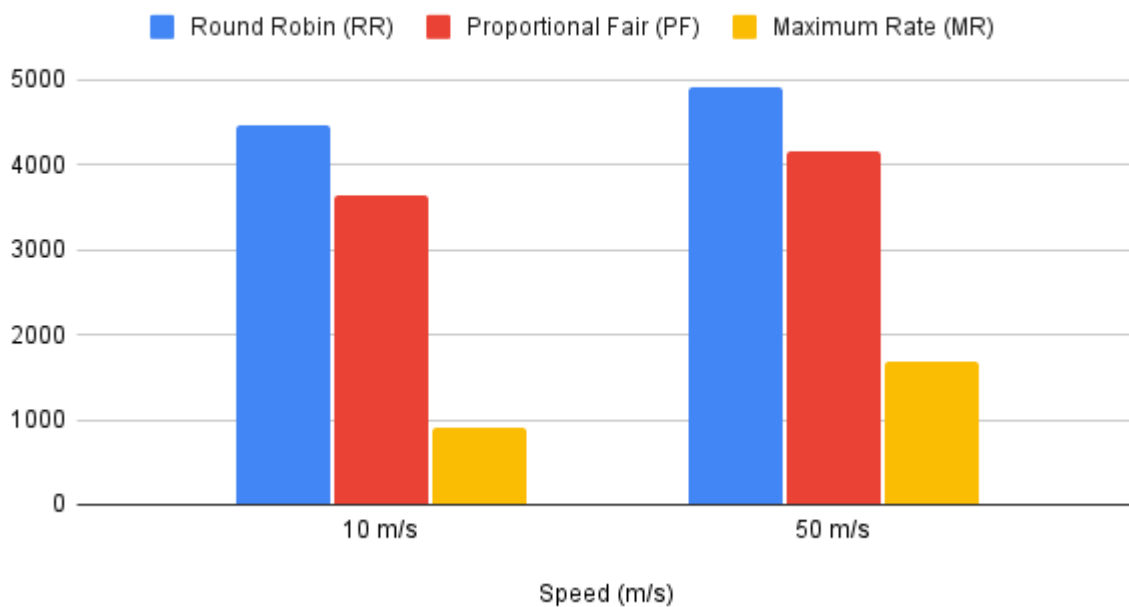
Average Packet Loss Rate (%)			
Speed (m/s)	Round Robin (RR)	Proportional Fair (PF)	Maximum Rate (MR)
10 m/s	79.2866148	64.1116296	47.2200776
50 m/s	83.3552906	66.1434068	50.4616772

Average Packet Delay (ms)			
Speed (m/s)	Round Robin (RR)	Proportional Fair (PF)	Maximum Rate (MR)
10 m/s	4459.22238	3631.747932	914.2561796
50 m/s	4910.651359	4163.760261	1683.771306

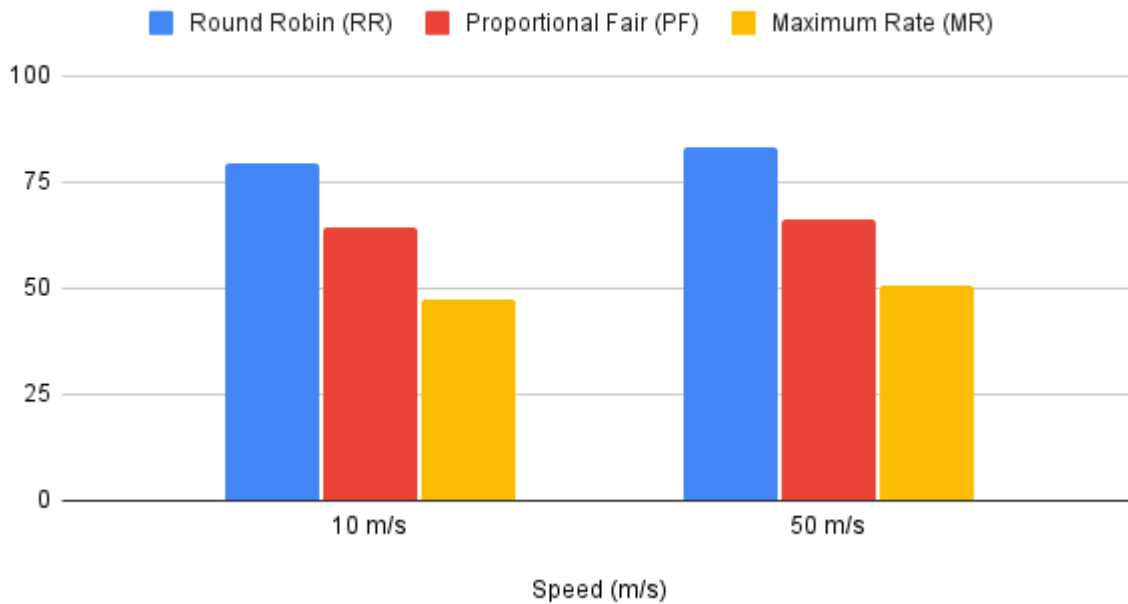
Task 3. Part A. Question 6 - Average Aggregate Throughput (Mbps)



Task 3. Part A. Question 6 - Average Packet Delay (ms)



Task 3. Part A. Question 6 - Average Packet Loss Rate (%)



By these results we can see that **Maximum Rate (MR), is the best performer** across the category followed by Proportional Fair (PF) and then Round Robin (RR).

Also, the **Average Throughput is slightly higher in 10m/s as compared to 50 m/s** across all algorithms. The same trend is followed by average packet loss rate and average delay but in reverse, i.e. they are slightly higher in 50 m/s as compared to 10m/s.

As compared to static scenarios, we can see that the **algorithms perform slightly worse than their static counterparts.**