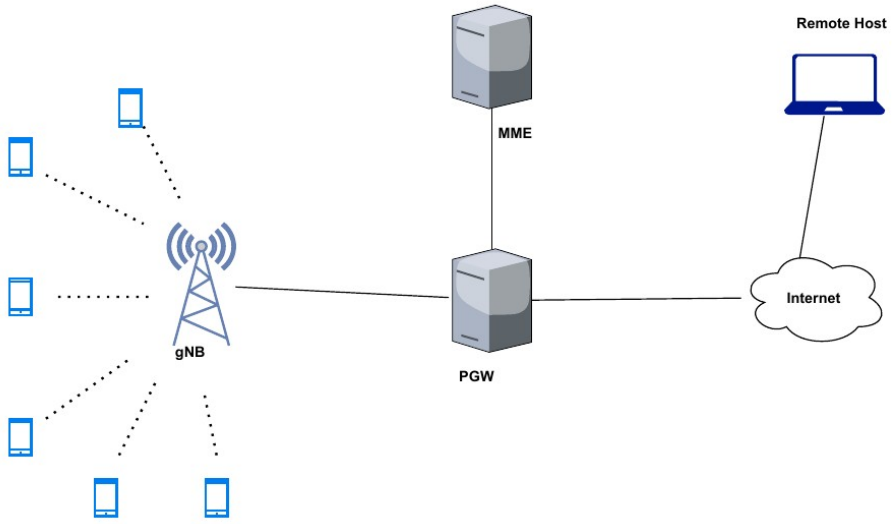
Understanding the impact of MAC scheduling algorithms, numerology, and mobility in 5G NR

Max. Group Size: 2 students
Marks: 20

The objective of this assignment is to understand the effect of MAC Scheduling algorithms, numerology and mobility in 5G using NS-3 NR Module (NSA mode). Further, you need to evaluate and compare the performance of different Scheduling algorithms and Numerology.

Create a topology as shown in the below figure and set parameters mentioned in the below table. Add P-GW and a Remote Host to this topology and connect them directly with a point-to-point link.



Simulation Parameter	Value
Number of UEs	6; 1 Downlink UDP Flow per UE from the Remote Host.
Number of gNBs	1
Locations of UE (in meters)	(10,0), (1000,0), (3000,0), (-10,0), (-1000,0), (-3000,0)
Base Station position	(0,0)

gNB Tx Power	23 dBm
S1-U Link Delay between gNodeB and P-GW	2 ms
P2P link between P-GW and Remote Host	Data Rate: 10 Gbps Link Delay: 5 ms
Channel model	3GPP, LoS
Channel bandwidth	50 MHz
Central frequency	6 GHz for numerologies 0,1,2 28 GHz for numerology 3
Scenario	UMa_LoS
Shadowing	disabled
Numerologies	0,1,2 (FR1: 6GHz) 3 (FR2: 28 GHz)
Application Type	UDP Client and UDP Server
BandWidth Part	1 bandwidth part (1 for DL). Create one component carrier (CC) and set the parameters “Numerology”, ”Pattern”, and ”TxPower”.
RLC MaxTxBufferSize	999999999
Antennas for all the UEs	NumRows: 2 NumColumns: 4 AntennaElement: IsotropicAntennaModel
Antennas for all the gNbs	NumRows: 4 NumColumns: 8 AntennaElement: ThreeGppAntennaModel
BeamformingMethod	DirectPathBeamforming
Error Model	NrEesmIrT1

Packet Size	1500 bytes
AmcModel	ShannonModel
Height of Base Station and UE	10 Meters / 1.5 Meters
Full buffer case (UDP Traffic)	Set minimum 30 Mbps per each DL flow (1500

	Byte packets, 2500 packets per sec)
Non Full buffer case (UDP Traffic)	Set maximum 12 Mbps per each DL flow (1500 Byte packets, 1000 packets per sec)
Total simulation time	5 seconds (Static Scenario) 20 seconds (Mobile scenarios)
Number of seeds per experiment	5; RngRun1 = “Last TWO DIGITS of one of your ROLL NUMBERS” RngRun2 = RngRun1+1 and so on…

Task 1: Understanding the impact of throughput and delay achieved by UEs using three different MAC scheduling algorithms (e.g., Round Robin (RR), Proportional Fair (PF), and Maximum Rate (MR)). Use additional simulation parameters mentioned below for this task and fill the values in the table.

Part A:

i) Analysing average aggregate throughput, packet loss rate and packet delay for Full buffer case

Simulation Parameters

Numerology	1
NrMacScheduler	Tdma, Ofdma

Average Aggregate Throughput (Mb/s): Sum up individual UE throughputs

given by the flow monitor to get aggregate throughput of 6 UEs in each experiment and take average of the aggregate throughputs after repeating it for 5 seeds (RngRuns)

	RR		PF		MR	
	TDMA	OFDMA	TDMA	OFDMA	TDMA	OFDMA
Average Aggregate Throughput (Mb/s)						
Average Packet Loss Rate						
Average Packet Delay						

Note: You can calculate avg loss rate/delay from flow monitor stats.

Q1. Based on the values measured, provide an analysis of the trends observed and quantify improvement in performance (i.e., throughput, loss and delay) for different scheduling algorithms studied.

ii) Repeat the above set of experiments for Non Full Buffer case and fill the measurements in the table (same as previous one)

Q2. Based on the values measured for non full buffer case, provide an analysis of the trends observed and quantify improvement in performance (i.e., throughput and delay) for different scheduling algorithms studied.

Part B: Analysing throughput, loss and delay achieved for each UE in Full Buffer Case by using the simulation parameters mentioned below and fill the values in the table.

Simulation Parameters

Numerology	1
#Seeds	1 (Set RngRun = “Last TWO DIGITS of one of your ROLL NUMBERS”)
NrMacScheduler	Tdma, Ofdma

Throughput (Mb/s), loss rate and delay (m/s):

NrMacScheduler = Tdma									
UE ID	RR			PF			MR		
	Throughput	Loss Rate	Delay	Throughput	Loss Rate	Delay	Throughput	Loss Rate	Delay
1									
2									
3									
4									
5									
6									

NrMacScheduler = Ofdma									
UE ID	RR			PF			MR		
	Throughput	Loss Rate	Delay	Throughput	Loss Rate	Delay	Throughput	Loss Rate	Delay
1									

2									
3									
4									
5									
6									

Q3. Based on the values reported in above tables, provide an analysis of the trends observed and quantify improvement in performance (i.e., throughput, loss and delay) for different scheduling algorithms studied. Also, comment on the impact of NrMacScheduler type on the results obtained.

Task 2: Understanding the impact of different Numerologies (0 to 3) in Full Buffer Case. Use the additional simulation parameters mentioned below and fill the values in the table.

Simulation Parameters

Part A:

Numerologies	0,1,2,3
NrMacScheduler	TdmaPF

Average Aggregate Throughput (Mb/s):

	Numerology 0	Numerology 1	Numerology 2	Numerology 3
Average Aggregate Throughput (Mb/s)				
Average Loss Rate				
Average Delay				

Q4: Based on the values measured provide an analysis of the trends observed and quantify improvement in performance (i.e., throughput, loss rate and delay) for different Numerologies. Which numerology is more suitable for time-sensitive

traffic?

Part B: Analysing throughput, loss rate, and delay achieved for each UE for different numerologies in Full Buffer Case . Use the simulation parameters mentioned below and fill the values in the table.

Numerology	0,1,2, 3
NrMacScheduler	TdmaPF
#Seeds	1 (Set RngRun = “Last TWO DIGITS of one of your ROLL NUMBERS”)

Throughput (Mb/s), loss rate and delay (m/s):

NrMacScheduler = TdmaPF									
UE	Numerology 0			Numerology 1			Numerology 2 & 3		
	Throughput	Loss Rate	Delay	Throughput	Loss Rate	Delay	Throughput	Loss Rate	Delay
1									
2									
3									
4									
5									
6									

Q5: Based on the values measured provide an analysis of the trends observed and quantify improvement in performance (i.e., throughput, loss rate and delay) for different numerologies. Comment on how fair is PF.

Task 3. Understanding the impact of Mobility in Full Buffer Case. Refer here to know more about these RandomWalk2d Mobility Model. Using the simulation parameters mentioned below and fill the values in the table.

Simulation Parameters

Numerology	1
NrMacSchedulerTdma	PF
Simulation Time	20 Seconds
UE mobility model	RandomWalk2d Mobility
Speeds	10 m/s, 50 m/s
Seeds	5

Average Aggregate Throughput (Mb/s):

Speed (meter/s)	RR	PF	MR
10			
50			

Avg Loss Rate :

Speed (meter/s)	RR	PF	MR
10			
50			

Avg. Delay (ms):

Speed (meter/s)	RR	PF	MR
10			

50			

Q6: Based on the values measured, provide an analysis of the trends observed and quantify improvement/loss in performance (i.e., throughput, loss rate and delay) for different mobile scenarios. Compare these results with that of the static scenario.

Your main script (e.g., GroupID#asg1.cc) should take scheduler type, speed, RngRun, numerology and fullBufferFlag as inputs. References section contains all necessary reading material to complete the assignments.

Deliverables

The following items are supposed to be included in a tar.gz file and uploaded on GC by one of the group members.

1. Assignment Report having all tables and graphs along with their detailed analysis of trends
2. The ns-3 scripts involved in creating the testing scenarios described above with appropriate names.
    a. main script (e.g., GroupID-Asg1.cc)
    b. other supporting (modified) scripts of NS-3, if any
3. README file should contain how to run your simulations.

NOTE:

- *Each of the above deliverables carries marks so you need to upload all valid docs, code, and scripts.*

References

1. Patriciello, Natale, et al. "An E2E simulator for 5G NR networks." *Simulation Modelling Practice and Theory* 96 (2019): 101933. https://drive.google.com/file/d/1YM7OOEJSP8gBpkyUR-S-6ZdS5G33Uib4/view?usp=sharing

2. Patriciello, Natale, et al. "5G New Radio numerologies and their impact on the end-to-end latency." *2018 IEEE 23rd international workshop on computer*

aided modeling and design of communication links and networks (CAMAD). IEEE, 2018. https://drive.google.com/file/d/1yeRL-sImQlCjoqaD1d-Ob8fJRslasn4w/view?usp=sharing

3. Patriciello, Natale, et al. "An improved MAC layer for the 5G NR ns-3 module." *Proceedings of the 2019 Workshop on Ns-3*. 2019. https://drive.google.com/file/d/1Y1SXK6YYFxtQDGKuVqXGvWAr8ZRIWeZS/view?usp=sharing

4. Ali, Zoraze, et al. "3GPP NR V2X Mode 2: Overview, Models and System-level Evaluation." *IEEE Access* (2021). https://drive.google.com/file/d/1hArO5um6GjGRkcjOJMyW2ELJYKqwUEDO/view?usp=sharing

5. NR module Documentation

https://drive.google.com/file/d/1pzK7CW8_L0DliakFDTrP3oSzZh7wevWw/view?usp=sharing