MobSys Lab 3: **Open RAN Advanced**

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Important Note

While copying text from the PDF, please make sure you respect the spacings. The spaces are not copyable from the PDF, so you should type them manually. For ease of use, a copy of all the code snippets is provided separately in the `code.sh` file.

After one week, a sample file for Wireshark PCAPs would be uploaded to Moodle. Students who cannot finish the lab on time, could use this PCAP to answer the questions at the end of the lab to at least get the grades for the questions.

1 Prerequisites

First, login again to your user account by running the following command:

```
$ gcloud auth login
```

This command will open a browser window and ask you to login to your Google account. If the browser did not open automatically, you can copy the URL from the terminal and paste it in your browser. After logging in, you will be asked to grant access to the Google Cloud SDK.

Now you need to retrieve the credentials for the GKE cluster of your group. To do so, run the following command:

```
$ gcloud container clusters get-credentials ors-cluster{group-id} \
    --region europe-west6 --project comsyslab
```

You should replace the `{group-id}` with your group number.

Now you should be able to use the CLI to interact with the platform. To test it out run the following command:

```
$ cli extract infra
```

In the result you should see a brief description of the infrastructure of the whole cluster, including the different nodes, their properties, and the associated radio components. This time you should see only two nodes.

2 Background

For doing this lab you need to be familiar with the following two concepts:

1. Resource Grid
2. Modulation and Coding Scheme (MCS)

2.1 Resource Grid

Imagine a table where its rows are units in frequency domain and its columns are units in time domain. In this table, each unit in frequency is equivalent to one subcarrier (defined by the subcarrier spacing) and each unit in time is one OFDM symbol. Each cell in this table is called a Resource Element (RE), and this table is called a Resource Grid. The resource grid is normally presented for one subframe in the time domain and the whole bandwidth of the corresponding bandwidth part in the frequency domain. 12 consecutive REs in the frequency domain is called a Resource Block (RB). Hence, the table 1 shows the RB size in kHz for different subcarrier spacings.

Subcarrier Spacing (kHz)	**RB Size (kHz)**
15	180
30	360
60	720
120	1440
240	2880
480	5760
960	11520

Table 1: RB Size for Different Subcarrier Spacings

3GPP defines the minium guard band from the total channel bandwidth to get the transmission bandwidth as given in the table 2. If the value of the guard band for a subcarrier spacing Δ and bandwidth B is presented by the function $g(\Delta, B)$, then the number of REs per each symbol in the time domain is given by the equation 1 and the number of RBs per symbol is given by the equation 2.

$$N_{RE} = \frac{B - 2g(\Delta, B)}{\Delta} \tag{1}$$

$$N_{RB} = \lfloor \frac{n_{RE}}{12} \rfloor \tag{2}$$

From here to calculate the number of RBs per frame, we should multiply the number of RBs per symbol by the number of symbols per frame, calculated by the equation 3.

$$N_{Sym} = 14 \times 10 \times 2^{\mu} \tag{3}$$

Let us have an example:

Bandwidth	SCS 15 kHz	SCS 30 kHz	SCS 60 kHz
5 MHz	242.5	505	N/A
10 MHz	312.5	665	1010
15 MHz	382.5	645	990
20 MHz	452.5	805	1330
25 MHz	522.5	785	1310
30 MHz	592.5	945	1290
40 MHz	552.5	905	1610
50 MHz	692.5	1045	1570
60 MHz	N/A	825	1530
70 MHz	N/A	965	1490
80 MHz	N/A	925	1450
90 MHz	N/A	885	1410
100 MHz	N/A	845	1370

Table 2: Guard band values in kHz for different bandwidths and subcarrier spacings (presented only for FR1)

- Subcarrier spacing: 30 kHz
- Number of OFDM symbols: 14
- Bandwidth: 40 MHz

Given the equation 1, we can calculate the number of REs per symbol as follows:

$$N_{RE} = \frac{40000 - 2 \times 905}{30} = 1273$$

And given the equation 2, we can calculate the number of RBs per symbol as follows:

$$N_{RB} = \lfloor \frac{1273}{12} \rfloor = 106$$

Finally, given the equation 3, we can calculate the number of RBs per frame as follows:

$$N_{RB} = 106 \times 14 \times 10 \times 2^1 = 29680$$

2.2 Modulation and Coding Scheme (MCS)

The MCS is a value between 0 and 31 (5 bits) that is used to determine the modulation and coding scheme for a transport block. The MCS values could come from one of the three tables in the 3GPP standard. [1] The Modulation Order (Q_m) comes from which modulation scheme is used for the transport block as shown in the table 3.

[1] https://www.sharetechnote.com/html/5G/5G_MCS_TBS_CodeRate.html

Modulation	Q_m
QPSK	2
16QAM	4
64QAM	6
256QAM	8

Table 3: Modulation Order

Each of the indices then is translated to a Q_m value and a target coding rate R which are used to calculate the number of bits that can be transmitted in one resource element. Calculating the Transport Block Size (TBS) is very complicated and is not in the scope of this lab, but figure 1 from [2] shows how it is generally calculated.

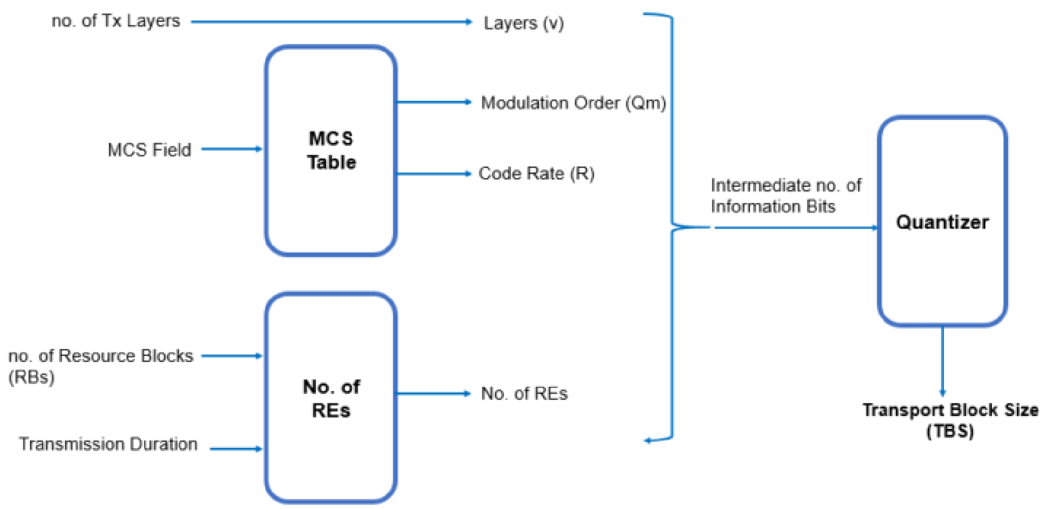

Figure 1: Transport Block Size (TBS) Calculation

3 xApp Lab

This experiment is to deploy a 5G Standalone (SA) network using OpenAirInterface (OAI) [3] RF Simulator gNB and OAI minimal 5GC, using the F1 Split architecture. We also deploy FlexRIC as the Near-RT RIC with a monitoring xApp. You need to edit the file `open-ran.yaml` for this section. Similar to the previous labs, apply the changes to the PLMN.

In this lab, you are going to deal with a CSV file extracted from the xApp. You could use any tool including Excel, LibreOffice Calc, or Python to analyze the CSV file. The Python code or the Excel file should be submitted as part of the lab report.

[2] https://www.techplayon.com/5g-nr-transport-block-size-tbs-calculation/
[3] https://openairinterface.org/

3.1 Deployment and Testing

Since you do not need the T-Tracer for this lab, remove the profile section from the YAML file, and you could also further reduce the delay of the second UEs attachement from 120 to 10 seconds. Furthermore, we only need the MAC SM in the file and you could remove the other SMs.

Deploy the file using the command `cli install network open-ran.yaml`. Check for the status of the deployment using the command `cli observe` and make sure all the Elements are in the `1/1 Y` state.

3.2 CSV Extraction

Use the following command to access to the MySQL shell for the xApps Shared Data Layer (SDL):

```
$ cli cic {element} run --follow -- sql
```

The period between the MAC service model indication messages by default is 10 ms, meaning to get records for two UE for the last 60 seconds, you need the last 12000 records. The following command would extract the last 12000 records from the MAC service model for the two UEs and save them in the `/etc/t9s/athena/wmi/mysql/private/test1.csv` file.

```
$ select tstamp, ngran_node, e2node_nb_id, frame, slot, dl_aggr_tbs, dl_aggr_prb, \
  rnti, dl_mcs1 from MAC_UE ORDER BY tstamp DESC LIMIT 12000 INTO OUTFILE \
  '/etc/t9s/athena/wmi/mysql/private/test1.csv' FIELDS TERMINATED BY ',' LINES \
  TERMINATED BY '\n';
```

Exit the MySQL shell using the `exit` command. Then use the following command to copy the file to your local machine:

```
$ cli cic {element} cat -- /etc/t9s/athena/wmi/mysql/private/test1.csv > test1.csv
```

Note

Everytime you run this command, you have to give it a different file name, otherwise it would fail.

Run a downlink TCP throughput test for the first UE for the duration of 45 seconds and then extract the CSV file. Extract the output of Iperf command for the throughput test as well and save it along with the CSV file.

Questions

1. Explain the meaning of each column in the CSV file based on the SQL query.
2. How many slots and frames are there in the CSV file?
3. Which UE (based on the RNTI) is the target of the throughput test?

3.3 Data Analysis Questions

In the dataset, TBS and PRB are defined as the aggregated values over the whole duration of the test. Hence, to calculate TBS and PRB per frame, you should subtract the value of the previous frame from the value of the current frame. For the PRBs, you have to pay attention to the TDD pattern to understand which symbols are downlink and which are uplink. The PRB utilization is the ratio of the number of PRBs used for the transmission to the total number of PRBs in that frame.

1. Plot the value of MCS for the target UE for the duration of the throughput test and explain the changes.

2. Plot TBS and PRB per frame for the target UE for the duration of the throughput test and explain the changes.

3. Calculate the average MAC throughput per second and compare it with the Iperf throughput report.

4. Calculate and plot the average PRB utilization per second for the target UE.

4 MCS Measurement

This experiment is to deploy a 5G Standalone (SA) network using OpenAirInterface (OAI) [4] RF Simulator gNB and OAI minimal 5GC, using the F1 Split architecture. You need to edit the file `mcs.yaml` for this section. Similar to the previous labs, apply the changes to the PLMN.

4.1 Testing

In the YAML file the maximum DL MCS is defined as an annotation. You need to run the following test for MCS values of 9, 16, and 28.

Deploy the file using the command `cli install network mcs.yaml`. Check for the status of the deployment using the command `cli observe` and make sure all the Elements are in the `1/1 Y` state.

Then measure the DL TCP throughput for each MCS for duration of 60 seconds each.

Questions

1. Explain how the MCS value affects the TCP throughput.

2. Plot the TCP throughput for each MCS value using a bar chart.

[4] https://openairinterface.org/