

Handover Observations in NSA Network and My Current Work

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Outline

- NSA Handover Observations
- Current Work
- Future Directions

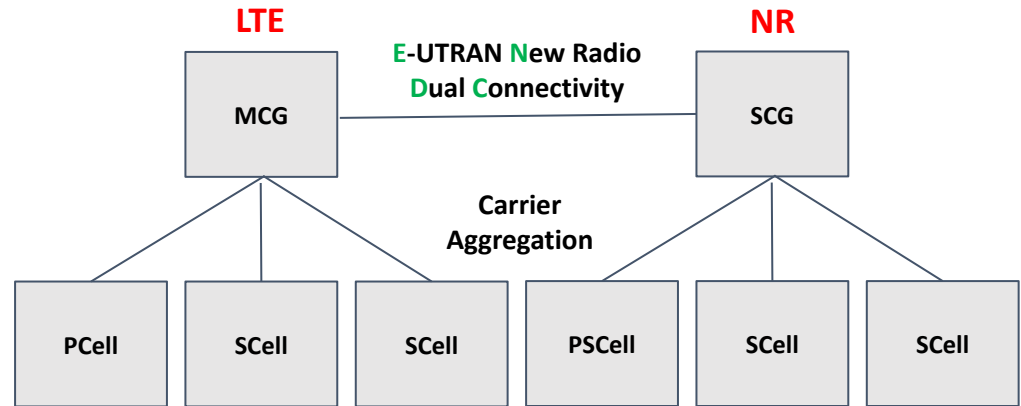
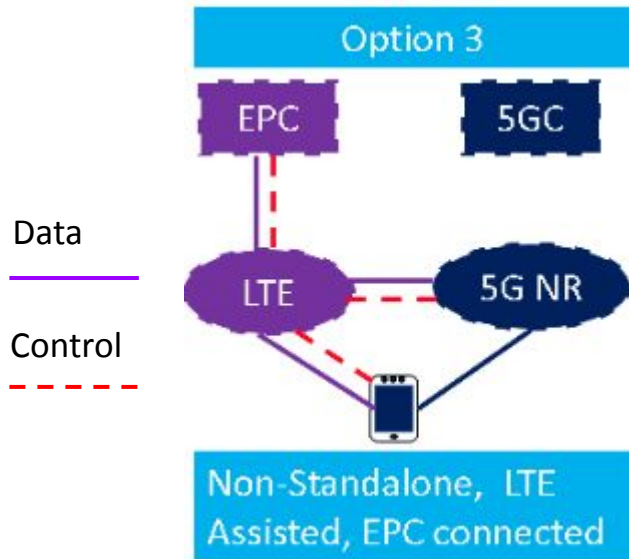


NSA Handover Observations



NSA Architecture

- Current 5G NR network construction is based on **NSA** architecture.
- **Dual connectivity** and **carrier aggregation** to enhance data rate.



Handover

- UE need to change its serving base station when moving. That is, **handover**.
- Handover procedure:

11	UE <--- SS	<u>RRC Connection Reconfiguration</u>	Cell 1	Measurement Control for Target Cell
12	UE ---> SS	RRCConnectionReconfigurationComplete	Cell 1	
13	UE ---> SS	Measurement Report	Cell 1	
14	UE <--- SS	<u>RRC Connection Reconfiguration</u>	Cell 1	Handover Command
15	UE ---> SS	PRACH	Cell 2	
16	UE <--- SS	RACH Response	Cell 2	
17	UE ---> SS	RRCConnectionReconfigurationComplete	Cell 2	PASS/FAIL

Event for Measurement Report

- Measurement Report is triggered by event, which is some condition of its signal strength.

Inequality A3-1 (Entering condition)

$$Mn + Ofn + Ocn - Hys > Mp + Ofp + Ocp + Off$$

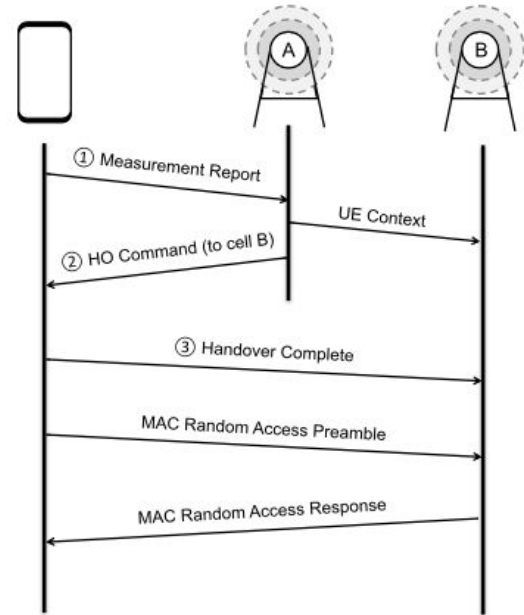
Inequality A3-2 (Leaving condition)

$$Mn + Ofn + Ocn + Hys < Mp + Ofp + Ocp + Off$$

Event Type	Description
Event A1	Serving becomes better than threshold
Event A2	Serving becomes worse than threshold
Event A3	Neighbour becomes offset better than serving
Event A4	Neighbour becomes better than threshold
Event A5	Serving becomes worse than threshold1 and neighbour becomes better than threshold2
Event A6	Neighbour become offset better than S Cell (This event is introduced in Release 10 for CA)
Event B1	Inter RAT neighbour becomes better than threshold
Event B1-NR	NR neighbour becomes better than threshold
Event B2	Serving becomes worse than threshold1 and inter RAT neighbour becomes better than threshold2
Event B2-NR	Serving becomes worse than threshold1 and NR neighbour becomes better than threshold2

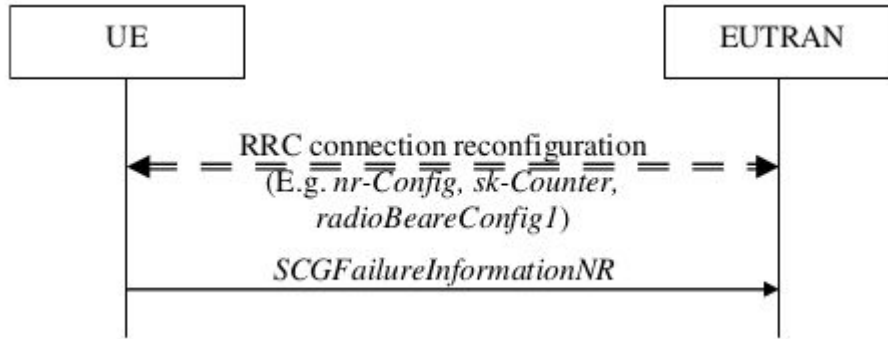
LTE and NR Handover

- LTE handover message: **mobilityControlInfo**, **lte-rrc.t304** in **rrcConnectionReconfiguration**.
- NR handover message: **reconfigurationWithSync**, **nr-rrc.t304** in **RRCReconfiguration**.

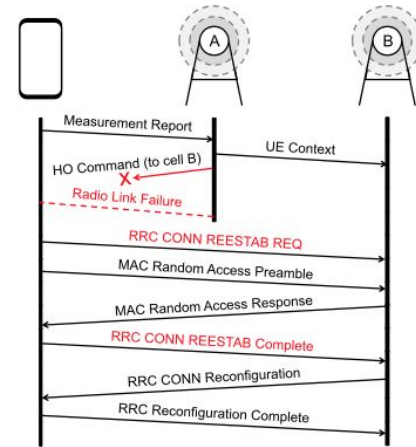


Failure HO

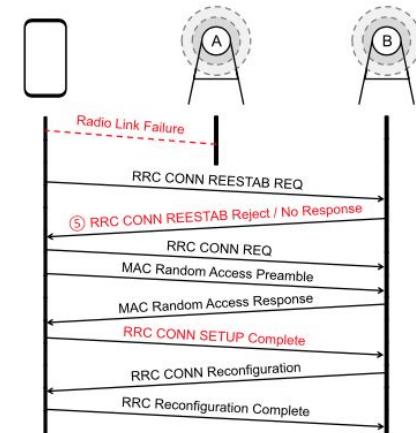
- LTE **rrcConnectionReestablishment**
 - success reestablishment -> Type II
 - rejected and reconnect -> Type III
- NR **SCGFailureInformationNR**



Type II



Type III



Replay Handover Occurrence

- Replay handover occurrence of experiment from the log with RRC message collected by mobileinsight. This way, I know what **event** triggered HO.

```
1 Initial PCI: 152 1750
2 =====
3 2023-02-04 16:50:25.495602
4 Setup -> 152 1750
5 RRC_connected: True
6 =====
7 2023-02-04 16:50:25.546710
8 MeasObjectToAddMod
9 {'1': (measObjectEUTRA (0), 1750), '2': (measObjectNR-r15 (5), 631000.0), '3': (measObjectEUTRA (0), 525), '4': (measObjectEUTRA (0), 3650)}
10 ReportConfigToAddMod
11 {'1': eventA3 (2) {'off': 2, 'hys': 1, 'tnt': 160}, '2': eventA2 (1) {'thr': -114, 'hys': 2, 'tnt': 1280}, '3': eventB1-NR-r15 (5) {'thr': '[-111&-110]', 'hys': 0, 'tnt': 100}, '4':
    {'thr': -140, 'hys': 1, 'tnt': 5120}, '5': eventA1 (0) {'thr': -140, 'hys': 1, 'tnt': 40}}
12 MeasIdToAddMod
13 {'1': ('1', '1'), '2': ('1', '2'), '3': ('2', '3'), '4': ('3', '4'), '5': ('3', '5'), '6': ('4', '4'), '7': ('4', '5')}
14 Add Scell: ('1', '152', '525')
15 Add Scell: ('2', '152', '3650')
16 =====
17 2023-02-04 16:50:25.664409
18 LTE-measurementReport
19 3 ('2', '3') (measObjectNR-r15 (5), 631000.0) eventB1-NR-r15 (5) 0
20 parameters: {'thr': '[-111&-110]', 'hys': 0, 'tnt': 100}
21 =====
22 2023-02-04 16:50:25.704163
23 LTE-measurementReport
24 5 ('3', '5') (measObjectEUTRA (0), 525) eventA1 (0) 0
25 parameters: {'thr': -140, 'hys': 1, 'tnt': 40}
26 =====
27 2023-02-04 16:50:25.704260
28 LTE-measurementReport
29 7 ('4', '5') (measObjectEUTRA (0), 3650) eventA1 (0) 0
30 parameters: {'thr': -140, 'hys': 1, 'tnt': 40}
31 =====
```

HO Classification

- LTE only mode: eNB; NSA mode: MN(eNB) + SN(gNB)

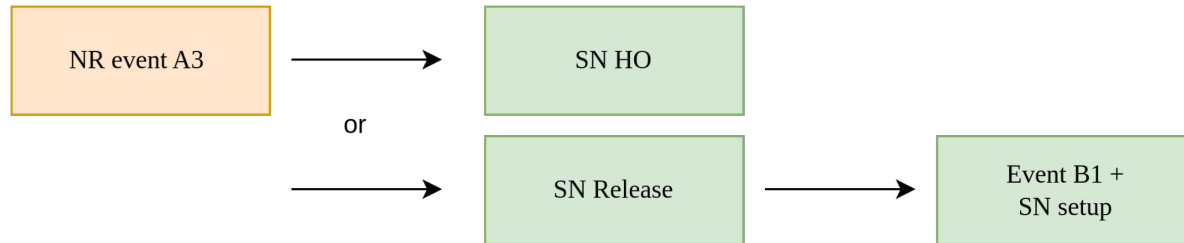
HO Type	Description
eNB HO	(eNB1) -> (eNB2)
MN HO with SN unchanged	(eNB1, gNB1) -> (eNB2, gNB1)
MN HO to eNB	(eNB1, gNB1) -> (eNB2)
SN setup	(eNB1) -> (eNB1, gNB1)
SN release	(eNB1, gNB1) -> (eNB1)
SN HO	(eNB1, gNB1) -> (eNB1, gNB2)

LTE and MN HO

- The type **eNB HO** and **MN HO with SN unchanged** are triggered by **EUTRAN event A3**.
- UE is under NSA mode most of the time, so almost all of the event A3 triggered event type is **MN HO with SN unchanged**.
- eNB HO is rare. Below is some of the conditions make it happens:
 - Inter frequency eNB HO triggered by event A5 after type III failure.
 - Event A3 happened during the time before SN setup.
- The UE carrier aggregation will maintain two SCells for CHT telecom.
 - e.g. 1 gNB PSCell + 1 lte eNB SCell or 2 lte eNB SCell

SN Setup, SN Release, and SN HO

- The type **SN Setup** is triggered by EUTRAN **event B1 NR**; the types of **SN release** and **SN HO** are triggered by **NR event A3**.
- NR event A3 will result in two end.



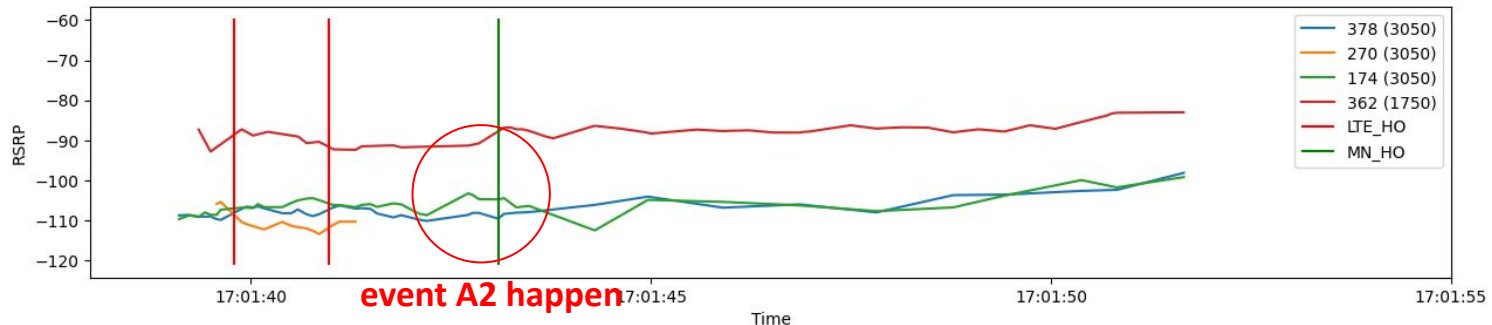
- The RRC control message of SN setup and SN release included **mobilityControlInfo, lte-rrc.t30** for CHT telecom implementation. -> SN setup and SN release may have the same effect as that of eNB/MN handover.

MN HO to eNB

- This type of HO is rare. It will be triggered when sometimes both **EUTRAN event A3** and **NR event A3** happen, or just after **EUTRAN event A3**.

Inter Frequency HO

- Serving Cell RSRP too low -> **event A2** -> event A3 for other frequency -> Inter frequency HO happen. Further, it's usually type **MN HO with SN unchanged**.



LTE Reestablishment and NR scgfailure

- **Event A5** is often happen after a **reestabilshment event**, and an **inter-frequency HO** happens.
- **NR scgfailure** will result in a **SN release** or sometimes a LTE **reestabilshment**.
- Cause of LTE reestablishment:
 - HandoverFailure and ReconfigFailure: happen when the UE can't complete rrcConnectionReconfiguration message with target cell.
 - OtherFailure: most common, the typically RLF.
- Cause of SCG Failure:
 - synchReconfigFailure-SCG: It is triggered when UE fails to complete NR RACH until T304 expires.

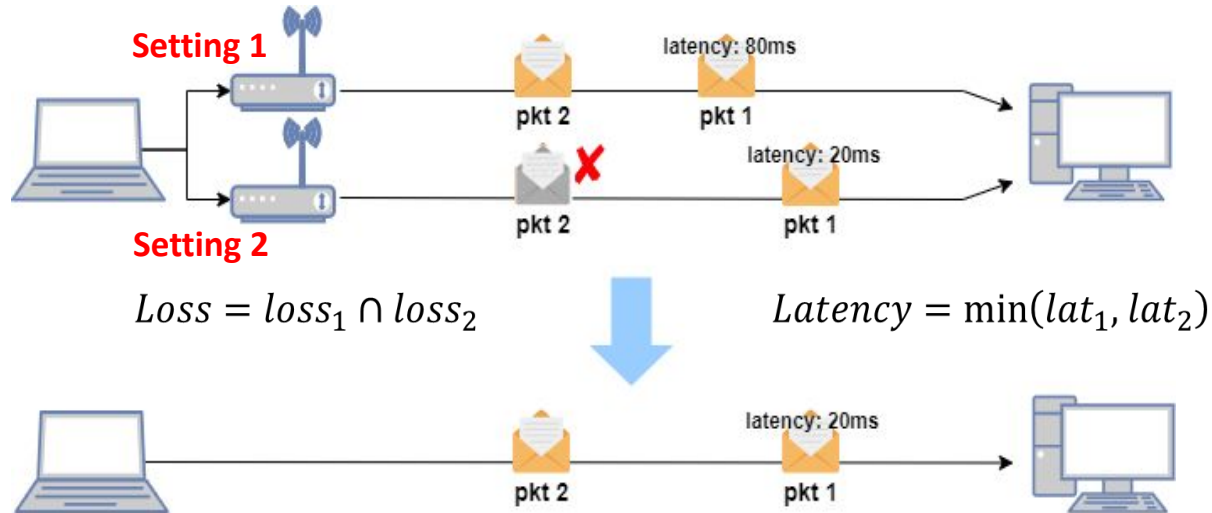


Current Work



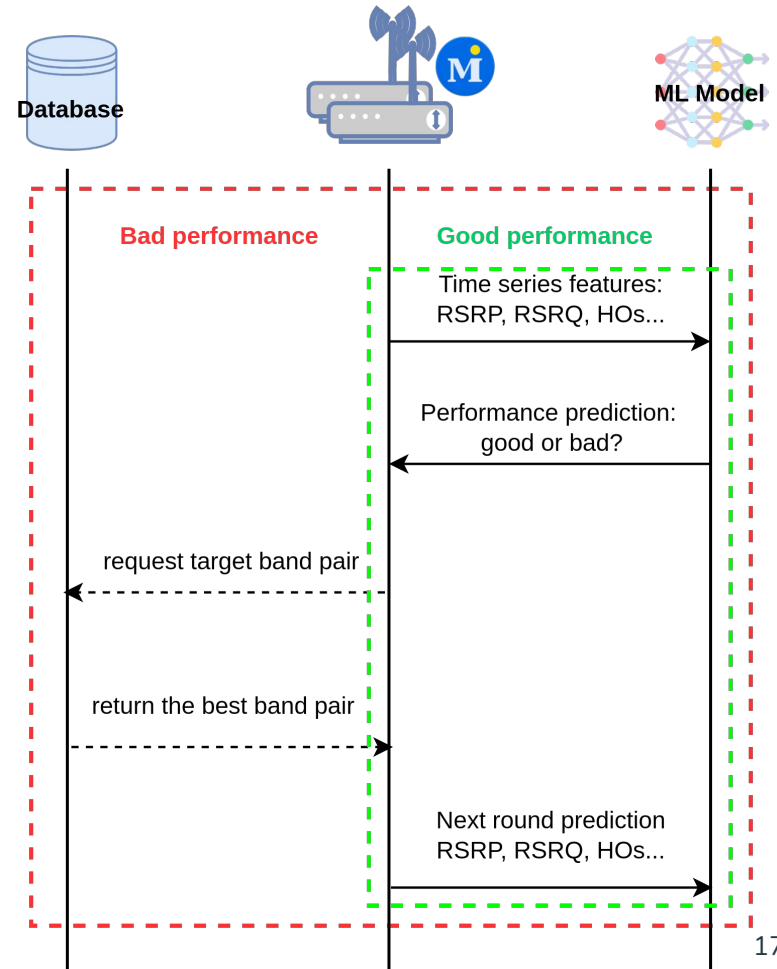
Multipath Transmission with Different Band Setting

- Multipath Transmission with redundant packet can enhance transmission reliability.
- Given interfaces different band settings to separate poor performance time.



Trying ML

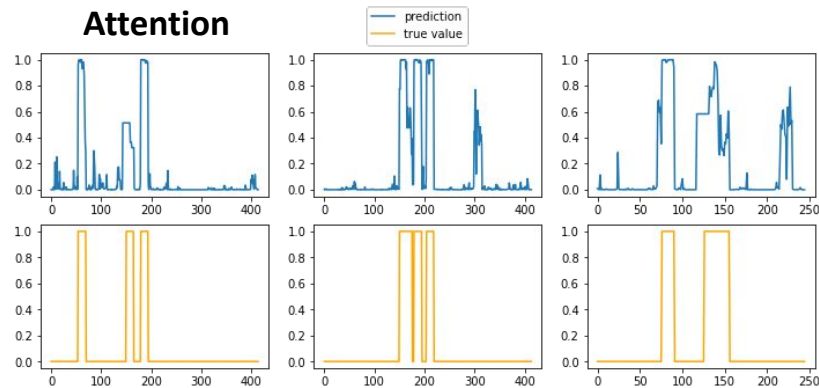
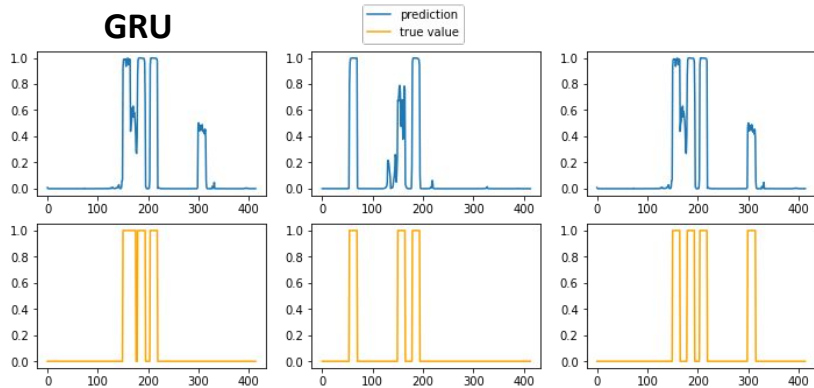
- Using machine learning to predict bad performance.
- If bad performance predicted, change band setting according to history database.



Training

Model	LSTM	GRU	attention
Loss	0.058	0.0672	0.0118

- 1: Loss or excessive latency happen in the next 15 seconds; 0: otherwise
- Small amount of data and no testing dataset yet. Just result on training dataset.
- Trying with time series model:

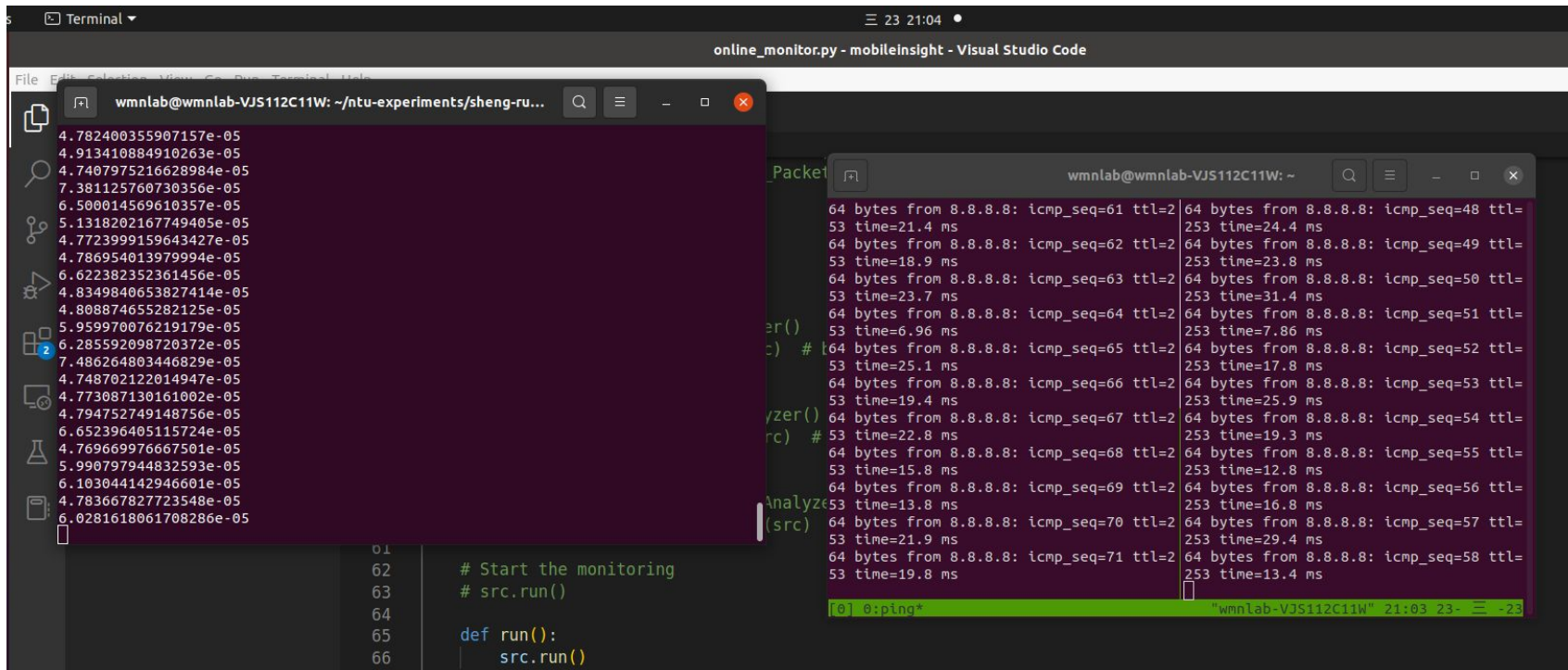


Implement

- online_features.py: Main program; it can use mobileinsight to online catch features (RSRP, RSRQ, Ho happened...) and have function to change band settings of devices.
- Store trained model to directory **model**
- database.csv: store historical performance of different band settings according to experiment time

```
wmnlab@wmnlab-GB-BRR7H-4700:~/ntu-experiments/sheng-ru/experiment/mobileinsight$  
ls  
database.csv      model             online_features.py  
device_to_serial.json  my_analyzer.py  online_monitor.py
```

Implement (continued)



The screenshot shows a Visual Studio Code editor window titled "online_monitor.py - mobileinsight - Visual Studio Code". The editor displays a Python script with the following code:

```
61  
62 # Start the monitoring  
63 # src.run()  
64  
65 def run():  
66     src.run()
```

Below the editor, a terminal window is open, showing the output of the script. The output consists of a list of floating-point numbers, each representing a measurement. The terminal window is titled "wmnlab@wmnlab-VJS112C11W: ~/ntu-experiments/sheng-ru...".

```
4.782400355907157e-05  
4.913410884910263e-05  
4.7407975216628984e-05  
7.381125760730356e-05  
6.500014569610357e-05  
5.1318202167749405e-05  
4.7723999159643427e-05  
4.786954013979994e-05  
6.622382352361456e-05  
4.8349840653827414e-05  
4.808874655282125e-05  
5.959970076219179e-05  
6.285592098720372e-05  
7.486264803446829e-05  
4.748702122014947e-05  
4.773087130161002e-05  
4.794752749148756e-05  
6.652396405115724e-05  
4.769669976667501e-05  
5.990797944832593e-05  
6.103044142946601e-05  
4.783667827723548e-05  
6.0281618061708286e-05
```

Below the list of numbers, the terminal shows the output of the script, which is a list of ping results. The output is as follows:

```
64 bytes from 8.8.8.8: icmp_seq=61 ttl=2 253 time=21.4 ms  
64 bytes from 8.8.8.8: icmp_seq=62 ttl=2 253 time=18.9 ms  
64 bytes from 8.8.8.8: icmp_seq=63 ttl=2 253 time=23.7 ms  
64 bytes from 8.8.8.8: icmp_seq=64 ttl=2 253 time=6.96 ms  
64 bytes from 8.8.8.8: icmp_seq=65 ttl=2 253 time=25.1 ms  
64 bytes from 8.8.8.8: icmp_seq=66 ttl=2 253 time=19.4 ms  
64 bytes from 8.8.8.8: icmp_seq=67 ttl=2 253 time=22.8 ms  
64 bytes from 8.8.8.8: icmp_seq=68 ttl=2 253 time=15.8 ms  
64 bytes from 8.8.8.8: icmp_seq=69 ttl=2 253 time=13.8 ms  
64 bytes from 8.8.8.8: icmp_seq=70 ttl=2 253 time=21.9 ms  
64 bytes from 8.8.8.8: icmp_seq=71 ttl=2 253 time=19.8 ms
```

The terminal window also shows a status bar at the bottom with the text "[0] 0:ping* wmnlab-VJS112C11W 21:03 23- -23".



Future Directions



Future Directions

- Training with more data, build testing dataset and try other model for better prediction.
- Run the code during experiment and see what will happen.
- Observe experiment data to get more idea.

Thanks!