Handover Observations in NSA Network and My Current Work

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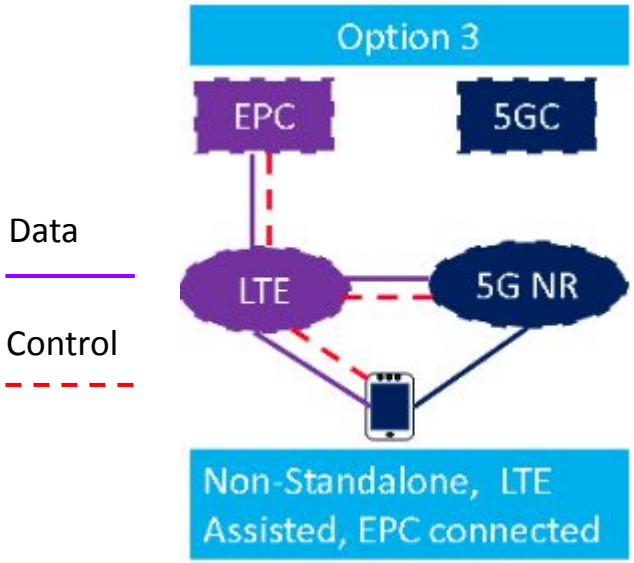
Outline

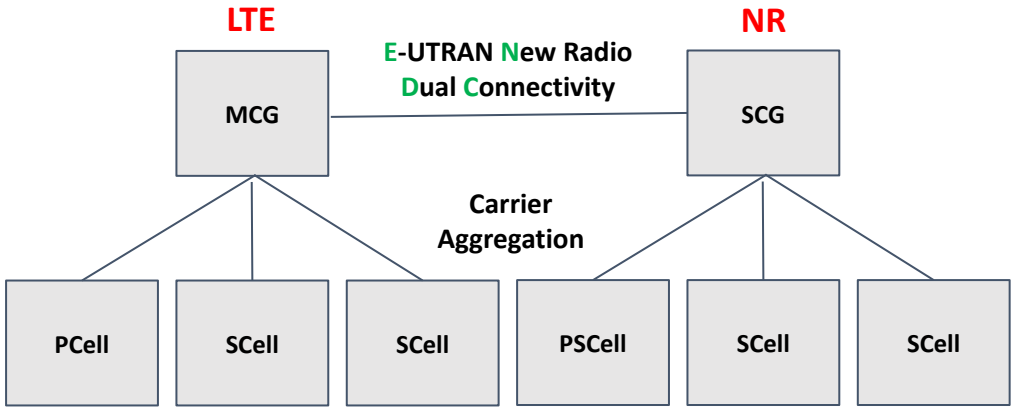
- NSA Handover Observations
- Current Work
- Future Directions

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	RRC Connection Reconfiguration	Cell 1	Measurement Control for Target Cell
12	UE ---> SS	RRCConnectionReconfigurationComplete	Cell 1	
13	UE ---> SS	Measurement Report	Cell 1	
14	UE <--- SS	RRC Connection Reconfiguration	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)

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

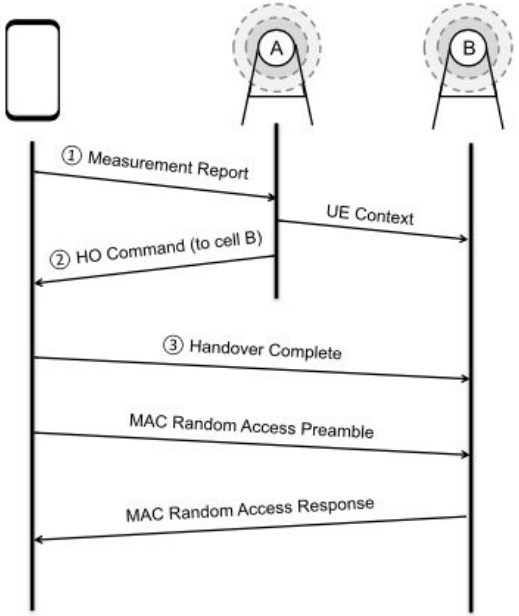
Inequality A3-2 (Leaving condition)

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

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

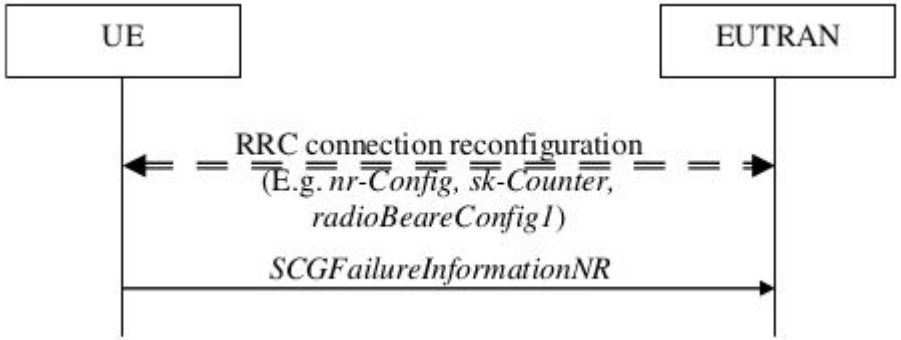
LTE and NR Handover

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

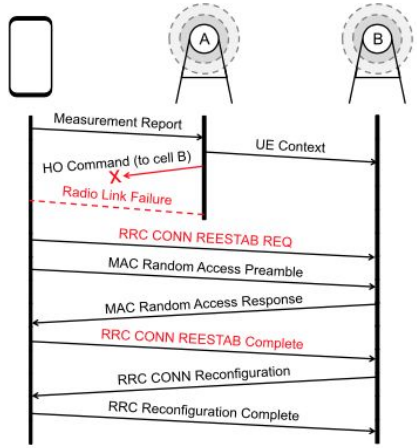


Failure HO

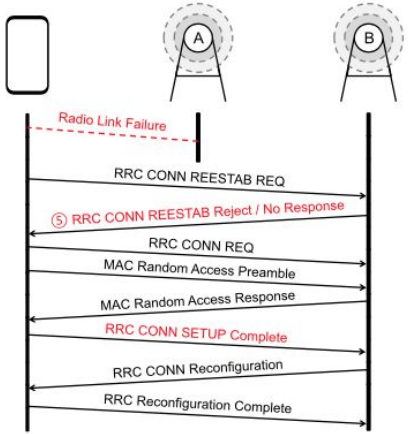
- LTE rrcConnectionReestablishment
  - success reestablishment -> Type II
  - rejected and reconnect -> Type III
- NR SCGFailureInformationNR



Type II



Type III



Replay Handover Occurence

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

```
Initial PCI: 152 1750
================================================
2023-02-04 16:50:25.495602
Setup -> 152 1750
RRC_connected: True
================================================
2023-02-04 16:50:25.546710
MeasObjectToAddMod
{'1': (measObjectEUTRA (0), 1750), '2': (measObjectNR-r15 (5), 631000.0), '3': (measObjectEUTRA (0), 525), '4': (measObjectEUTRA (0), 3650)}
ReportConfigToAddMod
{'1': eventA3 (2) {'off': 2, 'hys': 1, 'ttt': 160}, '2': eventA2 (1) {'thr': -114, 'hys': 2, 'ttt': 1280}, '3': eventB1-NR-r15 (5) {'thr': '[-111&-110)', 'hys': 0, 'ttt': 100}, '4'
 {'thr': -140, 'hys': 1, 'ttt': 5120}, '5': eventA1 (0) {'thr': -140, 'hys': 1, 'ttt': 40}}
MeasIdToAddMod
{'1': ('1', '1'), '2': ('1', '2'), '3': ('2', '3'), '4': ('3', '4'), '5': ('3', '5'), '6': ('4', '4'), '7': ('4', '5')}
Add Scell: ('1', '152', '525')
Add Scell: ('2', '152', '3650')
================================================
2023-02-04 16:50:25.664409
LTE-measurementReport
3 ('2', '3') (measObjectNR-r15 (5), 631000.0) eventB1-NR-r15 (5) 0
parameters: {'thr': '[-111&-110)', 'hys': 0, 'ttt': 100}
================================================
2023-02-04 16:50:25.704163
LTE-measurementReport
5 ('3', '5') (measObjectEUTRA (0), 525) eventA1 (0) 0
parameters: {'thr': -140, 'hys': 1, 'ttt': 40}
================================================
2023-02-04 16:50:25.704260
LTE-measurementReport
7 ('4', '5') (measObjectEUTRA (0), 3650) eventA1 (0) 0
parameters: {'thr': -140, 'hys': 1, 'ttt': 40}
------------------------------------------------
```

HO Classification

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

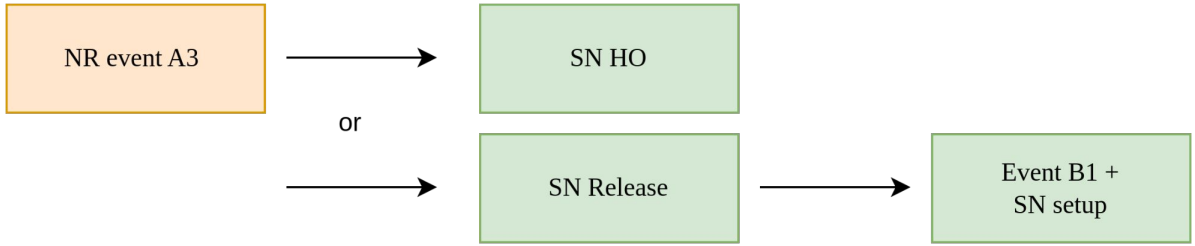
HO Type	Discription
eNB HO	(eNB1) -> (eNB2)
MN HO with SN unchanged	(eNB1, gNB1) -> (eNB2, gNB1)
MN HO to eNB	(eNB1, gNB1) -> (eNB2)
SN setup	(eNB1) -> (eNB1, gNB1)
SN release	(eNB1, gNB1) -> (eNB1)
SN HO	(eNB1, gNB1) -> (eNB1, gNB2)

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.



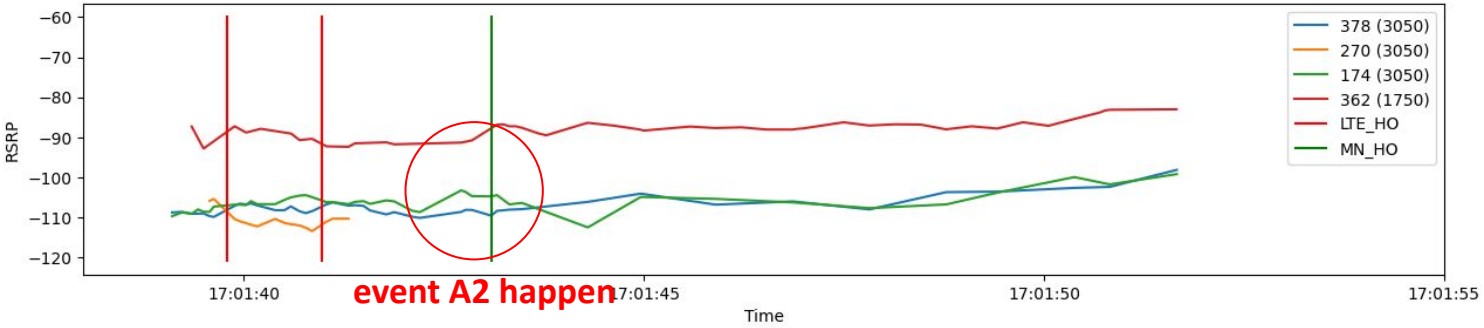
- The RRC control message of SN setup and SN release included mobilityControlInfo, lte-rrc.t30 for CHT telecom implementation. -> SN setup and SN release may have the same effect as that of eNB/MN handover.

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.



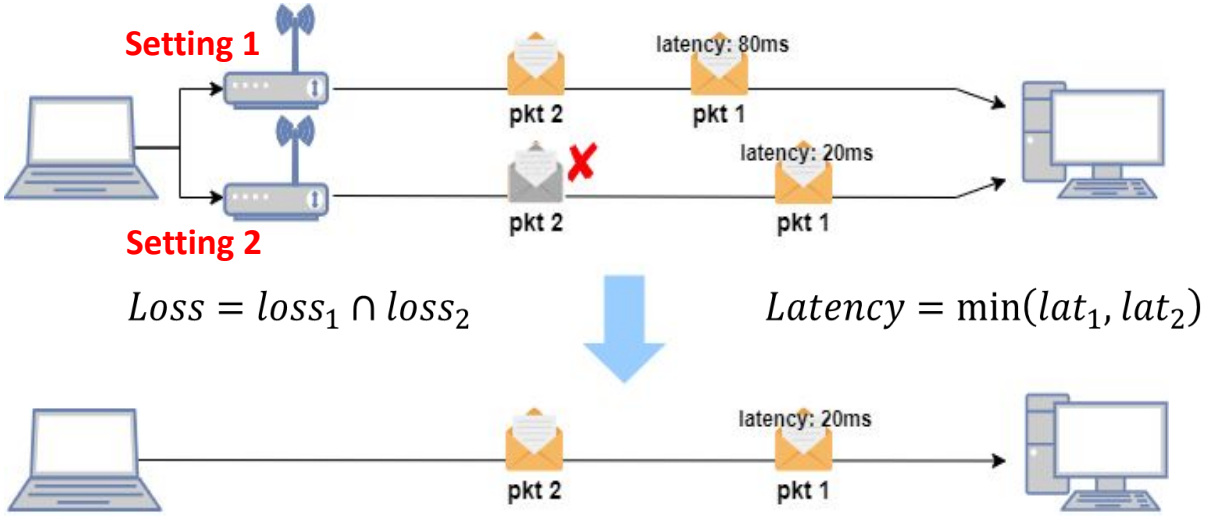
LTE Reestablishment and NR scgfailure

- 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

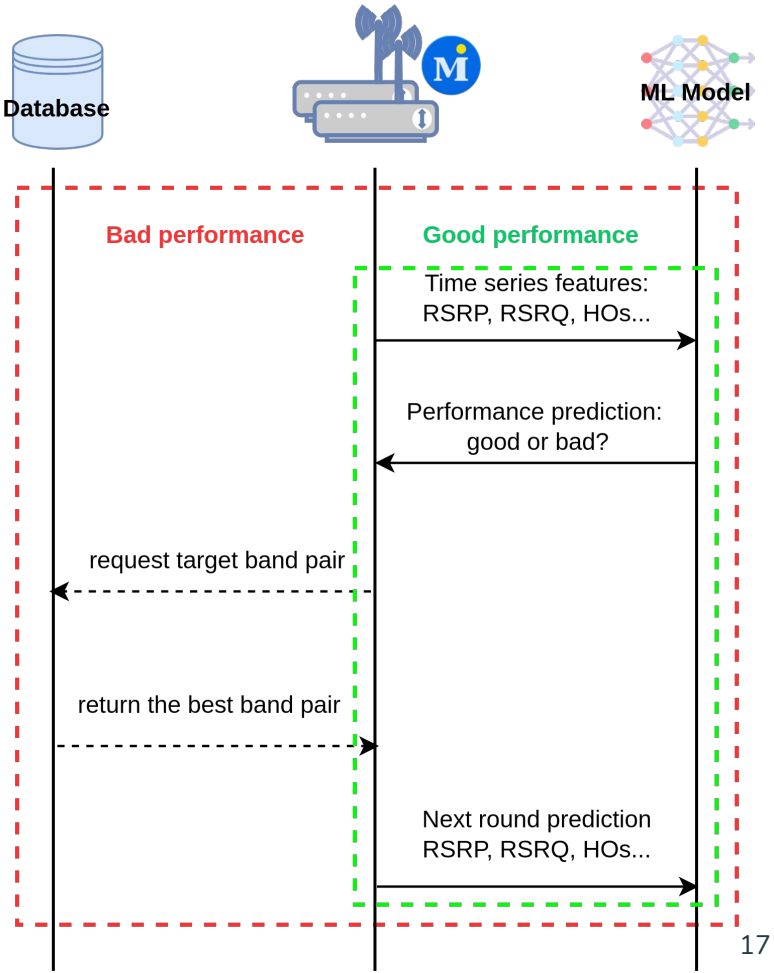
Multipath Transmission with Different Band Setting

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



Trying ML

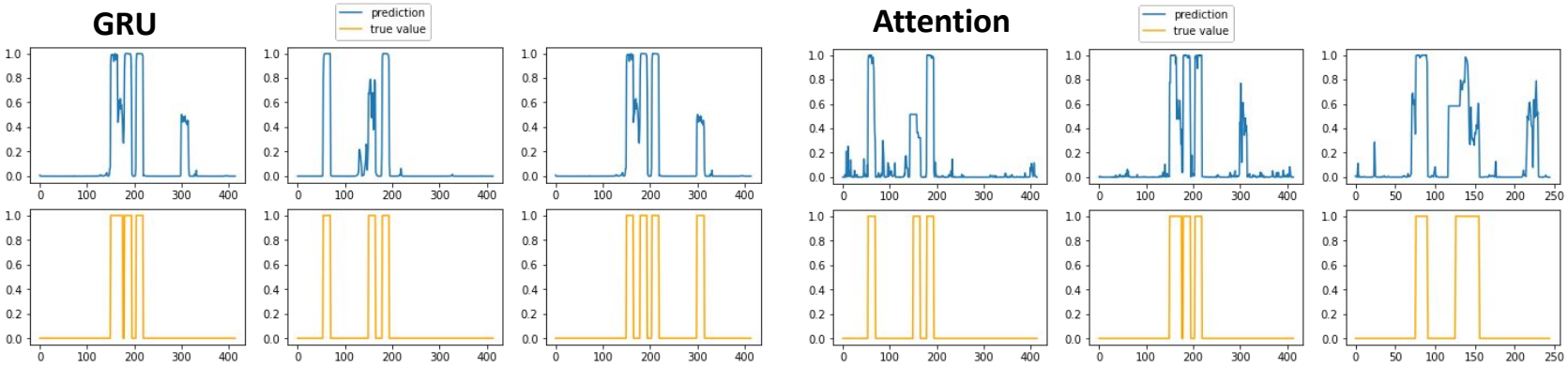
- Using machine learning to predict bad performance.
- If bad performance predicted, change band setting according to history database.



Training

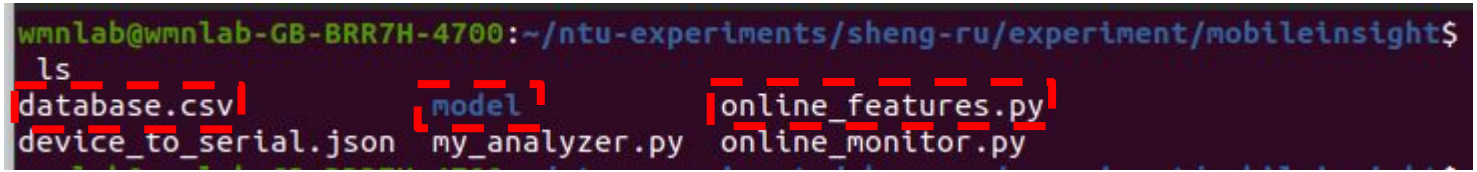
Model	LSTM	GRU	attention
Loss	0.058	0.0672	0.0118

- 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:

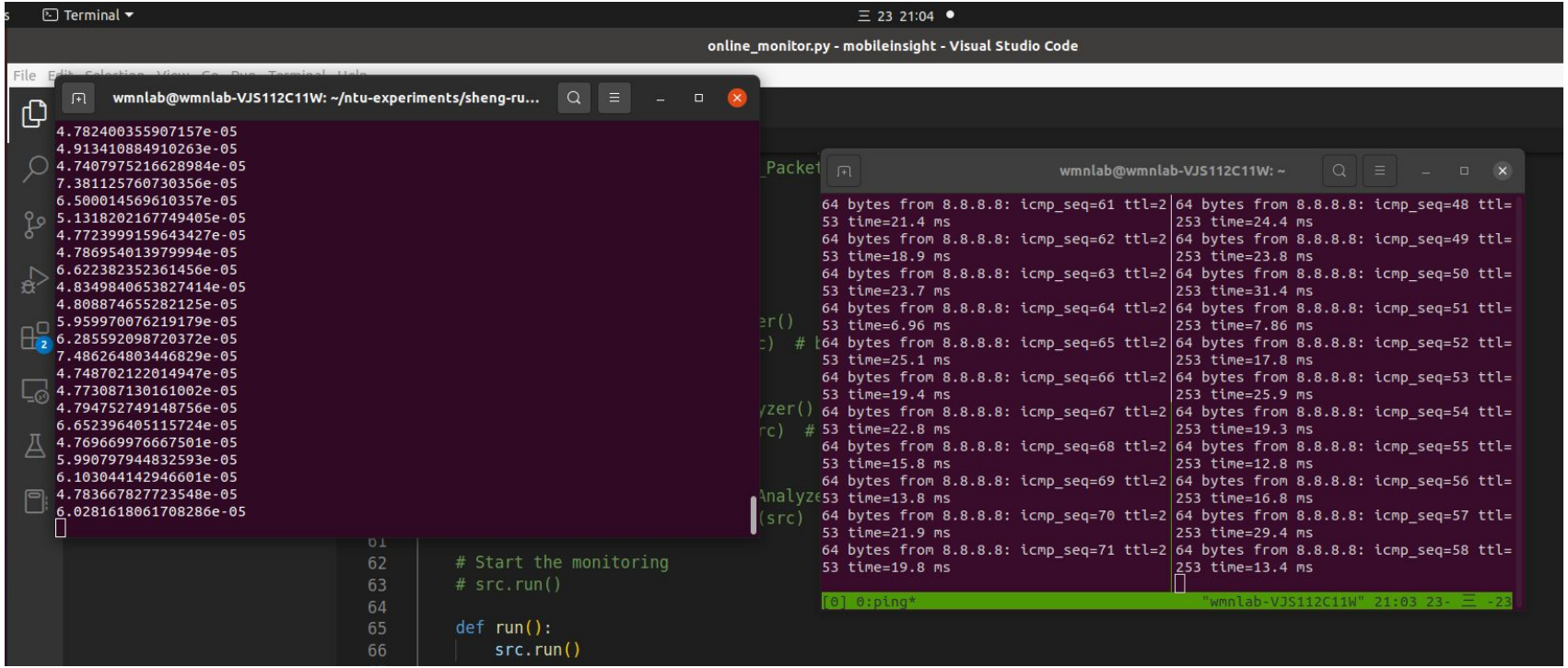


Implement

- 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



Implement (continued)



Future Directions

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- 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!