vivo

3GPP TSG RAN Meeting #98-e RP-223116

Electronic Meeting, December 12-16, 2022

Study on RRM measurement prediction for mobility optimization

Source: vivo

Document for: information

Agenda Item: 9.12

Motivation

In Rel-17, the AI/ML based mobility optimization was studied in the *FS_NR_ENDC_data_collect* SI and the subsequent WI in Rel-18 is ongoing.

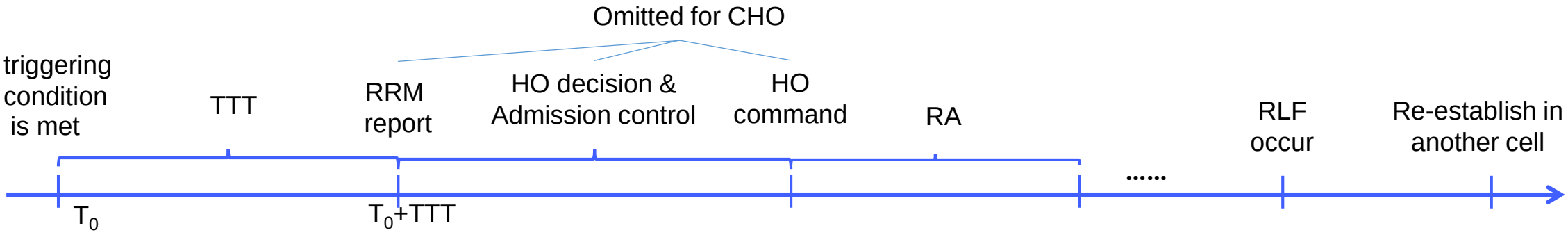
- The Model Inference function resides within the RAN node only.
- Some location-related information of UE (e.g., coordinates) was required as the input of AI/ML model.

Model inference	Pros	Cons
RAN node	- UE does not need to be AI capable. - No model transfer between UE and NW.	- Exposing UE location as input may introduce privacy concerns. - Limited UE info as input due to signaling overhead.
UE	- More detailed local info as input to improve accuracy without privacy concerns. - Less signaling overhead to exchange input, and local model inference can reduce latency and therefore interruptions	- If the model generalization is weak, the model management is complex, which includes frequent model update/switch when serving cell changes. (Can be addressed with good generalization) - The UE needs to be AI capable and additional storage to store the model. (Can be addressed as RAN1 will introduce UE AI capability)

❑ **Observation 1: For mobility optimization, if the Model Inference function can be deployed on the UE side:**

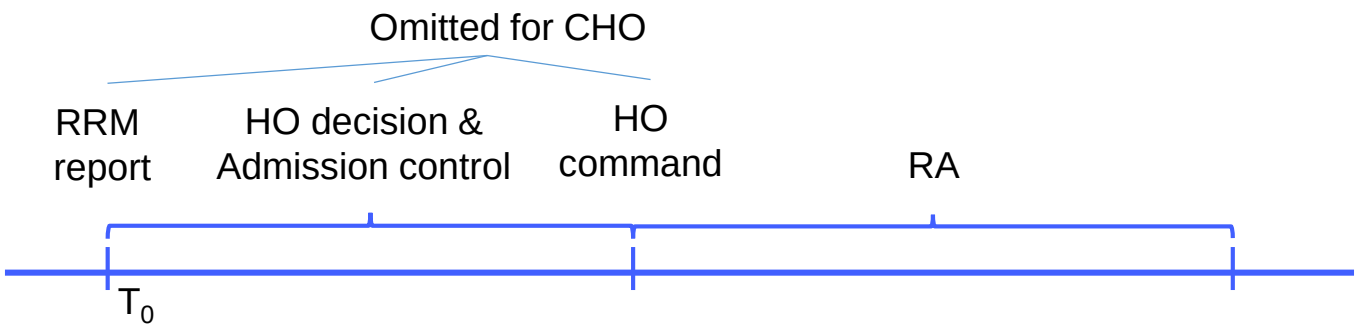
- **More detailed local information from UE can be utilized as the input to improve prediction accuracy without privacy concerns.**
- **Local model inference can reduce inference latency and therefore interruption.**

Potential Issues



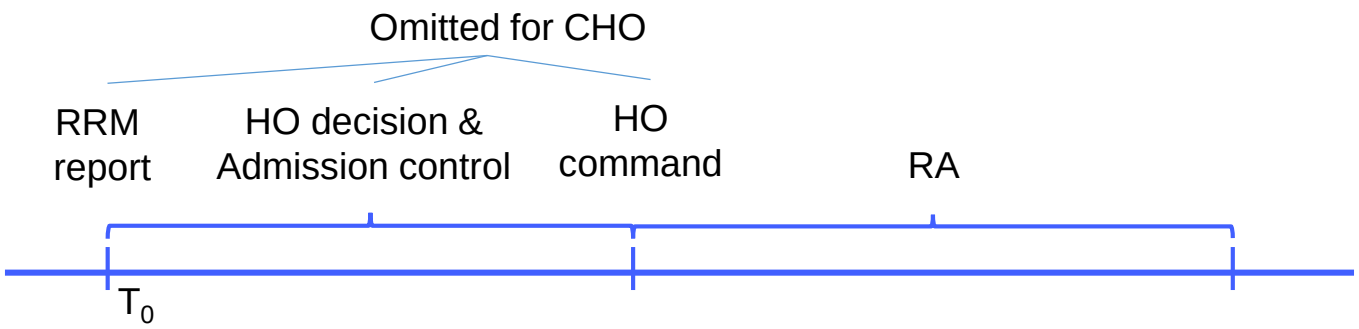
- For the legacy HO, the triggering condition for RRM reporting shall be met at T_0 and shall last for TTT (Time To Trigger) duration, which may lead to:
  - HO at a non-optimal time, poor user experience at source cell.
  - Failed to receive the HO command or failed to RA to the target cell, i.e., too-late HO.
- For CHO, the UE can RA to the target cell without receiving the HO command if the triggering condition is met during TTT. However, there is still a risk of RLF due to low SINR at the source cell during TTT and the UE cannot perform HO at a optimal time.
- The legacy solution to the above issue by reducing TTT duration may result in other unintended events, e.g., too-early HO, ping-pong HO, especially for the high-speed UEs.
- If an RLF occurs shortly after a successful HO, the UE may attempt to re-establish the radio link connection in a cell other than the source cell and the target cell, which is identified as HO to wrong cell.

Solution1: RSRP prediction based HO



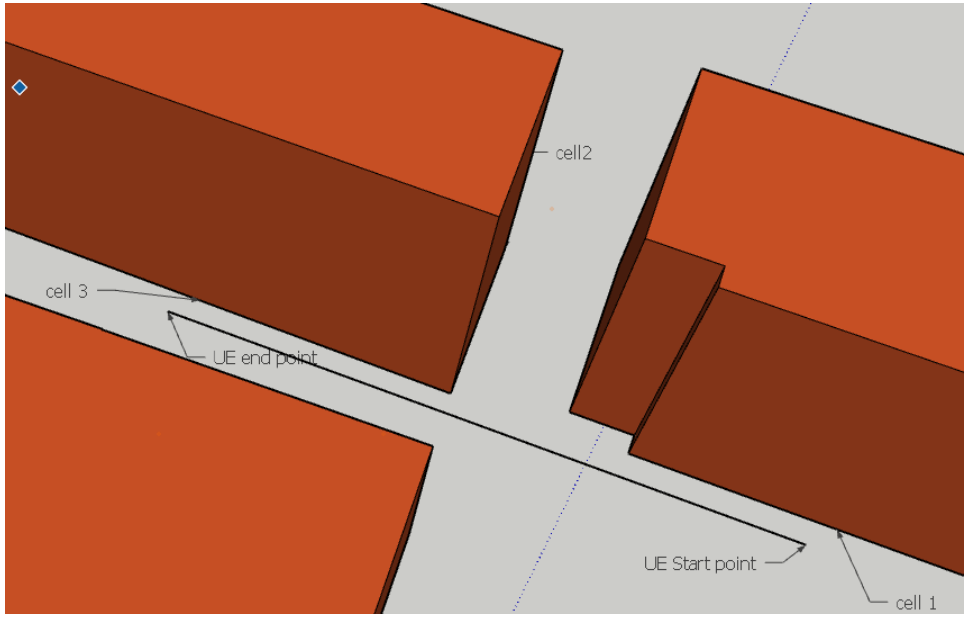
- The RSRP prediction is performed at the UE side.
- For the legacy HO, with RSRP prediction, the UE can send the RRM report once the triggering condition is met at T_0 (i.e., no need to wait for TTT duration).
  - RSRP prediction within the T_0 +TTT period shall meet the triggering condition,
  - The UE may send the RSRP prediction of neighbor cells during RA in the RRM report for HO decision,
  - Higher success rate for receiving HO command when the RRM report was sent at an optimal time.
- For CHO, with RSRP prediction, the UE can RA to the target cell once the triggering condition is met at T_0.
  - RSRP prediction within the T_0 + TTT period shall meet the triggering condition,
  - Lower risk of RLF at the source cell when the HO is performed at a optimal time.
- During the HO decision and target cell selection, the RSRP prediction can be used to reduce the unintended events, e.g., ping-pong HO, too early HO, HO to wrong cell.

Solution2: SINR prediction based HO

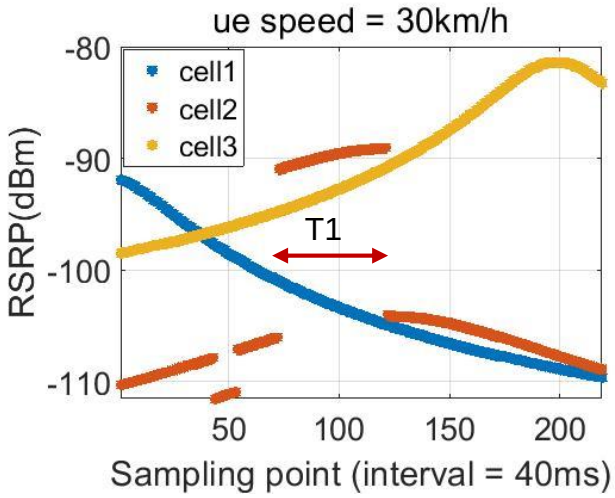


- The SINR prediction is performed at the UE side.
- For the legacy HO, with SINR prediction, the UE can send the RRM report once the triggering condition is met at T_0 (i.e., no need to wait for TTT duration).
  - SINR prediction of the serving cell within the T_0 +TTT period is below the threshold,
  - Higher success rate for receiving HO command when the UE still in the coverage of serving cell.
- Note that solution1 and solution2 can be combined to optimize the mobility performance.

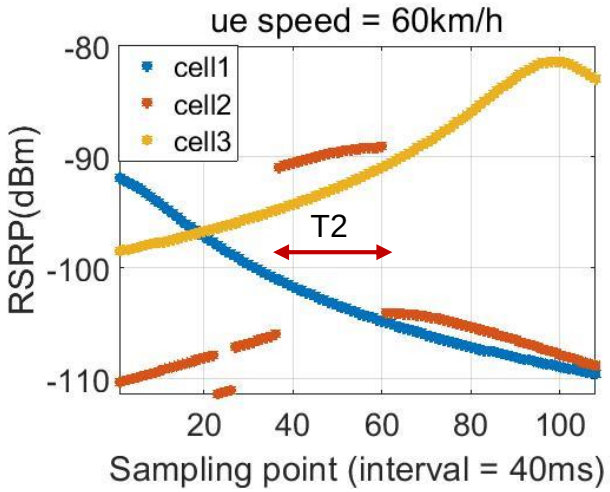
Scenario1: HO to wrong cell at crossover



Simulation scenario and UE trajectory



UE1 speed: 30km/h
T1 duration: 1960ms



UE2 speed: 60km/h
T2 duration: 960ms

- When the UE passes through the crossover, the RSRP of cell2 will change dramatically.
  - The UE1 at a low speed should handover to Cell2 upon RSRP rises to achieve better quality of service during T1 duration.
  - The UE2 at a high speed should handover to Cell3 rather than Cell2 to avoid HO to wrong cell or ping-pong HO.
- RSRP prediction is the key to achieve the above expected different UE behaviors.

Initial evaluation – scenario1

Accuracy of RRM measurement prediction

	Prediction 1	Prediction 2	Prediction 3
Cell 1	RMSE = 0.0044dB	RMSE = 1.08dB	RMSE = 0.26dB
Cell 2	RMSE = 0.0062dB	RMSE = 1.11dB	RMSE = 0.26dB
Cell 3	RMSE = 0.0844dB	RMSE = 1.23dB	RMSE = 0.28dB

Carrier Frequency: FR2, 30GHz

Prediction 1: RSRP of every 80ms in 320ms after T_0

Prediction 2: RSRP of 1s after T_0

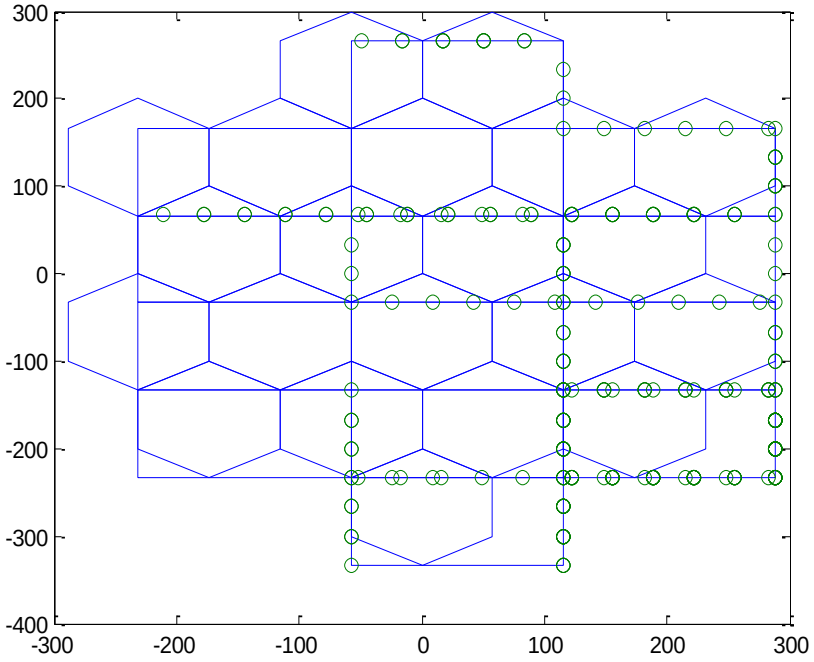
Prediction 3: RSRP of 2s after T_0

Expected signaling procedure

- Step1: UE1/UE2 decides to trigger the RRM reporting based on the predicted RSRP of every 80ms in 320ms after T_0
- Step2: The Source cell determines the target cell based on the predicted RSRP of 1s and/or 2s after T_0:
  - For UE1, the RSRP prediction of Cell2 will last for a specific period (T1>1s), and Cell2 is selected as target cell,
  - For UE2, the RSRP prediction of Cell2 will decrease at a short time (T2<1s), then Cell3 is selected as target cell.
- Step3: The UEs receive different HO commands and HO to separate suitable cells.

Scenario2: unintended event due to TTT

■ Simulation scenario



Simulation scenario and UE trajectory

■ Simulation assumption

Attributes	Values or assumptions
Carrier Frequency	FR1: 4GHz; FR2: 30GHz
TRP Number	7 sites, 3 sector per site
Channel Model	3D-Uma in TR 38.901, support Spatial consistency ISD = 200m
UE speed	120km/h
Mobility management	Event: A3; Hysteresis: 2dB; Offset: 1dB; TimeToTrigger: 320ms, 40ms Handover preparation time: 50ms; Handover execution time: 40ms
RLM	L1 measurement period: 20ms Qin sliding window length: 100ms Qout sliding window length: 200ms Qin threshold: -6dB; Qout threshold: -8dB N310: 1; N311: 1; T310: 1s
Handover model and corresponding metrics	As defined in TR 36.839 Short time of stay: served by the target cell for less than 1s after HO

Initial evaluation - RSRP prediction based HO

vivo

Accuracy of RSRP prediction

	Prediction 1	Prediction 2
FR1	RMSE = 0.38 dB	RMSE = 1.6 dB
FR2	RMSE = 1.3 dB	RMSE = 3.3 dB
Training dataset: Same large scale channel parameters for different drops Prediction 1: RSRP of every 80ms in 320ms after T_0 Prediction 2: RSRP of 1s after T_0		

Usage of RSRP prediction

- Legacy HO:
  - UE can decide whether to trigger the RRM reporting based on the predicted RSRP of every 80ms in 320ms after T_0,
  - Source cell can determine the target cell based on the predicted RSRP of 1s after T_0 to avoid too early HO or HO to wrong cell,
  - Source cell can forward the predicted RSRP to target cell for admission control.
- CHO:
  - UE can decide to trigger the target cell selection based on the predicted RSRP of every 80ms in 320ms after T_0,
  - UE can choose the target cell based on the predicted RSRP of 1s after T_0 to avoid too early HO or HO to wrong cell.

Initial evaluation - RSRP prediction based HO

vivo

■ **RSRP prediction based HO**

		Legacy HO, TTT = 320	Legacy HO, TTT = 40	AI based HO	CHO, TTT = 320	CHO, TTT = 40	AI based CHO
FR1	HOF rate	9.16%	2.2%	1.95%	0.28%	0.15%	0.32%
	Ping-pong HO rate	1.1%	3.6%	0.37%	1.0%	3.7%	0.37%
	Short Time of Stay (1s) rate	13.4%	18.9%	5.7%	13.6%	18.8%	5.67%
FR2	HOF rate	7.4%	2.5%	2.0%	0.42%	0.43%	0.44%
	Ping-pong HO rate	5.2%	10.3%	2.7%	5.2%	10.3%	2.7%
	Short Time of Stay (1s) rate	24.1%	36.7%	10.4%	24.4%	36.5%	10.8%

❑ **Observation 2: With RSRP prediction, the unintended events rate during HO and CHO can be significantly reduced, including HOF rate, ping-pong HO rate and short time of stay rate.**

Initial evaluation - SINR prediction based HO

Accuracy of SINR prediction

	prediction of the minimum SINR during TTT
FR1	RMSE = 0.79 dB
FR2	RMSE = 2.12 dB
Training dataset: Same large scale channel parameters for different drops	

Usage of SINR prediction

- Legacy HO:
  - If the predicted minimum SINR during TTT is below the threshold, UE can trigger the legacy RRM reporting.
  - Source cell can determine the target cell based on the reporting RSRP, i.e., real measurement RSRP.

Initial evaluation - SINR prediction based HO

vivo

■ **SINR prediction based HO**

		Legacy HO, TTT = 320	Legacy HO, TTT = 40	AI based HO
FR1	HOF rate	9.16%	2.2%	1.60%
	Ping-pong HO rate	1.1%	3.6%	1.87%
	Short Time of Stay (1s) rate	13.4%	18.9%	13.5%
	Average SINR during HO (dB)	1.81	3.00	6.01
	5% SINR during HO (dB)	-8.05	-4.81	-0.19
FR2	HOF rate	7.4%	2.5%	1.7%
	Ping-pong HO rate	5.2%	10.3%	9.8%
	Short Time of Stay (1s) rate	24.1%	36.7%	33.8%
	Average SINR during HO (dB)	6.24	10.28	12.7
	5% SINR during HO (dB)	-5.26	-0.54	3.77

❑ **Observation 3: With SINR prediction, the average SINR during the HO can be increased 2~6dB and 5% SINR can be increased 4~8dB, which will reduce the HOF rate, reduce ping-pong rate in short TTT and improve UE throughput during HO.**

Conclusion

- **Observation 1: For mobility optimization, if the Model Inference function can be deployed on the UE side:**
  - **More detailed local information from UE can be utilized as the input to improve prediction accuracy without privacy concerns.**
  - **Local model inference can reduce inference latency and therefore interruption.**
- **Observation 2: With RSRP prediction, the unintended events rate during HO and CHO can be significantly reduced, including HOF rate, ping-pong HO rate and short time of stay rate.**
- **Observation 3: With SINR prediction, the average SINR during the HO can be increased 2~6dB and 5% SINR can be increased 4~8dB, which will reduce the HOF rate, reduce ping-pong rate in short TTT and improve UE throughput during HO.**

- **Proposal 1: Study RRM measurement prediction based further mobility optimization in R19, including RSRP prediction and SINR prediction.**

THANK YOU