**3GPP TSG-RAN WG4 Meeting #116bis R4-2513096**

**Prague, Czech Republic, October 13th – 17th, 2025**

**Agenda Item: 7.12.2**

**Source: OPPO**

**Title:** **Simulation assumption for measurement prediction and indirect measurement event prediction for AI mobility**

**Document for:** **Approval**

# Introduction

In this contribution, the simulation assumptions and procedures for measurement prediction and indirect measurement event prediction considering the impact of measurement error are provided.

# Discussion

To decide the simulation assumption for measurement prediction in FR1 and FR2, the assumption used in RAN2 evaluation [3] in study item and in Rel-19 AI beam management use case [4] can be used as baseline.

## 2.1 Scenarios and sub-use cases

The following scenarios can be evaluated:

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| **Evaluation scenario** | **Methodology** |
| FR1 to FR1 intra-frequency temporal domain case A | intra-cell |
| FR1 to FR1 intra-frequency temporal domain case B | Intra-cell |
| FR1 to FR1 inter-frequency (frequency domain) (co-located case) | Inter-cell  |
| FR2 to FR2 intra-frequency temporal domain case A | Intra-cell |
| FR2 to FR2 intra-frequency temporal domain case B | Intra-cell |

FFS:

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| **Evaluation scenario** | **Methodology** |
| FR2 to FR2 inter-frequency (frequency domain) (co-located case) | Inter-cell  |

The following sub-use case can be evaluated for both FR1 and FR2:

* Sub-use case 2: L3 Cell-level measurement result(s) is predicted based on actual L3 cell-level measurement result(s).

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## 2.2 System level simulation assumptions for FR1 and FR2

Table 2.2-1: Simulation assumptions of FR1 and FR2

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| Parameters | Value for FR1 | Value for FR2 |
| Frequency Range | FR1@{4GHz,30kHz} as central frequency for intra-frequency scenarioFR1@{2GHz, 15/30kHz} as another frequency for inter-frequency scenario | FR2 @ 30 GHz; SCS: 120 kHz |
| Deployment | 2-tier model with wrap-around (7 sites, 3 sectors/cells per site) | 2-tier model with wrap-around (7 sites, 3 sectors/cells per site) |
| Channel model | UMa With distance-dependent LoS probability function defined in Table 7.4.2-1 in TR 38.901, fast fading and optional LOSsoft; without UErotation,Oxygen absorption, Time-varying Doppler shift, Explicit ground reflection model and blockage. Inter-frequency correlation model is optional. | UMiWith distance-dependent LoS probability function defined in Table 7.4.2-1 in TR 38.901, fast fading and optional LOSsoft;without UE rotation,Oxygen absorption, Time-varying Doppler shift, Explicit ground reflection model and blockage |
| System BW | 20MHz | 100MHz |
| UE speed | 30,60,90 km/h for study targeting measurement reduction (case B and inter-f)60,90,120 km/h for study targeting HO performance improvement (case A) | 30,60,90 km/h for study targeting measurement reduction60,90,120 km/h for study targeting HO performance improvement |
| UE distribution | 100% outdoor | 100% outdoor |
| BS Antenna Configuration | Option 1 as baseline: - Option 1 : 32 ports: (8,8,2,1,1,2,8), (dH,dV) = (0.5, 0.8)λ1,2 or 4 TX beams are assumed. | Antenna setup and port layouts at gNB: (4, 8, 2, 1, 1, 1, 1), (dV, dH) = (0.5, 0.5) λ8,16 or 32 TX beams are assumed |
| BS Antenna radiation pattern | 3-sector antenna radiation pattern, 8 dBi | TR 38.802 Table A.2.1-6 |
| UE Antenna Configuration | 4RX: (1,2,2,1,1,1,2), (dH,dV) = (0.5, 0.5)λ for (rank 1-4)2RX: (1,1,2,1,1,1,1), (dH,dV) = (0.5, 0.5)λ for (rank 1,2)1RX beam is assumed | Antenna setup and port layouts at UE: (1, 4, 2, 1, 2, 1, 1), 2 panels (left, right)4RX beams are assumed |
| UE Antenna radiation pattern | Omni-direction | TR 38.802 Table A.2.1-8 |
| BS Tx Power | 44dBm  | 40 dBm (baseline)FFS: Other values (e.g., 34 dBm)  |
| Maximum UE Tx Power | 23dBm (PC3) | 23 dBm |
| BS receiver Noise Figure | 5dB | 7 dB |
| UE receiver Noise Figure | 9dB | 10 dB |
| Inter site distance | 500m | 200 m |
| BS Antenna height | 25m | 10m |
| UE Antenna height | 1.5m | 1.5 m |
| Spatial consistency | companies report one of the spatial consistency procedures: - Option 1: Procedure A in TR38.901- Option 2: Procedure B in TR38.901 | companies report one of the spatial consistency procedures: - Option 1: Procedure A in TR38.901- Option 2: Procedure B in TR38.901 |
| UE trajectory model | 3 options in 38.843 section 6.3.1 | 3 options in 38.843 section 6.3.1 |
| UE trajectory boundary processing model | Companies report which of the following models they used:Option 1: wrap-around model, Option 2: circle-bouncing model,Option 3: boundary-terminated model | Companies report which of the following models they used:Option 1: wrap-around model, Option 2: circle-bouncing model,Option 3: boundary-terminated model |

Table 2.2-2 RRC parameters and UE sampling for RRM measurement prediction

|  |  |  |
| --- | --- | --- |
| Parameters | Value for FR1 | Value for FR2 |
| **L3 filtering parameter: FilterCoefficient** | 4 | 4 |
| **Measurement period** | 200ms | 400ms |
| **Consolidation parameter** | nrofSS-BlocksToAverage: 1absThreshSS-BlocksConsolidation: -110dbm | nrofSS-BlocksToAverage: 3absThreshSS-BlocksConsolidation: -110dbm |
| **Sampling period** | 40ms | 80ms |
| **L1 filtering** | Option 1: sliding Option 2: non-sliding  | Option 1: sliding Option 2: non-sliding |
| **Observation window** | 400ms | 800ms |
| **Prediction window** | 200ms | 400ms |

Table 2.2-3: 3-Sector BS antenna radiation pattern for above 6GHz (TR 38.802 Table A.2.1-6)

|  |  |
| --- | --- |
| Parameter | Values |
| Antenna element vertical radiation pattern (dB) |  |
| Antenna element horizontal radiation pattern (dB) |  |
| Combining method for 3D antenna element pattern (dB) |  |
| Maximum directional gain of an antenna element *GE,max* | 8dBi |

Table 2.2-4: UE antenna radiation pattern model 1 (TR 38.802 Table A.2.1-8)

|  |  |
| --- | --- |
| Parameter | Values |
| **Antenna element radiation pattern in** $θ''$ **dim (dB)** |  |
| **Antenna element radiation pattern in** $φ''$ **dim (dB)** |  |
| **Combining method for 3D antenna element pattern (dB)** |  |
| **Maximum directional gain of an antenna element *GE,max*** | 5dBi |

Note: are in local coordinate system.

Table 2.2-5 UE trajectory model and boundary processing model

|  |  |
| --- | --- |
| Parameters | Values |
| **UE trajectory model** | Option 1: Linear trajectory model with random direction change.- UE moving trajectory: UE will move straight along the selected direction to the end of an time interval, where the length of the time interval is provided by using an exponential distribution with average interval length, e.g., 5s, with granularity of 100 ms. - UE moving direction change: At the end of the time interval, UE will change the moving direction with the angle difference A\_diff from the beginning of the time interval, provided by using a uniform distribution within [-45°, 45°].- UE moves straight within the time interval with the fixed speed.Option 2: Linear trajectory model with random and smooth direction change.- UE moving trajectory: UE will change the moving direction by multiple steps within an time internal, where the length of the time interval is provided by using an exponential distribution with average interval length, e.g., 5s, with granularity of 100 ms.- UE moving direction change: At the end of the time interval, UE will change the moving direction with the angle difference A\_diff from the beginning of the time interval, provided by using a uniform distribution within [-45°, 45°].- The time interval is further broken into N sub-intervals, e.g. 100ms per sub-interval, and at the end of each sub-interval, UE change the direction by the angle of A\_diff/N. - UE moves straight within the time sub-interval with the fixed speed.Option 3: Random direction straight-line trajectories. - Initial UE location, moving direction and speed: UE is randomly dropped in a cell, and an initial moving direction is randomly selected, with a fixed speed.- The initial UE location should be randomly drop within the following blue area:where d1 is the minimum distance that UE should be away from the BS. - Each sector is a cell and that the cell association is geometry based.- During the simulation, inter-cell handover or switching should be disabled. |
| **UE trajectory boundary processing model** | Option 1: wrap-around model, Option 2: circle-bouncing model,Option 3: boundary-terminated model |
| Note 1: For training data generation:- For each UE moving trajectory: the total length of the UE trajectory can be set as T seconds if it is in time, or set as D meter if it is in distance.- The trajectory sampling interval granularity depends on UE speed. - UE can move straight along the entire trajectory, or- UE can move straight during the time interval, where the time interval is provided by using an exponential distribution with average interval length ΔT- UE may change the moving direction at the end of the time interval. UE will change the moving direction with the angle difference A\_diff from the beginning of the time interval, provided by using a uniform distribution within [-45°, 45°]- If the UE trajectory hits the cell boundary (the red line), the trajectory should be terminated. - If the trajectory length (in time) is less than the length of observation window + prediction window, the trajectory should be discarded. - The length of observation window + prediction window is not fixed and companies can report their values.Note 2: For the wrap-around model (option 1), when the UE hit the simulation border (the wrap-around contour), it will wrap around and enter the simulation area from a different point on the wrap-around contour. For the bouncing-circle model (option 2), when the UE hit the simulation border (the bouncing-circle), it will bounce back with a random angle and hence only area within circle can be used. For option 3, UE trajectory is terminated when UE hits the simulation border. Then another UE will be dropped randomly.  |

## 2.3 Link level simulation assumptions for baseband error

Table 2.3-1 General parameters for measurement prediction evaluations

|  |  |  |
| --- | --- | --- |
| Parameter | Value for FR1 | Value for FR2 |
| Carrier frequency | 2GHz, 4GHz | 30GHz |
| Subcarrier spacing | 30kHz | 120kHz |
| Channel bandwidth | 20MHz | 100MHz |
| Channel model | Fading channel* Baseline:
	+ TDL-C, DS=10ns
* Optional:
	+ CDL-C, DS=10ns
 | Fading channel* Baseline:
	+ TDL-C, DS=100ns
* Optional:
	+ CDL-C, DS=100ns
 |
| BS antenna configurations | Same as SLS | Same as SLS |
| BS antenna element radiation pattern | Same as SLS | Same as SLS |
| BS antenna height and antenna array down-tilt angle | 25m, 110° | 10m, 110° |
| UE antenna configurations | Same as SLS | Same as SLS |
| UE antenna element radiation pattern | Same as SLS | Same as SLS |
| UE moving speed | 30,60,90 km/h for case B and inter-f60,90,120 km/h for case A | 30,60,90 km/h for case B60,90,120 km/h for case A |
| Reference signal | SSB | SSB |
| DRX | No | No |
| Number of samples in L1 filtering | Baseline: * 1 sample

Optional: * 3 samples
* 5 samples
 | Baseline: * 1 sample

Optional: * 3 samples
* 5 samples
 |
| L1 filtering approach | Option 1: sliding Option 2: non-sliding  | Option 1: sliding Option 2: non-sliding |
| Note 1: TXRU weights mapping for BS and UE is up to company. |

Table 2.3-2 Cell-specific parameters for FR1 and FR2

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Unit** | **Value for cell 1** | **Value for cell 2** |
| RF channel  | - | Channel 1 | Channel 1 |
| PBCH and DMRS power offset with respect to NR-PSS and NR-SSS | dB | 0 | 0 |
| Data and control PSD relative to NR-PSS and NR-SSS | dB | 0 | 0 |
| SSB periodicity | ms | 20 | 20 |
| SSB bandwidth | RB | 20 | 20 |
| SSB SCS | kHz | 30 | 120 |
| RB Utilization | % | 100 | 100 |
| Data Modulation | - | QPSK | QPSK |
| CP Length | - | Normal | Normal |
| Frequency Offset relative to UE frequency reference | Hz | Option 1: 0Option 2: 5ppm | - |
| Relative Delay of 1st Path (synchronous) | µs | 0 | CP/2 |
| SINR  | dB | [-6, -3, 0, 3]  | - |
| SNR | dB | [-2.7]When cell 1 SINR = -3dB: If serving cell is 9dB higher than neighbor cellSame calculation for other SINR.  | [-11.7] When cell 1 SINR = -3dB: If serving cell is 9dB higher than neighbor cell |
| SNR for ground truth derivation  | dB | High SNR | High SNR |

## 2.4 Simulation assumptions for RF error

The impact of RF errors should be considered. Following assumptions can be used to generate RF errors.

* Truncated Gaussian distribution under [±4] dB RF error ($μ=0, σ^{2}$=[4]) is used for FR2
* Truncated Gaussian distribution under [±2.5] dB RF error ($μ=0, σ^{2}$=[2.5]) is used for FR1
	+ 2Rx chains with independent RF error per chain (same distribution for each chain)
	+ For inter-frequency prediction, independent RF error for each frequency (same distribution)

## 2.5 Performance metrics

At least the following performance characteristics are to be provided

KPI 1: Absolute accuracy for predicted L3-RSRP

* Max (abs (95%-tile L3-RSRP), abs (5%-tile L3-RSRP)) on the CDF curve of L3-RSRP difference between the predicted L3-RSRP and the ground truth of L3-RSRP for a certain cell

KPI 2: Relative accuracy for predicted L3-RSRP

* Max (abs (95%-tile L3-RSRP), abs (5%-tile L3-RSRP)) on the CDF curve of relative L3-RSRP difference between two cells.
	+ Relative L3-RSRP difference = (reported predicted L3-RSRP of cell 1 – reported RSRP of cell 2) – (ground truth of RSRP of cell 1 – ground truth of RSRP of cell 2),
		- cell 1 and cell 2 are on the same frequency
		- the reported RSRP of cell 2 can be measured or predicted.

Note: the ‘ground truth’ underlined refers to:

* the reported L3-RSRP measurement result under sufficient high SNR for FR2 and FR1.

## 2.6 Simulation procedures

We provide the following procedures for companies to perform simulations to evaluate the predicted L3-RSRP accuracy considering the impact of measurement error.

The simulated cases include:

* Case 1: Measurement error will be considered in training dataset, model input during inference and ground-truth.

For Case 1, the simulation procedures include:

1. Companies to generate ideal L3-RSRP dataset from the SLS assumption defined in section 2.2.
2. Use the LLS assumptions defined in section 2.3 to generate L3-RSRP difference as the baseband errors.
3. Use the Simulation assumptions for RF error defined in section 2.4 to generate RF errors.
4. Add the measurement error into the ideal SLS dataset in 1st step to derive the dataset with measurement errors.
* Both baseband errors and RF errors are included.
* Measurement error assumptions follow 2nd step and 3rd step.
1. Add L3 filtering to the dataset with added measurement error generated from the 4th step.
2. Use subset samples of the dataset generated from the 5th step for training models.
3. Filter UEs in the other subset samples of the dataset with added measurement error (non-overlapped samples with the subset dataset in 6th step) which SINR>= -6dB (use this SINR range as the starting point) to derive the dataset for inference.

Note: UE distribution is 100% outdoor

1. Use the dataset with measurement error for inference in 6th step to evaluate the performance metrics in section 2.5 assuming that the ground truth is with the measurement error.

## FFS: Reference model

For better alignment of the performance between companies, it would be better to perform simulations based on a reference model. The model description in Fig. 1 is an example of reference model performance evaluation, while it is not the intention to preclude other reference models.



Fig. 1 Reference model description

## FFS: Dataset alignment

### Dataset sharing format

Companies are encouraged to share their own simulation dataset based on the following format:

**Dataset format**

Use NumPy for dataset sharing

Use npy – single array in each file

**Data file format**

* Dataset file format: N (samples) with added measurement error.

Note: Each element of the dataset will be a float32 real number

**Note 1:** Dataset files can be split into multiple sub-files to enable easier upload.

* Use the 2 digits for split files starting from 00, increment for each additional file.
* Split files and then archive each sub-file

**Note 2:** The full Dataset files from each company follows the ratio of [training samples, validation samples, testing samples] = [90%, 5%, 5%]

**File naming scheme**

* Folders for AI/ML data sharing and current WI/use case to be created under “RAN4 folder”
* Subfolder created for each meeting
* File naming scheme (dataset file)
	+ a unique identifier for the company (4 characters – list to be maintained by RAN4 secretary, same as the identifier used in beam management)
	+ meeting number
	+ dataset can be split in multiple files – 2 digits
	+ files to be compressed to zips and uploaded

*Example for folder:*

*Folders to be created under https://www.3gpp.org/ftp/tsg\_ran/WG4\_Radio/*

*Folder for datasets: /Data\_sharing/NR\_AIML\_Mob/Datasets/R4\_XXX*

*Example for dataset file:*

*OPP0R4\_117\_00.npy*

### Dataset parameter

**Dataset size**

The dataset size shall be greater than [100,000] if company uses its own dataset for simulation.

# Conclusions

In this contribution, we provide the simulation assumption for measurement prediction in AI mobility and got the following proposals:

**Proposal 1: RAN4 to discuss and approve the simulation assumption in this contribution.**

# References

1. RP-251864 New WI: Artificial Intelligence (AI)/Machine Learning (ML) for mobility in NR, RAN#108
2. RP-252899 Revised WI: Artificial Intelligence (AI)/Machine Learning (ML) for mobility in NR, RAN#109
3. 3GPP TR 38.744: “Study on Artificial Intelligence (AI)/Machine Learning (ML) for Mobility in NR”
4. R4-2511797 WF on updated simulation assumption for AI based beam management, RAN4#116
5. 3GPP TR 38.901: "Study on channel model for frequencies from 0.5 to 100 GHz"