**3GPP TSG RAN WG1 #109-e R1-220xxxx**

**e-Meeting, May 09 – May 20, 2022**

**Agenda item:** **9.2.3.1**

**Source:** Moderator (Samsung)

**Title:** Feature lead summary #1 evaluation of AI/ML for beam management

**Document for:** Discussion and Decision

# Introduction

In RAN#94-e, Rel-18 new study item on “Study on Artificial Intelligence (AI)/Machine Learning (ML) for NR Air Interface” was approved. The following use cases were identified as the initial set:

* Initial set of use cases includes:
  + CSI feedback enhancement, e.g., overhead reduction, improved accuracy, prediction [RAN1]
  + Beam management, e.g., beam prediction in time, and/or spatial domain for overhead and latency reduction, beam selection accuracy improvement [RAN1]
  + Positioning accuracy enhancements for different scenarios including, e.g., those with heavy NLOS conditions [RAN1]

The performance of AI/ML based algorithms for the use cases includes the following aspects:

1. Evaluate performance benefits of AI/ML based algorithms for the agreed use cases in the final representative set:
   * Methodology based on statistical models (from TR 38.901 and TR 38.857 [positioning]), for link and system level simulations.
     + Extensions of 3GPP evaluation methodology for better suitability to AI/ML based techniques should be considered as needed.
     + Whether field data are optionally needed to further assess the performance and robustness in real-world environments should be discussed as part of the study.
     + Need for common assumptions in dataset construction for training, validation and test for the selected use cases.
     + Consider adequate model training strategy, collaboration levels and associated implications
     + Consider agreed-upon base AI model(s) for calibration
     + AI model description and training methodology used for evaluation should be reported for information and cross-checking purposes
   * KPIs: Determine the common KPIs and corresponding requirements for the AI/ML operations. Determine the use-case specific KPIs and benchmarks of the selected use-cases.
     + Performance, inference latency and computational complexity of AI/ML based algorithms should be compared to that of a state-of-the-art baseline
     + Overhead, power consumption (including computational), memory storage, and hardware requirements (including for given processing delays) associated with enabling respective AI/ML scheme, as well as generalization capability should be considered.

In this contribution summarized the discussions and proposal on evaluation methodology (EVM) and KPIs from contributions submitted to AI 9.2.3.1 for beam management (BM).

The issues in this document are tagged and color coded with High Priority or Medium Priority. The issues that are in the focus of this round of the discussion are furthermore tagged FL3.

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#### FL3 Question 0-1a

* **Please consider entering contact info below for the points of contact for this email discussion.**

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# Evaluation methodology on AI/ML in beam management

## 1.1 Dataset construction (closed)

Most of the companies proposed to use the dataset generated based on statistical channel models for evaluation:

* Huawei/HiSi [1]: For AI/ML-based beam management evaluation, training inputs generated from simulation platform should be a baseline.
* ZTE [2]: Since the data sets and AI models used by different companies are different, it is necessary to provide common data sets and baseline models for simulation calibration and performance cross-validation.
* Ericsson [4]: Beam management should be evaluated based on the scenarios defined in (simulation assumption of Rel-17 BM in R1-2007151)
* CATT [6]: A few typical scenarios in TR 38.901 can be considered for the evaluations for AI/ML-based beam management.
* vivo [7]: Data set constructed based on 3GPP channel model from TR 38.901 is mainly considered for beam management case. SLS deployment is used to obtain dataset for performance evaluation.
* Apple [15]: System level simulator can be used to generate the dataset, where the number of cells can be 1 to speed up the dataset generation procedure and full spatial consistency modeling is recommended.
  + Other parameters can be selected based on traditional system level evaluation
* DCM [17]: 3GPP statistical channel models are considered in the evaluation for representative sub use-case selection.
* DCM [17]: Discuss and decide whether and which deterministic channel models should be used to capture the final evaluation results of selected sub use-cases.
  + Option 1: Field data as indicated in SID.
  + Option 2: Ray-tracing channel model.
  + Option 3: Map-based hybrid channel model as defined in TR38.901.
* Lenovo [18]: Generate the dataset for the model training and evaluation for beam management sub use cases based on the statistical models in TR 38.901 taking in to account spatially consistency.
* Nokia/NSB [19]: The preliminary phase uses synthetic data generated from a system-level simulator that implements the 3GPP statistical channel models from 3GPP TR 38.901. The list of assumptions detailed in Table 2.1 2 can be considered for system-level simulations of different beam management sub-use cases.
* NVIDIA [21]: Use the simulation assumptions in TR 38.901 as a starting point for the evaluation of AI/ML based algorithms for beam management.
* Qualcomm [23]: RAN1 to use channel model in TR 38.901 for the evaluations on AI/ML for temporal beam prediction. A set of simulation assumptions should be agreed upon for evaluation purposes.
* Qualcomm [23]: RAN1 to use channel model in TR 38.901 for the evaluations on AI/ML for codebook-based spatial domain beam prediction. A set of simulation assumptions should be agreed upon for evaluation purposes.

Some companies suggested to encourage companies to provide common/public dataset for training and validation for cross check purposes. In [14], a website for mobile communication open dataset was mentioned as <http://www.mobileai-dataset.com/>.

* Vivo [7]: It is encouraged for companies to provide publicly accessible dataset for training and validation for cross-check purposes.
* Intel [20]: A common dataset across companies should be considered for each use-case to ensure robustness and fair comparison of AI/ML model performance taking into account, a reasonable dataset size.

Moreover, one company proposed that no need to use field data for the study item beam management use case, while two companies proposed that real data should be part of the evaluation work, and suggested to encourage companies to contribute realistic data to develop and evaluation.

* Ericsson [4]: No need for field data for the study item BM use case
* DCM [17]: Discuss and decide whether and which deterministic channel models should be used to capture the final evaluation results of selected sub use-cases.
  + Option 1: Field data as indicated in SID.
  + Option 2: Ray-tracing channel model.
  + Option 3: Map-based hybrid channel model as defined in TR38.901
* NVIDIA [21]: Identifying existing sets of real data should be part of the evaluation work for AI/ML based beam management.
* NVIDIA [21]: Companies are encouraged to contribute real data to develop and evaluate AI/ML based algorithms for beam management.

Based on the above views, the following proposal related to dataset construction can be considered.

#### 1st round: FL1 High Priority Question 1-1(closed)

**Proposal 1-1:**

* **Dataset constructed based on 3GPP channel model(s) in TR 38.901 is used for beam management use case.**

**Question 1-1:**

1. Whether the above proposal 1-1 can be adopted?
2. Whether real data/field data is optionally needed as part of the study?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | Y |  |
| Nokia, NSB | Y | Yes, Support a)  Optional field data should be fine but should not be the main focus. |
| Xiaomi | Y | Support a) |
| vivo | Y | At least in SI stage, no need to introduce real data/field data |
| Intel | Y | Statistical channel models are OK as long dataset generation assumptions can be well aligned across companies |
| NVIDIA | Y | Support a)  Support b) to consider optional field data. |
| OPPO | Y | The real data / field data are welcome and can be used optionally. |
| AT&T | Y |  |
| CATT | Y | Support a).  Field data can be optionally used, if companies have interest. |
| LGE | Y | a) Support.  b) We think stochastic channel model is enough to evaluate AI/ML for BM. |
| Ericsson | Y | Support a) |
| ZTE, Sanechips | Y | a) Support.  b) Field data is optionally needed but should be placed at a lower priority. |
| CAICT | Y | Field data is not necessary for sub case down selection at least. |
| Samsung | Y | Yes for a)  For b), no need to spend time on field data at this stage. |
| Fujitsu | Y | It’s not necessary to use the real data/field data in initial stage. |
| CMCC | Y |  |
| MediaTek | Y | In SI phase, we can use dataset generated by 3GPP model(s) |
| HW/HiSi | Y | a) Support  b) Field data is optional needed and should not be mandatory. |
| InterDigital | Y | a) We support using 3GPP channel model(s) for the evaluation.  b) We are fine with having real/field data if it is optional. |
| Lenovo | Y | 1. Yes 2. Open to the idea of having field data as optional. Further discussions are needed to decide on collecting the field data. |
| Qualcomm | Y | 1. We believe TR 38.901 encapsulates the necessary tools (e.g., spatial consistency) for the use cases under consideration. 2. No need for optional real data/field data. |
| Futurewei | Y | We support a). Field data may be optionally used by companies but should not be required. |
| NTT DOCOMO | Y |  |

Summary of Question 1-1:

All the companies support proposal 1-1, the views on real data/field data are as below:

* No need (at this stage) (7): vivo, LGE, CAICT, Samsung, Fujitsu, MediaTek, Qualcomm
* Fine as optional (9): Nokia/NSB, NVIDIA OPPO, CATT, ZTE/Sanechips, HW/HiSi, InterDigital, Lenovo, FUTUREWEI

Based on the summary, moderator suggests to not focus on real data/field data for evaluation. The discussion on field data can be triggered if there is company volunteering to provide field data.

## 1.2 Dataset generation and evaluation assumptions with SLS

Most of companies proposed to use SLS to evaluate the performance of beam management. Two companies explicitly proposed to use evaluation methodology (EVM) for Rel-17 beam management (R1-2007151), while other companies provided detailed proposals and analysis for the evaluation assumption for SLS. Table 1-1 in appendix summarized the main parameters proposed/used in some contributions.

* Ericsson [4]: Beam management should be evaluated based on the scenarios defined in (simulation assumption of Rel-17 BM), which are summarized in the appendix
* Samsung [9]: Consider Table A.2.5-2 (for SLS) and Table A.1.6.4 (for LLS) of TR 38.802 as the starting point for Rel-18 AI/ML for beam management evaluation, based on which necessary modifications/simplifications can be further discussed for the specific evaluation purpose and/or sub use case.
* LGE [13]: Reuse agreed simulation assumptions in Rel-17 BM (R1-2007151) except AI/ML related function for Rel-18 evaluation on AI/ML for beam management.
* CAICT [14]: Umi scenario with carrier frequency 30GHz could be considered as baseline for dataset construction and performance comparison.
* Nokia/NSB [19]: The preliminary phase uses synthetic data generated from a system-level simulator that implements the 3GPP statistical channel models from 3GPP TR 38.901. The list of assumptions detailed in Table 2.1 2 can be considered for system-level simulations of different beam management sub-use cases.
* Intel [20]: For temporal domain beam prediction, system level simulation based urban deployment e.g., dense urban and urban macro and related 3GPP channel models should be used for dataset generation
* NVIDIA [21]: The evaluation scenarios for beam management include UMi-street canyon and UMa scenarios.
* NVIDIA [21]: Focus on millimeter wave frequencies for the evaluation of AI/ML based algorithms for beam management.
* AT&T [22]: Consider both a single-cell and multi-cell SLS evaluation scenarios
* AT&T [22]: Consider modified Urban Macro and Indoor Hotspot layouts with non-uniform inter-site distances and antenna height/orientations
* AT&T [22]: Consider a venue/stadium layout with a dense deployment of base stations/TRPs oriented towards one or more cluster of users

Based on the above views, the following proposal related to evaluation methodology can be considered. Moreover, Table 1 in Appendix summarized and simplified the baseline assumptions Table 1 and Table 2 in R1-2007151 for Rel-17 BM EVM. The parameters for high-speed train scenario were removed comparing with the tables in R1-2007151, which will be separated discussed in Question 1-9. Companies are encouraged to indicate necessary changes of those parameters and the reasons.

#### 1st round: FL1 High Priority Question 1-2

**Proposal 1-2:**

* **For dataset construction and performance evaluation for AI/ML based BM, SLS is the baseline tool.**

**Question 1-2:**

1. Whether the above proposal 1-2 can be adopted?
2. Which parameters in Table 1 on baseline assumptions for SLS need to be modified, and why?
3. Whether Dense Urban scenario (FR2) can be used as the baseline assumption for AI/ML for BM? If the answer is yes, which parameters in Table 2 need to be updated, and why?
4. Any other scenario(s) can be optionally considered for dataset generation and performance evaluation of AI/ML for BM?

Note: Mixed scenario(s) for generalization can be discussed in section 2.2.1. This question only focuses on single scenario case for dataset and performance evaluation.

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | Y | For simulation assumption, we think we should add FR1 related parameters since one use case is to use FR1 to predict FR2 beam. For scenario, we think 1 cell with 3 sectors can be added to be aligned with intra-cell mobility assumption in R17. For UE speed, we suggest adding 30 km/h. |
| Nokia, NSB | Y | b.) “One UE is dropped for each of the 21 sectors/cells"., we do not support this assumption for the reasons as follows:   * it is an oversimplified scenario that would complicate the data generation as the data collected for each network drop is limited, * SLS perf evaluation is not realistic as the single UE assumption does impact the interference and consequently the throughput, which is likely to provide unreal results. * At least 10 UEs/sector dropped uniformly in random points of the sector should be considered.   Also, “UE Speed 120 km/h” is not realistic for Dense Urban scenario. Consider including also 30/45/60/75/90 km/h. These speeds could also be sub-use case specific.  c.) Yes.  The scenario "UMa LOS" is too simplistic as building and other static street objects may obstruct the BS-UE link. We suggest that for a given link, the models decide whether the channel propagation conditions are LoS or NLoS, by considering a distance-dependent LoS probability function as currently done in 38.901.  d.) yes, we suggest considering other options for list of assumptions in [19] (detailed in Table 2.1 2 (right hand side column)) for beam prediction in spatial domain for throughput & latency reduction. |
| Xiaomi | Y | First we want to clarify that the parameters in Table 1 will be used for beam prediction in both spatial domain and time domain?  Then for b), we also think that based on “One UE is dropped for each of the 21 sectors/cells”, it is not better for data collection. For UE speed, we prefer to add 30km/h. |
| vivo | Y | We prefer 80% indoor and 20% outdoor for spatial domain beam prediction and 100% outdoor for temporal domain prediction.  For UE speed, 120km can be optional. 30km/h should also be included.  For gNB and UE antenna configuration, single panel can also be optional configurations to reduce the simulation time and effort in addition to multiple panel simulations.  The number of Tx beams and Rx beams should be aligned, and we prefer at least a total of 256 beam pairs should be used. |
| Intel | N | Q1-2a: In our understanding, LLS based channel models are good enough for spatial domain beam prediction and SLS based data is needed only for temporal domain beam prediction use case. Therefore, the baseline assumption should be sub-use-case specific.  Q.1-2b: Considering Table 1, the UE dropping should be revisited along with trajectory modeling and UE speed. Rel-17 MIMO EVM was for mobility with highway traffic. In temporal beam prediction, the use case should be further refined, and highway traffic may not be the only scenario of interest. A more general assumption of random UE dropping and straight-line motion at a lower speed can be considered to collect traces of UE beam switching data for temporal prediction.  For both the remaining questions, the assumptions should be sub-use-case specific and Dense Urban for example should be relevant only for the temporal domain prediction. |
| NVIDIA | Y | Support Proposal 1-2 |
| OPPO | Y | a) Yes  b) For the sub use case of beam prediction in spatial domain, it seems not mandatory for UE to move at high speed e.g. 60km/h or even higher speed. When UE travels at low speed, e.g. 3km/h, the beam prediction in spatial domain can be evaluated.  c) Indoor hotspot (office scenario) also serves as classic FR2 deployment and should be considered for dataset generation and evaluation for spatial domain prediction. |
| AT&T | Y | d) A stadium/venue scenario could optionally be considered as well as the indoor hotspot deployment scenario - both for FR2 |
| CATT | Y | It is good to focus on FR2 only. Additionally, AI-based beam management seems more attractive in outdoor due to the challenge brought by high speed. Indoor scenario may not need AI-based approach urgently.  For b), we are open to further consider additional slower UE speed(s), e.g. 3km/h, 30km/h.  For traffic model, FTP traffic shall be evaluated. |
| LGE | Y | a) Support.  b) Agree with adding 3 km/h, 30 km/h for UE speed.  c, d) OK. sub use case-specific scenarios can be optionally considered and companies can provide detailed assumption. |
| Ericsson | Y | 1. Agree 2. -We encourage the possibility of using other traffic models than full buffer. Full buffer cannot be used to make strong predictions of the usefulness of a feature and hence doesn’t provide any insights that assist in drawing SI conclusions.   -Other UE speeds than 60/120 km/h should also be simulated given the Dense Urban scenario. Such as 3/10/30 km/h |
| ZTE, Sanechips | Y | We generally think that the baseline SLS assumptions should be sub-use-case specific to distinguish the spatial-domain and time-domain beam prediction. The following revisions are suggested to be considered further.   1. UMi scenario for spatial-domain beam prediction and HST scenario for time-domain beam prediction can be optionally simulated. 2. Multiple UEs can be dropped for each of the 21 sectors/cells for AI/ML model generalization improvement. 3. As mentioned by some other companies, more UE mobility such as 3km/h, 30km/h and 300km/h can be included for evaluation. 4. An UE antenna configuration of 2 panels (left, right) can also be taken into consideration especially for spatial-domain beam prediction. As captured in Table A.2.1-4 of TR 38.802, a suitable configuration option of UE antenna is provided as (Mg, Ng) = (1, 2) for NR MIMO evaluation. |
| CAICT | Y | SLS for FR2 with single scenario case for dataset should be baseline. |
| Samsung | Y | 1. Yes. Although we think LLS can be used for time domain beam prediction, at this stage we think LLS should also be considered, especially considering some of LLS is effective for some use cases of time domain prediction. 2. For Table 1, the following parameters can be further considered:   - Same as comments from Apple and others, 30kmph can be a good starting point to be researched.  - For panel number, as indicated in our paper, the simplified BS antenna configuration with only 1 panel used can be considered, which is equivalent in beam selection accuracy performance to be evaluated in Phase-I.  - For beam correspondence, to simplify the study, we can prioritize BC without SRS assistance, which is more common in existing product.   1. Yes. Parameters in Table 2 is good to us.   Other scenarios can be considered if the existing SLS setup is not appropriate for a certain use case which is accepted in the use case email thread. |
| Fujitsu | Yes | 1. Yes. 2. The beam prediction in spatial domain and time domain should be provided with different parameter tables.   In table 1, 120km/h in urban scenario is not practical, UE mobility with 30km/h and 90km/h are recommended.  For spatial domain prediction, at least the following parameters are recommended   * Low UE mobility (e.g. 3km/h)   more UE drops per sector/cell (e.g. 10 dropped UEs per sector/cell) for easy training data collection. |
| CMCC | Y | a) Besides SLS, LLS based channel model can be optional used.  b) and d) We propose to consider two scenarios. One is dense urban with low UE speed (e.g., 30km/h, 60km/h), another is HST/highway scenario with UE speed 120km/h, 350km/h, 500km/h. |
| MediaTek | Y | b. The number of UEs dropped in each cell needs not to be limited. Also, lower UE speeds may need to be considered (e.g., 3km/h and 30km/h)  c. We agree that FR2 can be used as the baseline assumption |
| HW/Hisi | Y | a) LLS should also be considered at least for spatial domain prediction.  b) For table 1, the following modification can be considered:   * BW can be 20MHz for simplifying simulation and accelerating model training at the beginning stage * 3km/h , 30km/h can be added to UE speed * For gNB and UE antenna configuration, single panel can be optional to reduce the simulation time and this would also show the performance gain.   c) yes, NLOS should also be considered. |
| InterDigital | Y | a) We agree that system level simulation should be a baseline.  b) 1. We believe that the suggest evaluation assumptions are focused on L1-RSRP evaluation with time domain prediction, but includes some other evaluation assumptions for system level performance and spatial domain prediction. We suggest to provide different evaluation assumptions for each scenario reflecting our comments in the below.  2. One UE dropped for each cell may be fine for L1-RSRP measurement but not fine for evaluating system performance. We suggest to include 10 UEs for evaluation system performance.  3. 120 km/hr in dense urban is not a realistic evaluation assumption. We suggest to add 3km/hr and 30 km/hr.  4. Link adaptation, traffic model and UE receiver type are for evaluating system level performance, but system level performance is not included in ‘Algorithm details (when applicable)’. We suggest adding system level performance.  5. For evaluating system level performance, full buffer traffic model is not realistic. We suggest using FTP model instead of full buffer traffic.  c) We are fine with Dense Urban scenario (FR2).  d) For spatial domain prediction, view, indoor channels such as indoor factory should be included as well as dense urban. For indoor scenario, we suggest the following antenna configuration.  Panel model 1, Mg = 1, Ng = 1, P = 2, dH = 0.5λ, (M, N, P, Mg, Ng) = (2, 4, 2, 1, 1) |
| Lenovo | Y | 1. Yes 2. Along with `High Speed@FR2’, it is recommended to also consider moderate and low speeds, for example, including 3km/hr and 30km/hr for UE Speed for spatial domain beam prediction. 3. Yes. 4. Consider defining a set of multiple scenarios/configurations, such as low/moderate UE speeds, Different antenna configurations (with more than one antenna panel) at gNB/UE. It is also recommended to define baseline EVM that can evaluate the generalization and scalability of the proposed models. |
| Qualcomm |  | 1. Yes 2. 1- “One UE is dropped for each of the 21 sectors/cells” 🡪 In this case, we need to make sure the training dataset is generic enough. To achieve this, we can consider sufficient number of random initial UE deployment in each cell and random UE trajectory, as discussed in Option #2 and Option #3 in Section 1.2.2 of this document. Considering random UE trajectory, the prospect of moving UEs across different cells need to be considered, as it will affect the beam prediction performance.   2- More set of UE speeds should be added including but not limited to 30 km/h. To evaluate the generalization capability of AI/ML model, it would be beneficial to have the option to train and test over different UE speeds.   1. Yes, but do not see the necessity to consider “UMa LOS” as the baseline scenario. Baseline scenario could be UMa with mixed LOS/NLOS. 2. Indoor hotspot can also be considered as a scenario with 3km/h UE speeds. The prospects of random UE trajectory and therefore moving across cells need to be considered. |
| Futurewei | N | For dataset construction for AI/ML based BM, SLS is used. However, system level simulation is not needed for performance evaluation. In the case of spatial domain prediction, the beam prediction accuracy (e.g., in term of RSRP difference comparing to full sweeping) is already a proper and straightforward metric of performance and system simulation does not really add new information even with significantly more efforts for this use case. Same can be said for time domain prediction sub use case. |
| NTT DOCOMO | Y | As other companies proposed, we also think low speed and FR1 should be considered. |

Summary of Question 1-2:

The following table summarized the comments from companies:

|  |  |  |
| --- | --- | --- |
| Parameters | Values | Comments |
| Frequency Range | FR2 @ 30 GHz,   * SCS: 120 kHz * BW: 80 MHz | Consider FR1 as well:   * Supported by (2): Apple, NTT DOCOMO |
| Scenarios | High speed @FR2:   * Dense Urban (macro-layer only, TR 38.913) @FR2, 200m ISD, 2-tier model with wrap-around (7 sites, 3 sectors/cells per site), 100% outdoor   One UE is dropped for each of the 21 sectors/cells (see mobility description below) | For Dense Urban:   * cell with 3 sectors:   + : Apple * More UE per sector:   + Supported by (9) : Nokia/NSB, Xiaomi, ZTE/Sanechips, Fujitsu, MediaTek, InterDigital, Qualcomm   Other scenarios:   * Indoor factory:   + Supported by: InterDigital * Indoor hotspot (for spatial domain)   + Supported by: OPPO, AT&T, Qualcomm * Stadium/venue   + Supported by: AT&T * HST/highway   + Supported by: CMCC(120km/h, 350km/h, 500km/h.) ZTE(300km/h) |
| UE Speed | For Dense Urban: 60 km/hr and 120 km/hr | 30km/h   * Supported by (13): Apple, Xiaomi, vivo, CATT, LGE, Ericsson, Samsung, Fujitsu, MediaTek, HW/HiSi, InterDigital, Lenovo   3km/h (for spatial domain prediction)   * Supported by (10): OPPO, CATT(open), LGE, Ericsson, Fujitsu, MediaTek, HW/HiSi, InterDigital, Lenovo   Other speed:   * 45/60/75/90km/h (sub-use case specific): Nokia/NSB * 10km/h: Ericsson * 300km/h: ZTE * 90km/h: Fujitsu * More UE speed: Qualcomm |
| Transmission Power | Maximum Power and Maximum EIRP for base station and UE as given by corresponding scenario in 38.802 (Table A.2.1-1 and Table A.2.1-2) |  |
| BS Antenna Configuration | (M, N, P, Mg, Ng) = (4, 8, 2, 2, 2). (dV, dH) = (0.5, 0.5) λ. (dg,V, dg,H) = (2.0, 4.0) λ  Companies to explain TXRU weights mapping.  Companies to explain beam selection.  Companies to explain number of BS beams | Single panel   * Vivo, Samsung, HW/Hisi   For indoor scenario:   * Panel model 1, Mg = 1, Ng = 1, P = 2, dH = 0.5λ, (M, N, P, Mg, Ng) = (2, 4, 2, 1, 1)   + Supported by: InterDigital |
| BS Antenna radiation pattern | TR 38.802 Table A.2.1-6, Table A.2.1-7 |  |
| UE Antenna Configuration | Number/location of panels: 3 panels (left, right, and back)  Panel structure: 1x4x2 or (M, N, P) = (1, 4, 2), dH = 0.5 λ  Companies to explain TXRU weights mapping.  Companies to explain beam and panel selection.  Companies to explain number of UE beams | 2 panels (left, right) with (Mg, Ng) = (1, 2)   * Supported by: ZTE, Sanechips   Single panel   * Supported by: HW/Hisi |
| UE Antenna radiation pattern | TR 38.802 Table A.2.1-8, Table A.2.1-10 |  |
| Beam correspondence | Companies to explain beam correspondence assumptions (in accordance to the two types agreed in RAN4) | Prioritize BC without SRS assistance   * Samsung |
| Link adaptation | Based on CSI-RS |  |
| Traffic Model | Full buffer | FTP traffic   * Supported by: CATT, InterDigital   Other traffic   * Supported by: Ericsson |
| Inter-panel calibration for UE | Ideal, non-ideal following 38.802 (optional) – Explain any errors |  |
| Control and RS overhead | Companies report details of the assumptions |  |
| Control channel decoding | Ideal or Non-ideal (Companies explain how it is modelled) |  |
| UE receiver type | MMSE-IRC as the baseline, other advanced receiver is not precluded |  |
| BF scheme | Companies explain what scheme is used |  |
| Transmission scheme | Multi-antenna port transmission schemes  Note: Companies explain details of the using transmission scheme. |  |
| Other simulation assumptions | Companies to explain serving TRP selection  Companies to explain scheduling algorithm |  |
| Algorithm details (when applicable) | Companies to report:   * Beam reporting mechanism * Beam metric L1-RSRP * Number of active panels | System level performance.  InterDigital |
| Other potential impairments | Not modelled (assumed ideal).  If impairments are included, companies will report the details of the assumed impairments |  |

Table 2 Baseline assumptions for SLS: Additional simulation assumptions for Dense Urban scenario (FR2) mainly from TR 38.802 Table A.2.1-1, and TR 38.901.

|  |  |  |
| --- | --- | --- |
| Parameters | Values | Company’s view |
| Carrier Frequency | 30 GHz |  |
| Scenario | UMa LOS | Mixed LOS/NLOS   * Nokia, Qualcomm * considering a distance-dependent LoS probability function as currently done in 38.901.   NLoS:   * HW/HiSi |
| System BW | 80 MHz | 20MHz   * HW/HiSi |
| BS Tx Power | 40 dBm |  |
| Maximum UE Tx Power | 23 dBm |  |
| BS receiver Noise Figure | 7 dB |  |
| UE receiver Noise Figure | 10 dB |  |
| Inter site distance | 200m |  |
| BS Antenna height | 25m |  |
| UE Antenna height | 1.5 m |  |
| Car penetration Loss | 38.901, sec 7.4.3.2: μ = 9 dB, σp = 5 dB |  |

#### 2nd round: FL2 High Priority Question 1-2a

Moreover, most of companies support proposal 1-2, i.e., to use SLS as baseline too, although some company think LLS can be used as well. For the sake of progress, moderator suggest the companies can be flexible for SLS as baseline too.

Based on the above summary, the following proposal can be considered:

**Proposal 1-2:**

* **For dataset construction and performance evaluation for AI/ML based BM, SLS is the baseline tool.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU (Beijing Jiao Tong University) , Spreadtrum, CMCC, MediaTek, NVIDIA, Qualcomm, InterDigital** |
| Objecting companies | **[HW/HiSi] (**we are not objecting to SLS, but see a clear benefit with using LLS additionally to easily obtain the RSRP for spatial domain BM and would to discuss why some proponents would object to LLS at this stage). **Futurewei, Lenovo** (not objecting SLS, accepting 1-2a), Intel (Not OBJECTING but think 1.2A should be adopted) |

**Proposal 1-2a:**

* **For dataset construction and performance evaluation for AI/ML based BM, SLS is the baseline tool.**
  + **LLS can be used as a complementary evaluation methodology for AI/ML in beam management**

|  |  |
| --- | --- |
| Supporting companies | **DCM, Fujitsu, Samsung, HW/HiSi, CMCC, Lenovo, Intel** |
| Objecting companies | **Nokia (sub-bullet), CATT, CAICT, Ericsson, MediaTek, Futurewei, Qualcomm** |

**Question 1-2a:**

1. Please provide your view on **Proposal 1-2** and **Proposal 1-2a**:

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | For BM, it is not clear to us how the proponents of LLS plans to simulate as it is not be possible to evaluate anything meaningful to our reading. |
| LGE | Support proposal 1-2. |
| CATT | Agree with Nokia. Evaluate effort on SLS should be enough. |
| CAICT | We believe SLS is enough for dataset construction and performance evaluation. |
| Vivo | Support 1-2. We can live with Proposal 1-2a. |
| Ericsson | SLS should be sufficient for the scope of the SI |
| Samsung | For Proposal 1-2a, an LLS can be used for at least dataset construction, so we can use it at least for the Phase I evaluation (i.e., evaluation on beam measurement related KPIs) as a simpler metric. To provide dataset for the model generalization, at least, CDL extension should be considered which includes spatially continuous modelling and provides channels with different UE locations. Reusing the CDL extension used in the Rel-17 HST-SFN EVM and applying random trajectory in our discussed paper can be considered for the time domain prediction. We are also open to use of CDL extension applying spatial consistent in 9.6.3.1 in TR38.901 for the spatial domain prediction and time domain prediction. |
| HW/HiSi | Sypport 1-2a |
| CMCC | For spatial domain beam prediction, dataset generated from SLS and evaluated with beam measurement related KPIs can be used for initial phase evaluation. |
| MediaTek | We believe that SLS is enough. |
| Futurewei | We will use SLS to generate labels for AI/ML model training. For performance evaluation of AI/ML based BM, we believe the performance of AI/ML model (L1-RSRP difference) already reflects the system level performance and we don’t need additional step of using SLS for BL. To understand better the proponents’ position, we need to understand how companies plan to conduct system simulation for performance evaluation. For example:   * In the case of spatial prediction, is the beam selection done at the beginning of the simulation and then fixed for the simulation time? If that’s the case, what additional insight does it provide comparing to (L1-RSRP difference)? * In the case of time domain prediction, do you plan to run the system simulation for a very long time such that performance impacts from representative events can be captured? |
| Lenovo | We support Proposal 1-2a as we think LLS can also be an effective EVM. |
| Qualcomm | For the reasons mentioned before (including possible overfitting issue), we see no strong reason for considering LLS, and believe SLS should be sufficient. |
| Intel | For spatial domain prediction, LLS channel models can be used to prepare datasets for Phase 1 evaluations. Since the RSRP data is generally normalized for pathloss, different orientation of UE/BS arrays along with random AoA, AoD, ZoA, ZoD can yield enough variability for a meaningful dataset construction. In addition, LOS/NLOS or mixed channel models can be used construct datasets. While are OK with using SLS as the main tool, we don’t see a reason to preclude CDL channel models at this early stage. |
| InterDigital | We support Proposal 1-2. In our view, although LLS can provide good performance evaluation method with relatively low evaluation complexity, it is difficult to show adequate analysis for AI/ML based beam prediction. |

#### 3rd round: FL3 High Priority Question 1-2b

Summary of Question 1-2a

**Proposal 2-1** with only SLS as baseline tool has 18 companies support while 4 companies prefer to have LLS as well.

**Proposal 2-1a** with SLS as baseline and LLS as complementary evaluation methodology has 8 companies support while has 7 companies objected.

Feature feels that the situation is similar as for CSI evaluation. Therefore, FL would like to try the similar wording as current agreement for CSI, and hope companies can be flexible to accept this proposal.

**Proposal 2-1b:**

* **For the performance evaluation of the AI/ML in beam management, system level simulation approach is adopted as baseline**
  + **Link level simulation is optionally adopted**

|  |  |
| --- | --- |
| Supporting companies | **DCM, OPPO, CAICT, CMCC, CATT, Fujitsu, LGE, Samsung,Ericsson, HW/HiSi, Nokia, Lenovo, Qualcomm, Xiaomi, MediaTek, ZTE** |
| Objecting companies | **Futurewei** |

**Question 1-2b:**

1. Please provide your view on **Proposal 1-2b**:

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | We are fine with proposal 1-2 and 1-2a. For the progress, we prefer to make LLS part FFS in the proposal 2-1b. While considering the evaluation methodology of SLS, we can discuss whether to adopt LLS optionally on the side. |
| OPPO | We can live with it for the sake of progress |
| CAICT | We are fine with the proposal. |
| CMCC | For spatial domain beam prediction, dataset generated from SLS and evaluated with beam measurement related KPIs can be used for initial phase evaluation. |
| CATT | We are fine with the proposal. |
| LGE | OK |
| Ericsson | OK |
| HW/HiSi | Support.  There seems to be a typo on the proposal. Shouldn’t the numbering be 1-2b? |
| Nokia | Ok for the sake of progress. |
| Futurewei | We responded to this question in round 2 discussion.  We will use SLS to generate labels for AI/ML model training. For performance evaluation of AI/ML based BM, we believe the performance of AI/ML model (L1-RSRP difference) already reflects the system level performance and we don’t need additional step of using SLS for BL. To understand better the proponents’ position, we need to understand how companies plan to conduct system simulation for performance evaluation. For example:   * In the case of spatial prediction, is the beam selection done at the beginning of the simulation and then fixed for the simulation time? If that’s the case, what additional insight does it provide comparing to (L1-RSRP difference)?   In the case of time domain prediction, do you plan to run the system simulation for a very long time such that performance impacts from representative events can be captured? |
| ZTE, Sanechips | Support for progress. |

#### 2nd round: FL2 High Priority Question 1-2-1

**Proposal 1-2-1:**

* **At least for time domain prediction and spatial and time domain prediction (if support), Dense Urban (macro-layer only, TR 38.913) is the basic scenarios for dataset generation and performance evaluation.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel, InterDigital** |
| Objecting companies |  |

**Question 1-2-1:**

1. Please provide your view on **Proposal 1-2-1.**
2. Please indicate if any other scenario needs to be optional for time domain prediction and spatial and time domain prediction (if supported).

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Companies can report if they use other assumptions as always. RAN1 defining multiple scenarios could complicate the discussions and simulation efforts. |
| LGE | OK |
| CAICT | We support Dense Urban is used as baseline and open for other scenarios as optional. |
| Vivo | Fine with above proposal. However, we think A different scenarios should also be included, e.g., UMi, for generalization performance evaluation purpose. |
| HW/HiSi | Similar as Nokia |
| Futurewei | We are ok with the proposal and companies may report results for other scenarios as well if they wish. |
| Lenovo | Support |
| Qualcomm | Agree with proposal. Further, we believe other scenarios (including, but not limited to InH) can also be considered as optional, e.g., for assessing AI/ML model generalization performance. |
| Intel | Indoor scenarios can also be considered since they are also a very valid use case. We can mention that other scenarios are not precluded from the SI |
| InterDigital | We support the proposal. |

#### 3rd round: FL3 High Priority Question 1-2-1a

Summary of Question 1-2-1

All the companies are fine with the **Proposal 1-2-1**. One sub-bullet is added to clarify that other scenarios are not precluded. Moreover, some editorial changes are made, and align the terminology in email discussion [06] for sub-use case discussion.

**Proposal 1-2-1a:**

* **At least for temporal beam prediction ~~and spatial and time domain prediction (if suppor~~t), Dense Urban (macro-layer only, TR 38.913) is the basic scenario~~s~~ for dataset generation and performance evaluation.** 
  + **Other scenarios are not precluded.**

|  |  |
| --- | --- |
| Supporting companies | **OPPO, CAICT, CMCC, CATT, Fujitsu, LGE, Samsung,Ericsson, HW/HiSi, Nokia, Futurewei, Lenovo, Qualcomm, Xiaomi, MediaTek, ZTE** |
| Objecting companies |  |

**Question 1-2-1a:**

a) Please provide your view on **Proposal 1-2-1a.**

|  |  |
| --- | --- |
| Company | Comments |
| Fujitsu | Support it. |
| LGE | OK |

#### 2nd round: FL2 High Priority Question 1-2-2

**Proposal 1-2-2:**

* **For spatial domain prediction, down select among one of the options for the basic scenarios for dataset generation and performance evaluation.** 
  + **Option 1: Dense Urban (macro-layer only, TR 38.913)**
  + **Option 2: Indoor hotspot**
  + **Option 3: Other scenarios**

|  |  |
| --- | --- |
| Supporting companies for option 1 | **Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel, InterDigital** |
| Supporting companies for option 2 | **Qualcomm, Intel** |
| Supporting companies for option 3 | **Vivo(UMi can also be included for generalization performance evaluation)**  **InterDigital (Indoor Factory can be included as optional)** |

**Question 1-2-2:**

1. Please provide your view on **Proposal 1-2-2.**
2. Please indicate if any other scenario needs to be optional for time domain prediction and spatial and time domain prediction (if supported).

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Companies can report if they use other assumptions as always. RAN1 defining multiple scenarios could complicate the discussions and simulation efforts. |
| NTT DOCOMO | Support the proposal.  For generalization evaluation, companies can use different environments from one selected as baseline. |
| LGE | Support option 1 as baseline. InH or other scenarios can be optionally used. |
| OPPO | We are also open to Option 2. |
| CATT | We prefer option1. AI/ML-based beam management is more suitable for outdoor scenarios where high UE speed may make beam management challenging. |
| CAICT | We support option 1 as baseline and open for other scenarios. |
| ZTE, Sanechips | Option 1 can be a baseline with other scenarios being optionally used. |
| vivo | **UMi can also be included for generalization performance evaluation** |
| HW/HiSi | Option 1, other scenarios can be optional |
| MediaTek | We should focus on Dense Urban scenario. |
| Futurewei | We are ok with the proposal and companies may report results for other scenarios as well if they wish. |
| Lenovo | Support |
| Qualcomm | Agree with proposal. Further, we believe other scenarios (including, but not limited to InH) can also be considered as optional, e.g., for assessing AI/ML model generalization performance. |
| Intel | Support Option 1 and 2. In our view, there is no need to down-select. Baseline and other optional scenarios can be listed, and it is up to companies to report which scenarios are under consideration |
| InterDigital | We are fine with Option 1 and propose to add Indoor Factory scenario as optional. |

#### 3rd round: FL3 High Priority Question 1-2-2a

Summary of Question 1-2-2

The summary of supporting companies for basic scenarios for spatial domain prediction:

* Option 1: Dense Urban (macro-layer only, TR 38.913)
  + Supported by (23): Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, FUTUREWEI, LENOVO, Qualcomm, Intel
* Option 2: Indoor hotspot
  + Supported by (2): Qualcomm, Intel
* Option 3: Other scenarios
  + Vivo

Assumptions for generalization evaluation will be discussed separated in section 2.2.1. Based on the inputs, the following proposal can be considered (with alignment of the terminology):

**Proposal 1-2-2a:**

* **For spatial-domain beam prediction, Dense Urban (macro-layer only, TR 38.913) is the basic scenario for dataset generation and performance evaluation.** 
  + **Other scenarios are not precluded.**

|  |  |
| --- | --- |
| Supporting companies | **DCM,OPPO, CAICT, CMCC, CATT, Fujitsu, LGE, Samsung,Ericsson, HW/HiSi, Nokia, Futurewei, Lenovo, Qualcomm, Xiaomi, MediaTek, ZTE** |
| Objecting companies |  |

**Question 1-2-2a:**

a) Please provide your view on **Proposal 1-2-2a.**

|  |  |
| --- | --- |
| Company | Comments |
| Fujitsu | Support it. |
| LGE | OK |

#### 2nd round: FL2 High Priority Question 1-2-3

**Discussion points 1-2-3:**

For single scenarios of dataset generation and performance evaluation for with AI/ML in BM, the following assumptions are used:

* Carrier Frequency: 30GHz

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, InterDigital** |
| Objecting companies |  |

* Scenarios:
  + For Dense Urban (macro-layer only, TR 38.913),
    - Deployment: 200m ISD, 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.
    - System BW: 80MHz
  + ~~FFS on other scenarios for each sub-use case, including~~ 
    - ~~Indoor hotspot, Indoor factory, Stadium/venue, HST/highway~~

|  |  |
| --- | --- |
| Supporting companies | **Nokia, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, InterDigital** |
| Objecting companies |  |

* UE Speed
  + For spatial domain beam prediction: 3km/h, FFS on other optional speed
  + For time domain beam prediction: 30km/h, FFS on other optional speed

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo (also would like to have 60km/h),Ericsson, Samsung, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, InterDigital** |
| Objecting companies |  |

* UE distribution:
  + UE distribution:
    - For data generation: company report the assumptions.
    - For performance evaluation: [1] UE per sectors/cells at least for dataset generation.
  + For spatial domain beam prediction: 80% indoor and 20% outdoor
  + For temporal domain prediction: 100% outdoor
  + Node: UE trajectory modeling is discussed separately

|  |  |
| --- | --- |
| Supporting companies | **Nokia (other than the first bullet), vivo, Samsung, MediaTek, Lenovo, InterDigital (other than the first bullet)** |
| Objecting companies | **Nokia (first bullet), InterDigital (the first bullet, in addition “temporal domain” should be changed to “time domain”)** |

* BS Antenna Configuration
  + Down-select among following options
    - Option 1: Four panels: (M, N, P, Mg, Ng) = (4, 8, 2, 2, 2), (dV, dH) = (0.5, 0.5) λ. (dg,V, dg,H) = (2.0, 4.0) λ
    - Option 2: One panel: (M, N, P, Mg, Ng) = (2, 4, 2, 1, 1), (dV, dH) = (0.5, 0.5) λ.
    - Option 3: One panel: (M, N, P, Mg, Ng) = (4, 8, 2, 1, 1), (dV, dH) = (0.5, 0.5) λ.

|  |  |
| --- | --- |
| Supporting companies for option 1 | **Nokia (baseline), LGE, ZTE, Ericsson, Lenovo, Qualcomm** |
| Supporting companies for option 2 |  |
| Supporting companies for option 3 | **Nokia (optional), DCM (baseline) , Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel (Baseline), InterDigital** |

* UE Antenna Configuration
  + Down-select among following options
    - Option 1: 3 panels (left, right, and back): Panel structure: 1x4x2 or (M, N, P) = (1, 4, 2), dH = 0.5 λ
    - Option 2: 2 panels (left, right) with (Mg, Ng) = (1, 2)

|  |  |
| --- | --- |
| Supporting companies for option 1 | **Nokia, LGE, OPPO, ZTE, vivo. Ericsson, Qualcomm** |
| Supporting companies for option 2 | **Nokia, DCM, LGE, CATT CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel** |

* Traffic Model: FFS on one or both options for system performance evaluation (if support)
  + Option 1: Full buffer
  + Option 2: FTP model 3 with 50B packets and 1ms mean inter-arrival time

|  |  |
| --- | --- |
| Supporting companies for option 1 | **Nokia, Fujitsu, CATT, CAICT, Ericsson, Samsung, CMCC, MediaTek, NVIDIA, Lenovo, Qualcomm** |
| Supporting companies for option 2 | **Nokia, CATT, vivo, Ericsson, NVIDIA, Qualcomm InterDigital (for throughput measurement. We are not still sure that what’s the meaning of Full buffer and FTP traffic for L1-RSRP measurement. In this case, CSI-RS/CSI reporting periodicity/offset should be enough.)** |

**Question 1-2-3:**

1. Please provide your views on the discussion points 1-2-3
2. For the parameter in Table 1/ 2 in the appendix not listed in proposal 1-2-1, please indicate whether you have any further proposed values or discussion point.
3. Any other parameters need to be aligned/defined as parameters.

|  |  |
| --- | --- |
| Company | Comments |
|  |  |
| Nokia | We do have a strong concern on “UE distribution” part.   * “Company to report the assumptions” : this does not have alignment that seems critical for evaluation mythology. * “UE per sectors/cells at least for dataset generation” : As mentioned before in earlier round, we suggest at least 10 UEs/sector dropped uniformly in random points of the sector should be considered. With a single UE assumption, SLS perf evaluation is not realistic as the single UE assumption does impact the interference and consequently the throughput, which is likely to provide unreal results. Also, having one UE drop it is an oversimplified scenario that would complicate the data generation as the data collected for each network drop is limited.   A similar view seems to be supported by multiple companies.  More UE per sector:   * + Supported by (9) : Nokia/NSB, Xiaomi, ZTE/Sanechips, Fujitsu, MediaTek, InterDigital, Qualcomm |
| Fujitsu | a) for UE Antenna Configuration, single panel should not be precluded.  b) Some constraints for the range of selective beams per TRP sector (Dense urban, macro-layer only) are recommended such as [-60, 60] in azimuth domain and [90, 160] in zenith domain |
| LGE | Our view is provided in the table above.  For UE distribution, 100% outdoor can be the baseline for spatial domain beam prediction.  For FTP model, prefer to add option 3 as below, which is more typical scenario in Rel-17 EVM. And, we support option 3.   * + Option 3: FTP model 1 with packet size 0.5 Mbytes (Other FTP model is not precluded.) |
| CATT | Generally fine with FL’s proposal.  One concern in UE distribution: it seems only discussing dataset construction (and reported by companies) but no clear reference for the number of actual dropped UE. But the UE number may have significant impact to throughput. |
| Xiaomi | Prefer not to evaluate throughput. |
| ZTE, Sanechips | To ease dataset generation and avoid too unrealistic scenario assumption, we generally think that multiple UEs (typically at least 20 UEs) can be dropped per sectors/cells. |
| vivo | 60km/h speed should also be considered. |
| Ericsson | More than one speed should be considered, for example 60 km/h as well. |
| HW/HiSi | a) UE with a single panel should not be precluded. More UEs per sector would be considered for facilitating data generation. |
| Futurewei | We agree with Xiaomi that throughput evaluation is not important as L1-RSRP difference/gap already reflects system performance. |
| Lenovo | UE speed: For time domain beam prediction: 30km/h, FFS consider 120km/h, (highways scenario)  BA Antenna configuration: We recommend both Option 1 and Option 3 |
| Qualcomm | UE speed: for time domain beam prediction, more speeds should be considered, e.g., 60 km/h.  UE distribution: Suggest adding indoor to time domain prediction as well. Believe indoor should not be precluded.  BS antenna configuration: As we are considering an outdoor setting, suggest changing option 3 parameters to: (M, N, P, Mg, Ng) = (8, 32, 2, 1, 1), (dV, dH) = (0.5, 0.5) λ or adding Option 4 with these new parameters.  UE antenna configuration: Prefer Option 1, OK with Option 2.  Traffic model: Is Option 2 meant to target a specific scenario, e.g., URLLC? The 50B payload may be limiting and suggest not limiting to this specific scenario and have more options targeted for different use cases. |
| Intel | For UE distribution, the second sub-bullet is not clear. It talks about performance evaluation and data generation. From our perspective, the dataset can be generated from many UEs randomly dropped in the deployment. No need to limit the number of UEs since RSRP and beam index may not depend on interference. For performance evaluation, we do not think full end to end SLS simulation is required. But if supported, we should use the standard 10UEs/cell deployment. The 1 UE per cell deployment from Rel-17 beam management was a special case assumption and not valid for general performance evaluation. |
| InterDigital | In our view, 1 UE per sector is not enough to evaluate whether proposed specification enhancements are beneficial or not. At least 10 UEs or even 20 UEs should be considered for the evaluation. In addition, we are not sure the meaning of traffic model in L1-RSRP measurement. Do we actually evaluate L1-RSRP or optimal beams for scheduled PDSCHs? In the previous Table 1, L1-RSRP measurement was based on CSI-RS. In that case, actually for L1-RSRP measurement/reporting, there’s no need to define any traffic model for the evaluation. |
| HW/HiSi |  |

#### 3rd round: FL3 High Priority Question 1-2-3a

Summary of the question 1-2-3

Table 1.2-1 Assumption for Dense Urban

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Values** | **FL’s summary** |
| **Frequency Range** | FR2 @ 30 GHz   * SCS: 120 kHz | For FR2@30GHz: 22 supporting companies on 30GHz in 2nd round, no objecting company. |
| **Deployment** | 200m ISD, 2-tier model with wrap-around (7 sites, 3 sectors/cells per site) | 20 supporting companies;  No objecting company. |
| **Channel mode** | UMa with distance-dependent LoS probability function defined in Table 7.4.2-1 in TR 38.901. | 20 supporting companies;  No objecting company. |
| **System BW** | 80MHz | 20 supporting companies;  No objecting company. |
| **UE Speed** | * For spatial domain beam prediction, 3km/h * For time domain beam prediction: 30km/h (baseline), 60km/h (optional) * Other values are not precluded | 20 supporting companies;  No objecting company.  Three companies suggest to have 60km/h as well.  FL adjusted proposal, to resolve potential concerns from companies.  Also note that, assumptions for generalization is separated discussed in section 2.2.1 |
| **UE distribution** | * 10 UEs per sectors/cells for evaluation. More UEs per sectors/cells for data generation is not precluded. * For spatial domain beam prediction: 100% outdoor * For time domain prediction: 100% outdoor | As commented by Nokia and some other companies in 1st around.  The intention for 2nd round is not limited number of UE for data generation for training, while for performance, from FL’s view single user should be enough.  For UE distribution, one company comment 100% outdoor shall be used for spatial domain beam prediction as well. The proposal is adjusted accordingly.  Let’s have some discussion for these issues |
| **Transmission Power** | Maximum Power and Maximum EIRP for base station and UE as given by corresponding scenario in 38.802 (Table A.2.1-1 and Table A.2.1-2) | No comment received in 1st round |
| **BS Antenna Configuration** | * Option 3: One panel: (M, N, P, Mg, Ng) = (4, 8, 2, 1, 1), (dV, dH) = (0.5, 0.5) λ as baseline * Other assumptions are not precluded.   Companies to explain TXRU weights mapping.  Companies to explain beam selection.  Companies to explain number of BS beams | 23 companies support option 3 as baseline. 1 company support this as optional.  6 companies support option 1 as baseline.  Therefore, FL suggests to have option 3 as baseline, while other options are not precluded.  No comment received on the last three bullets in the 1st round. |
| **BS Antenna radiation pattern** | TR 38.802 Table A.2.1-6, Table A.2.1-7 | No comment received on the last three bullets in the 1st round. |
| **UE Antenna Configuration** | * Option 2: 2 panels (left, right) with (Mg, Ng) = (1, 2) as baseline * Other assumptions are not precluded   Companies to explain TXRU weights mapping.  Companies to explain beam and panel selection.  Companies to explain number of UE beams | 19 companies support option 2  7 companies support option 1  Therefore, FL suggests to have option 2 as baseline, while other options are not precluded.   * No comment received on the last three bullets in the 1st round. |
| **UE Antenna radiation pattern** | TR 38.802 Table A.2.1-8, Table A.2.1-10 | No comment received on the last three bullets in the 1st round. |
| **Beam correspondence** | Companies to explain beam correspondence assumptions (in accordance to the two types agreed in RAN4) | One company suggest to prioritize BC without SRS assistance  In FL’s understanding, this can be reported by company. |
| **Link adaptation** | Based on CSI-RS | No comment received on the last three bullets in the 1st round. |
| **Traffic Model** | Option 1: Full buffer as baseline  Other options are not precluded | 11 companies support option 1.  6 companies support option 2.  One company suggest to add Option 3 as “FTP model 1 with packet size 0.5 Mbytes (Other FTP model is not precluded.)”  In FL’s opinion, option 1 has slightly majority, and would like to check whether full buffer as baseline and companies can reports other options can be accepted or not. |
| **Inter-panel calibration for UE** | Ideal, non-ideal following 38.802 (optional) – Explain any errors | No comment received on the last three bullets in the 1st round. |
| **Control and RS overhead** | Companies report details of the assumptions |
| **Control channel decoding** | Ideal or Non-ideal (Companies explain how it is modelled) |
| **UE receiver type** | MMSE-IRC as the baseline, other advanced receiver is not precluded |
| **BF scheme** | Companies explain what scheme is used |
| **Transmission scheme** | Multi-antenna port transmission schemes  Note: Companies explain details of the using transmission scheme. |
| **Other simulation assumptions** | Companies to explain serving TRP selection  Companies to explain scheduling algorithm |
| **~~Algorithm details (when applicable)~~** | ~~Companies to report:~~   * ~~Beam reporting mechanism~~ * ~~Beam metric L1-RSRP~~ * ~~Number of active panels~~ | In FL’s opinion, there is no strong need to have this. In general, companies can report necessary assumption. |
| **Other potential impairments** | Not modelled (assumed ideal).  If impairments are included, companies will report the details of the assumed impairments | No comment received on the last three bullets in the 1st round. |
| **BS Tx Power** | 40 dBm |
| **Maximum UE Tx Power** | 23 dBm |
| **BS receiver Noise Figure** | 7 dB |
| **UE receiver Noise Figure** | 10 dB |
| **Inter site distance** | 200m |
| **BS Antenna height** | 25m |
| **UE Antenna height** | 1.5 m |
| **Car penetration Loss** | 38.901, sec 7.4.3.2: μ = 9 dB, σp = 5 dB |

**Proposal 1-2-3a:**

* **For dataset generation and performance evaluation for AI/ML in beam management, take the parameters (when applicable) in Table 1.2-1 for Dense Urban scenario**

|  |  |
| --- | --- |
| Supporting companies | **DCM, CAICT, CMCC, CATT, Fujitsu, LGE, Samsung, Ericsson, [HW/HiSi] (with parameter update), Nokia, Futurewei, Lenovo (with changes), Qualcomm, MediaTek, ZTE** |
| Objecting companies |  |

**Question 1-2-3a:**

a) Please provide your view on **Proposal 1-2-3a.**

|  |  |
| --- | --- |
| Company | Comments |
| FL | The intention to add “(when applicable)” is try to resolve the concerns from some companies that this does not imply that system performance will be the baseline KPIs. It is still open to discuss in section 2.1.2.  Moreover, the assumptions for generalization will be discussed separately in section 2.2.1 |
| OPPO | Although the typical implementation for UE is using 3 panels, we can live with it for the sake of progress |
| CAICT | We can support FL’s proposal. |
| Fujitsu | Support it. |
| LGE | OK |
| Ericsson | We don’t see the reason, or which company that suggested not evaluating indoor UEs for the spatial-beam prediction scenario. Suggest reverting to assume 80% indoor 20% outdoor split. The performance KPIs could be reported for each category if needed. |
| HW/HiSi | We suggest to also include a single-cell scenario in the deployment part. This could be a simple option to obtain results quickly |
| Nokia | Ok with the proposal. |
| Lenovo | **Consider the following changes in Table 1.2-1:**  **UE Distribution:** For spatial domain beam prediction: 80% indoor and 20% outdoor as in 38.901 and performance reported separately for indoor and outdoor UEs.  **BS Antenna Configuration**: We should also add Option 1: Four panels: (M, N, P, Mg, Ng) = (4, 8, 2, 2, 2), (dV, dH) = (0.5, 0.5) λ. (dg,V, dg,H) = (2.0, 4.0) λ, in addition to the single panel Option 3. |
| Qualcomm | Agree with the Proposal. If a mixed indoor/outdoor scenario is considered, the prospect of UE indoor/outdoor status update should be considered as the UE moves along a random trajectory (at least applicable to temporal beam prediction). |
| Xiaomi | Unnecessary of the traffic model since it is unnecessary to evaluate the throughput for beam prediction. |
| ZTE, Sanechips | Support the proposal for progress. We agree with Ericsson to consider 80% indoor and 20% outdoor UE distribution for spatial domain beam prediction. Besides, we prefer to add HST scenario with a UE speed of 300km/h as optimal. |
| InterDigital | We support 80% indoor and 20% outdoor UE distribution. We are open to discuss Qualcomm’s proposal on indoor/outdoor status update. In our view, if we support Qualcomm’s proposal, then RAN1 needs to update indoor/outdoor status decision method as well (e.g., UE indoor/outdoor decision based on UE position for the initial UE drop). |

### 1.2.1 Spatial consistency

Several companies discussed spatial consistency for UE time domain beam prediction.

* Vivo [7]: Spatial consistency should be modeled for UE mobility scenario for time domain beam prediction.
* Samsung [9]: For evaluation of beam prediction in the time domain, in addition to the spatially-consistent mobility modelling and UE trajectory modelling, the selection of UE speed, blockage [Section 7.6.4 in TR 38.901], and/or UT rotating [Section 7.6.7 in TR 38.901] should be considered.
* Samsung [9]: Spatially-consistent UE mobility modelling: Procedure A in clause 7.6.3.2 in TR38.901
  + Note: Spatial consistency model is needed to evaluate beam prediction performance, by generating the correlated cluster power, delay, AOD/AOA/ZOD/ZOA.
* Futurewei [12]: To properly model and assess the performance of prediction in time domain, spatial consistency along the mobility trajectory needs to be ensured.
* Apple [15]: System level simulator can be used to generate the dataset, where the number of cells can be 1 to speed up the dataset generation procedure and full spatial consistency modeling is recommended.
  + Other parameters can be selected based on traditional system level evaluation
* Lenovo [18]: Generate the dataset for the model training and evaluation for beam management sub use cases based on the statistical models in TR 38.901 taking in to account spatially consistency.
* Nokia/NSB [19]: A suitable UE mobility model is needed for the spatial-temporal domain beam prediction study.
  + As shown in table 2.4-1, the current UE mobility model for spatial-temporal beam prediction assumes a straight trajectory traveled by the UE with a random direction and channel spatial consistency type-A defined in TR 38.901.
* Intel [20]: Spatially consistent large-scale parameter generation should be used for mobility evaluations. Additionally, only spatial consistency model B in [TR 38.901] can be used for mobility evaluation.

Based on the above views, the following proposal related to spatial consistency for mobility evaluation can discussed.

#### 1st round: FL1 High Priority Question 1-3

**Question 1-3:**

1. Whether spatial consistency should be modeled for time domain beam prediction?
2. Which procedure can be used, procedure A or procedure B in TR38.901, and why?

|  |  |
| --- | --- |
| Company | Comments |
| Apple | a) Y. We think it is also needed for spatial domain beam prediction  b) We think cluster level spatial consistency defined in 7.6.3.1 in 38.901 is enough. |
| Nokia, NSB | 1. Yes, since spatial consistency enables to capture the correlated behaviour of the channel for UE moving over a path 2. We support the use of spatial consistency procedures defined in TR38.901. |
| vivo | a) Support spatial consistency for time domain prediction  b) section 7.6.3.1 in 38.901 is sufficient |
| Intel | Spatial consistency should be modeled and as explained in our paper, Model B in TR38.901 is relevant for mobility where the UE moves across the deployment in a trajectory. |
| NVIDIA | 1. Yes, it’s necessary to model spatial consistency 2. Though the use of spatial consistency procedures defined in TR38.901 can be the baseline, it would be good to check its modeling accuracy. |
| OPPO | a) Yes  b) We are open to procedure A or B |
| AT&T | 1. Yes, needed for spatial and time domain 2. Prefer Model B in TR38.901 |
| CATT | a) This depends on the sub-use case. While it is true that spatial consistency modelling is important for time domain prediction, it is not needed for spatial domain prediction. It can be an optional choice, which is highly recommended for time domain prediction case. |
| LGE | a) Support. It is needed for time domain prediction.  b) Same view as Apple and vivo. Section 7.6.3.1 in 38.901 is enough. |
| Ericsson | 1. Yes, It should also be modeled for spatial beam domain prediction. 2. Our preference is procedure B |
| ZTE, Sanechips | a) It is necessary for spatial consistency modelling to ensure that propagation parameters maintain continuity across multiple realizations. This is particularly important for predicting future optimal beams when the UE moves along a trajectory.  b) We are open to procedure A and B. Per our understanding, procedure A in TR38.901 is more complex than procedure B, yet closer to reality. Compared with procedure B that channel parameters such as delay/power/angles are independent for different UE positions, procedure A applies an iterative algorithm to update the propagation parameters with a restricted moving distance of the UE between consecutive channel realizations. |
| CAICT | 1. Y. If channel prediction is simulated, spatial consistency should be considered. 2. We are open to both procedure A or B. |
| CAICT | a) Yes, spatial consistency model is necessary here.  b) Procedure A for spatial-consistent UE mobility modeling in clause 7.6.3.2 can be used for UE to update the channel cluster power/delay/angles, which helps to generate the consistency for UE with movement. |
| Fujitsu | Spatial consistency should be modeled for time domain beam prediction. It’s not necessary for spatial domain prediction. |
| CMCC | 1. Yes   b) We prefer to use procedure B, since it is closer to realistic scenario. |
| MediaTek | 1. Yes 2. We believe that spatial consistency for mobility needs to be modeled. Procedure B in section 7.6.3.2 of TR38.901 is preferred. |
| Huawei/Hisi | 1. Yes spatial consistency should be modeled. We are open to discuss the details |
| InterDigital | a) Yes as optional. Any company applied a spatial consistency model can report it in their contribution.  b) Procedure B |
| Lenovo | 1. Yes, needed for time domain beam prediction. We think it is not needed for spatial domain beam prediction. 2. We think Procedure A would be sufficient. |
| Qualcomm | 1. Yes, it should also be modeled for spatial (+ temporal) beam prediction 2. Procedure A incorporates temporal evolution of the channel and is our preferred option. We are also open to consider procedure B in which spatial information of Rx positions is taken into account in updating channel realizations which may be beneficial in modeling UE movement on a given trajectory |
| Futurewei | 1. Yes 2. Procedure A in TR38.901. |
| NTT DOCOMO | 1. Yes. It is necessary to model spatial consistency to consider the mobility. 2. We support the use of spatial consistency procedures defined in TR38.901. |
| PML | a) Yes  b) We are open to procedure A or B, and we consider ray tracing to model spatial consistency in the urban scenarios. |

Summary of Question 1-3:

All the companies think spatial consistency should be modeled for time domain beam prediction.

The following options are mentioned:

* Option 1: Spatial consistency defined in 7.6.3.1 in TR 38.901
  + Supported by (7): Apple, Nokia/NSB, vivo, NVIDIA, LGE, NTT DOCOMO
* Option 2: Procedure A in TR38.901
  + Supported by (8): OPPO, ZTE/Sanechips, CAICT, Samsung, Lenovo, Qualcomm, Futurewei
* Option 3: Procedure B in TR38.901
  + Supported by (11): Intel, OPPO, AT&T, Ericsson, ZTE/Sanechips, CAICT, CMCC, MediaTek, InterDigital. Qualcomm (2nd )

In moderator’s understanding, if the simulation considers UE mobility, spatial consistency model defined in 7.6.3.1 I TR 38.901 is not sufficient. Either Procedure A or Procedure B in TR 38.901 shall be considered. Therefore, moderator suggest the companies support Option 1 can further consider Option 2 or 3, or provide explanations on the reasons why Option 1 is sufficient.

#### 2nd round: FL2 High Priority Question 1-3a

**Proposal 1-3:**

* **At least for time domain beam prediction, down-select to one of the following options for spatial consistency:**
  + **Option 1: Spatial consistency defined in 7.6.3.1 in TR 38.901**
  + **Option 2: Procedure A in TR38.901**
  + **Option 3: Procedure B in TR38.901**
* **Note: this spatial consistency model also can be applied to spatial + time domain beam prediction (if selected as a sub-use case).**

|  |  |
| --- | --- |
| Supporting companies for option 1 | **LGE, vivo (also fine with Option3), MediaTek** |
| Supporting companies for option 2 | **Nokia, DCM, OPPO (either 2 or 3), CATT, CAICT, Xiaomi, PML, ZTE, vivo, Samsung, Spreadtrum, CMCC(2nd), NVIDIA, Futurewei, Lenovo, Qualcomm** |
| Supporting companies for option 3 | **Nokia, OPPO (either 2 or 3), CATT, PML, ZTE, vivo, Ericsson, HW/HiSi, CMCC(1st), NVIDIA, Futurewei, Qualcomm, Intel, InterDigital** |

**Question 1-3a:**

1. Please indicate whether proposal 1-3 can be adopted?
2. Please further explain the reason of one of three options.

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Nokia | Y | We understand that the spatial consistency defined in 38.901-7.6.3.1 is not sufficient to catch the channel evolvement in time and we are open with using either procedure A or B.    But regarding procedure A, we understand that it cannot apply over long distance because it assumes the scatters and reflectors are unchanged. If movement of relatively long distance is to be modeled and if procedure A is to be used, there need to be multiple separated locations along the trajectory and channel parameters need to be independently generated for these locations. For example, factors like large scale fading need to be generated for each of these locations. Between each two these two locations there can be a short distance interval and at each of these locations, applying procedure A for the short distance interval.  Under this usage, we assume over the short distance interval it won’t have drastic pathloss change and procedure A can be applied. |
| NTT DOCOMO | Y | Option 2(Procedure A in TR38.901) is preferred. Comparing to Option 1 and Option 3, it generates the successive channels along the UE movements by taking the UE velocity and distance into account in the small-scale parameters, which can better emulate the real channel with mobility. |
| LGE | Y | Regarding the note, we are not sure that the consistency model also needs to be applied for spatial domain beam prediction. |
| CAICT | Y | We share the same view as 1st round and Procedure A in TR 38.901 could be used for baseline. |
| vivo | Y | We believe Option 1 can also be used for performance evaluation with short time prediction.  We are also ok for option 2 and 3. |
| Samsung | Y | As mentioned in the TR, both Procedures A and B can serve the purpose to generate the spatially-consistent mobility modelling, and we prefer to follow Procedure-A. |
| HW/HiSi | Y | We prefer option 3 because it is more realistic in our view, especially when considering a relatively long UE trajectory with medium moving speed. |
| MediaTek | Y | For moving UEs, Option 1 considers the spatial consistency of small-scale parameters when UE moves to a different location. Option 2 and 3 further consider the time evolution. Option 1 works for both throughput and mobility study. We can consider Option 1 as baseline for simplicity. |
| Lenovo | Y | Prefer Option 2. |
| Qualcomm | Y | OK with both Procedures A and B and prefer Procedure A (Option 2). |
| Intel | Y | Note that for actual UE movement in SLS, only procedure B works and not procedure A. Procedure A is for classical SLS assumption of stationary UEs where doppler is used for modeling mobility. |
| InterDigital | Y | Prefer Option 3. |

#### 3rd round: FL3 High Priority Question 1-3b

For spatial consistency in time domain beam prediction:

* + Option 1: Spatial consistency defined in 7.6.3.1 in TR 38.901
    - **Supported by (3):** LGE, vivo (also fine with Option3), MediaTek
  + Option 2: Procedure A in TR38.901
    - **Supported by (16):** Nokia, DCM(1st), OPPO (either 2 or 3), CATT, CAICT(1st), Xiaomi, PML, ZTE, vivo, Samsung, Spreadtrum, CMCC(2nd), NVIDIA, Futurewei, Lenovo(1st), Qualcomm
  + Option 3: Procedure B in TR38.901
    - **Supported by (14):** Nokia, OPPO (either 2 or 3), CATT, PML, ZTE, vivo, Ericsson, HW/HiSi(1st), CMCC(1st), NVIDIA, Futurewei, Qualcomm, Intel, InterDigital

Most of companies think procedure A/B is needed. only 3 companies support option 1 while also fine with option two options. Therefore, we have the following option for further discussion. Between option 2 and 3, option 2 has slightly majorities.

**Proposal 1-3a:**

* **At least for temporal beam prediction, companies report the one of spatial consistency procedures:**
  + **Procedure A in TR38.901**
  + **Procedure B in TR38.901**

**Proposal 1-3b:**

* **At least for temporal beam prediction, Procedure A in TR38.901 is baseline assumption for spatial consistency procedures. Procedure B in TR38.901 can be assumed optionally.**

**Proposal 1-3c:**

* **At least for temporal beam prediction, Procedure B in TR38.901 is baseline assumption for spatial consistency procedures. Procedure A in TR38.901 can be assumed optionally.**

|  |  |
| --- | --- |
| Supporting companies for Proposal 1-3a | **DCM, OPPO, CAICT, CMCC, CATT, Fujitsu, Samsung, Ericsson, HW/HiSI (second preference), Nokia, Futurewei, Lenovo, Qualcomm, Xiaomi, MediaTek, ZTE, InterDigital** |
| Supporting companies for Proposal 1-3b | **DCM, CAICT, Samsung, Nokia, Lenovo, Qualcomm, Xiaomi** |
| Supporting companies for Proposal 1-3c | **CMCC, LGE, HW/HiSI** |

**Question 1-3b:**

a) Please provide your view on the proposal 1-3a / proposal 1-3b/ proposal 1-3c

|  |  |
| --- | --- |
| Company | Comments |
| FL | In FL’s understanding, either option can work. Therefore, FL may consider to recommend the proposal with majority. |
| Nokia | We are fine with the proposal. As mentioned before, companies shall report the assumptions when applying Procedure A over long distance (E.g. If movement of relatively long distance is to be modeled, there need to be multiple separated locations along the trajectory and channel parameters need to be independently generated for these locations.) |
| InterDigital | We added our position for the 2nd round summary as our view is missing. We are fine with Proposal 1-3a. |

### 1.2.2 Trajectory model for UE mobility

Some companies pointed out that impact of discontinuous UE trajectory model needs to be considered.

* Samsung [9]: The impact of discontinuous UE trajectory model on the beam prediction performance shall be considered for UE mobility model selection.
* Nokia/NSB [19]: A suitable UE mobility model is needed for the spatial-temporal domain beam prediction study.
  + As shown in table 2.4-1, the current UE mobility model for spatial-temporal beam prediction assumes a straight trajectory traveled by the UE with a random direction and channel spatial consistency type-A defined in TR 38.901.
* Intel [20]: The UE trajectory should be sampled at least at the minimum decorrelation distance of the large-scale parameters corresponding to the scenario of evaluation.

Moreover, in [9], there options are proposed for the trajectory model for UE mobility:

* Observation 1-1: For the trajectory model for UE mobility, at least the following options exist:
  + Option #1: Linear and fixed trajectory model, e.g., the intra-cell mobility model in Table 2 of R1-2007151.
  + Option #2: Linear trajectory model with random direction change.
  + Option #3: Linear trajectory model with random and smooth direction change.

Based on the above views, the following questions can be discussed for UE trajectory model.

#### 1st round: FL1 Medium Priority Question 1-4

**Question 1-4:**

1. Whether the UE trajectory model in Table 2 of R1-2007151 is sufficient for the training and/or evaluation of time and/or spatial domain beam prediction?
2. If the answer of a) is no, how to define the trajectory model including the following two options?
   * Option #2: Linear trajectory model with random direction change.
   * Option #3: Linear trajectory model with random and smooth direction change.

|  |  |
| --- | --- |
| Company | Comments |
| Apple | We think it depends on the use case. For spatial domain beam prediction, this is not needed. For time domain beam prediction, it depends on the duration of the monitoring window. If the duration is small, a fixed direction (the direction is randomly generated for each UE) for a UE is enough; if the duration is large, we can consider option 2 or option 3. |
| Nokia, NSB | a) No, it is not sufficient, especially for training and/or evaluation of spatial domain beam prediction.    b) Trajectory model for time beam prediction can be defined considering the distance BS-UE taken from uniform distribution on [dmin, ISD/2], where d\_min is min distance BS-UE, as well as the angle that defines the UE trajectory crossing the sector taken from uniform distribution on [0, 360].   * Spatial beam prediction training and evaluation data requires multiple UEs dropped uniformly in random points of the sector. Then, the UE may adopt the trajectory model defined for time beam prediction. * Option #2 requires an additional parameter that defines the direction Update Distance as well as the turn Probability of the UE after travelling the direction Update Distance. * Option #3 requires in addition of the parameters defined for option#2, an additional parameter that defines turn Angle Limit, to have a smooth changing of UE direction.   Also, we think a clear separation on EVM for training data generation and performance evaluation is needed, and the distance for the trajectories used for training data generation can be short, depending on UE speed. In this case, linear and fixed trajectory of short distance for training data generation shall suffice. Of course, for performance evaluation, the trajectory shall be much longer and more versatile.  Considering this aspect, we can consider another option,  Option#4: Training on random orientation straight-line trajectories. Evaluate on options#1/2/3. |
| vivo | For temporal prediction, ‘No’ to the option1 since it would create overfitting issues.  We would be fine with either Option2 or Option3. UE trajectory can be modeled as in 37.885, and random direction change or smooth direction change described in option 2 and option 3 can be further modeled based on the trajectories defined in 37.855. |
| Intel | Q1-4a: No. The trajectory is relevant only for temporal domain beam prediction which needs collection of mobility trace. The Rel-17 MIMO EVM has a trajectory model with a highway use case which may not be the only relevant case and using this fixed trajectory will lead to overfitting.  Q1-4b: Consider more general UE trajectory modeling where UE is randomly dropped within a deployment, a random direction of travel is chosen and moves in a straight line for a fixed time at a given speed. Many such traces need to be collected to form the dataset for temporal beam prediction. |
| OPPO | a) Yes. But for beam prediction in spatial domain, it is not necessary to model the UE trajectory. |
| AT&T | Agree with Intel and Nokia |
| CATT | Agree with OPPO. |
| LGE | We also think UE trajectory model can be up to each sub use case. For non-HST scenario, either option 2 or option 3 is fine for us. |
| Ericsson | a) For spatial domain we think it could be sufficient.  B) Sharing the view by Vivo that it might create too optimistic results, due to overfitting. Investigating option 2 and 3 should not be precluded. Note that, in general, UE moving at **constant** speed and/or constant rotation should lead to more predictable behavior than dynamic speed/rotation. Another option is to enable modelling of non-constant UE speed. |
| ZTE, Sanechips | We agree with Intel and OPPO that the UE trajectory model is not necessary for spatial-domain beam prediction. For the time-domain beam prediction, we may consider more realistic or complex UE trajectories (such as curve, circular or a combine trajectory) since straight-line trajectory would be rather restricted. |
| CAICT | Y. We believe simple UE trajectory model is enough. |
| Samsung | a) No. For this very simplified UE trajectory model, the randomness is overlooked, and solely based on that, the evaluation will be oversimplified to be justified.  b) we prefer both options2 and 3 at least in the phase of performance evaluation. Both option 2 and 3 are proposed to avoid unrealistic turn over by following a fixed trace, which is not likely to happen. One example of Option-2 can be:   * UE moving trajectory: UE will move straightly 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 move straightly within the time interval with the fixed speed. |
| Fujitsu | It depends on the sub use cases. For spatial domain beam prediction, it’s not necessary to model UE trajectory. |
| CMCC | 1. No. UE trajectory model in Table 2 is not enough flexible. 2. We think it depends on the scenario. For urban scenario, more general UE trajectory model to allow random direction of travel is preferred. For highway/HST use cases, fixed trajectory is sufficient. Both scenarios can be considered. |
| MediaTek | 1. No. At least for time-domain beam prediction, we need to model some kind of UE moving direction change. 2. We would be fine with Option 2, 3, or even other more complicated trajectory modeling. |
| Huawei/Hisi | Not needed for spatial domain BM.  For time domain we agree with other companies that it might depend in the application scenario.   1. For time-domain prediction, it is important to also decide the UE trajectory and how to model spatial consistency. These issues shall not be decoupled for time domain beam prediction. From our point of view, the UE trajectory model from R1-2007151 is not sufficient. For the question b), we are open to both choices but it depends on other simulations assumptions that still remain to be decided. |
| InterDigital | Agree with Intel and Nokia |
| Lenovo | 1. UE trajectory modeling is required only for time domain beam prediction and not for spatial domain beam prediction. 2. Prefer having Option #2 for the UE trajectory modeling. |
| Qualcomm | a) No, due to the fixed nature of the trajectory, the dataset may not be generic enough and the AI/ML model will be subject to overfitting.  b) To avoid the overfitting problem mentioned above, random direction change is desirable, and Option #3 is the most preferred due to providing more flexibility in data generation process and being less prone to overfitting.  In our view, UE orientation should also be taken into account in modeling UE trajectory, as it will affect the beam selection/prediction. Similar to the UE direction in Option #3 which is random and smooth, UE *orientation* can also be modeled to be random and smooth, mimicking realistic real-world scenarios. |
| Futurewei | For beam prediction in spatial domain, UE trajectory model is not needed. For beam prediction in time domain, linear trajectory with a fixed direction should be sufficient in most scenarios. We can consider option 2 and/or option 3. |
| PML | For beam prediction in temporal domain, the non-linear UE moving trajectory should be considered. |

Summary of Question 1-4:

For spatial domain beam prediction, most of companies think there is no need to model UE trajectory, and one company think option 1 is sufficient with option 1

* Option 1: Ericsson
* No need to model: OPPO, CATT, ZTE/Sanechips, Fujitsu, Huawei/Hisi, Intel, Futurewei

For time domain beam prediction, most of companies think option 1 is not enough.

* + Option #1: Linear and fixed trajectory model, e.g., the intra-cell mobility model in Table 2 of R1-2007151.
    - Supported by (4): OPPO, Apple(?), CATT, CAICT
  + Option #2: Linear trajectory model with random direction change.
    - Supported by (8): vivo, Intel(?), LGE, Ericsson(?), MediaTek, Samsung, Lenovo, Futurewei
  + Option #3: Linear trajectory model with random and smooth direction change.
    - Supported by (7): vivo, LGE, Ericsson(?), MediaTek, Samsung, Qualcomm, Futurewei
  + Option#4: Training on random orientation straight-line trajectories. Evaluate on options#1/2/3
    - Supported by (2): Nokia/NSB
  + Option #5: Curve, circular or a combine trajectory
    - Supported by (2): ZTE/Sanechips
  + Option #6: Enable modelling of non-constant UE speed
    - Supported by (1): Ericsson

Based on the above summary, the following proposals and questions are provided.

#### 2nd round: FL2 High Priority Question 1-4a

**Proposal 1-4-1:**

* **At least for spatial domain prediction in initial phase of the evaluation, UE trajectory model is not necessarily to be defined.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTEk, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel, InterDigital** |
| Objecting companies |  |

**Proposal 1-4-2:**

* **At least for time domain beam prediction in initial phase of the evaluation, UE trajectory model is defined. FFS on the details.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, PML, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel, InterDigital** |
| Objecting companies |  |

**Question 1-4a:**

1. Please provide your preference among Option #1~Option #6 for time domain beam prediction.
   * Option #1: Linear and fixed trajectory model, e.g., the intra-cell mobility model in Table 2 of R1-2007151.
     + Supported by (5): OPPO, Apple(?), CATT, CAICT, Futurewei (see our feedback for previous question)
   * Option #2: Linear trajectory model with random direction change.
     + Supported by (8): vivo, ~~Intel(?)~~, LGE, Ericsson(?), MediaTek, Samsung, Lenovo, Futurewei
   * Option #3: Linear trajectory model with random and smooth direction change.
     + Supported by (7): vivo, LGE, Ericsson(?), MediaTek, Samsung, Qualcomm, Futurewei
   * Option#4: Training on random orientation straight-line trajectories. Evaluate on options#1/2/3
     + Supported by (2): Nokia/NSB
   * Option #5: Curve, circular or a combine trajectory
     + Supported by (2): ZTE/Sanechips
   * Option #6: Enable modelling of non-constant UE speed
     + Supported by (1): Ericsson

|  |  |
| --- | --- |
| Supporting companies  of option 1 | **DCM, CATT, CAICT, Xiaomi CMCC, Futurewei** |
| Supporting companies  of option 2 | **CATT, vivo, Samsung, BJTU, Spreadtrum CMCC, MediaTek, Lenovo, Qualcomm** |
| Supporting companies  of option 3 | **PML, vivo, Samsung, BJTU, Spreadtrum CMCC, Qualcomm** |
| Supporting companies  of option 4 | **Nokia, Ericsson, BJTU, HW/HiSi, Qualcomm, Intel** |
| Supporting companies  of option 5 | **PML** |
| Supporting companies  of option 6 | **PML, Ericsson** |

**Please provide your view of the above options.**

**Please provide your description if support on of the option 4/5/6**

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | For option 1&5, we think the trajectory models are not flexible enough as it was also mentioned by other companies. We expect the model trained by the data generated from option 1&5 has low practical usage as we think it cannot perform temporal beam prediction accurately for any other different UE trajectories.  For option 3, we think the UE movement is not realistic as it models the UE keep changing direction in a short time interval.  For option 2&4, we have the following comments:   1. To clarify, option 2&4 should include multiple random drops of UE trajectories for training and evaluation. 2. The UE trajectory should either be defined with a fixed (short) total time interval or a fixed (short) total distance, or if the total time interval or total distance of UE trajectory is not defined, companies should have common understandings that ONLY relatively small segments in time or in distance on the UE trajectory will be extracted for training or evaluation purpose.   The reason is the channel correlated distance is limited as it is defined in 38.901-7.6.3. If the time interval or distance for each single training data sequence is too long, it will contain data samples that are not temporally correlated, and we expect the prediction will be impaired by training the model (with supervised learning) with uncorrelated data.  Therefore, we propose to have a fixed distance or fixed time interval UE trajectory generated at each drop.   1. The training trajectories and the evaluation trajectories should be either 2. Generated from the same trajectory model but different drops, or 3. Generated from different trajectory models. We consider this option is the closest to the realistic application.   To summarize, we have the following proposal for the UE trajectory modeling:   * 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 geographic based.     - During the simulation, inter-cell handover or switching should be disabled.   **For training data generation**   * For each UE moving trajectory: the total length of the UE trajectory can be set as T second if it is in time, of set as D meter if it is in distance.   + The value of T (or D) can be further discussed   + The trajectory sampling interval granularity depends on UE speed and it can be further discussed. * UE can move straightly along the entire trajectory, or * UE can move straightly during the time interval, where the time interval is provided by using an exponential distribution with average interval length   + 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 hit 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.   + At the current stage, the length of observation window + prediction window is not fixed and the companies can report their values.     **For evaluation data generation**   * At the first stage, the UE moving trajectory in the evaluation data set can be generated as same as the training data generation. * At the latter stage, the evaluation data set should include UE trajectories that are generated different to the training data generation.   + FFS the different UE trajectory generation method.   For option 6, we understand it is UE speed generalization issue but not related to the trajectory modeling.  Also, then spatial consistency model choice is important for trajectory modeling. Because the channels generated over the trajectory need to capture the changing of large-scale fading parameters, like pathloss. The pathloss changing over a long-distance trajectory cannot be ignored. But we understand that the current spatial consistency procedure A is only applicable to short distances as it does not update the pathloss as UE moves. So if procedure A is to be used, it has to be done multiple times with channel at multiple locations along the path and channel parameters need to be independently generated for these locations.  Also see our comments in 1-3a. |
| OPPO | We can follow majority view |
| CATT | Option 1 is basic and can model relative simple trajectory.  Option 2&3 can create relative adequate trajectory. Slightly prefer Option 2. |
| CAICT | We prefer simple trajectory as baseline and more option(s) is open. |
| vivo | We still prefer option 2 and option 3. Option1 would create overfitting issues. Other options would be difficult to align results with too much controlling parameters. |
| PML | e. The UEs moving on a pavement, road, crossroad, highway should be considered. |
| Ericsson | Option 6 can be an extension to option 1. Agree to the concern raised by Nokia, propose to add a note that the moving distance should be restricted by the channel correlated distance in 38.901. Note that for case 2, the key is to make sure one can utilize learnings from a UE moving in a certain path, for subsequent UEs moving on a similar path. It is not realistic to assume that all UEs move along same trajectory, hence it is very important to have a training set comprising several different trajectories. Otherwise, the results will be optimistic. |
| Samsung | Option #4 can be a simple metric while it still needs additional feature. We don’t think Option #6 is the trajectory model. It should be discussed in model generalization |
| HW/HiSi | Option 4 is more realistic than option 1 and at the same time not introducing too much complexity for modeling the trajectory. Even though option 4 only considers straight-line, the random direction introduces sufficient randomness for preventing model overfitting. Just note that option 4 is applicable to generate training data and testing data as well.  Additionally, the UE stops when it touches the cell boundary, handover and cell switch should be turned off in our view. |
| CMCC | For urban scenario, option 2/3 is more general. Option 1 can be viewed as a highway scenario. |
| MediaTek | We need to model some kind of UE direction change, but it needs not to be too complicated. |
| Qualcomm | As mentioned in the first round, suggest considering the following aspects:   * Incorporating UE orientation (and orientation changes) as it will affect the beam prediction performance. As the UE moves along the trajectory, considering a fixed UE orientation is a limiting factor, and assuming the same UE orientation across training and test datasets is also a limiting factor and may limit assessing the generalization capability of the AI/ML model. * For the options in which the trajectory is fixed, we can control and confine the trajectory to be within a cell. For random trajectories, we think the prospects of UEs moving across cells should be elaborated and discussed, as it will affect the beam prediction performance. |
| Intel | The assumptions from Nokia seem reasonable. We can model random UE drop with random orientation and random direction of travel and move the UE in a straight line trajectory for a predetermined amount of time T. Many such drops are used to construct a dataset of UE traces for training. |
| InterDigital | We agree with Nokia and Intel. |

#### 3rd round: FL3 High Priority Question 1-4b

The supporting companies updated as below:

* + Option #1: Linear and fixed trajectory model, e.g., the intra-cell mobility model in Table 2 of R1-2007151.
    - Supported by (6): DCM, CATT, CAICT, Xiaomi CMCC, Futurewei
  + Option #2: Linear trajectory model with random direction change.
    - Supported by (9): CATT, vivo, Samsung, BJTU, Spreadtrum CMCC, MediaTek, Lenovo, Qualcomm
  + Option #3: Linear trajectory model with random and smooth direction change.
    - Supported by (7): PML, vivo, Samsung, BJTU, Spreadtrum CMCC, Qualcomm
  + Option#4: Training on random orientation straight-line trajectories. Evaluate on options#1/2/3
    - Supported by (7): Nokia, Ericsson, BJTU, HW/HiSi, Qualcomm, Intel, InterDigital
  + Option #5: Curve, circular or a combine trajectory
    - Supported by (1): PML
  + Option #6: Enable modelling of non-constant UE speed
    - Supported by (2): PML, Ericsson

As commented by several companies, option 2/3/4 are more suitable. Moreover, the intention of **proposal 1-4-3** is to define UE trajectory. We can further discuss which one to use for generation and performance verification. For next round, further discuss on the following options:

**Proposal 1-4-3:**

* **For temporal beam prediction, the following options can be considered as a starting point for UE trajectory model. Other options are not precluded.** 
  + **Option #2: Linear trajectory model with random direction change.**
  + **Option #3: Linear trajectory model with random and smooth direction change.**
  + **Option #4: ~~Training on~~ Random orientation straight-line trajectories. ~~Evaluate on options#1/2/3~~**
* **Generalization issue is FFS including generation from the same trajectory model but different drops, or generation from different trajectory models**

|  |  |
| --- | --- |
| Supporting companies | **DCM, CAICT, CMCC, CATT, LGE, Samsung, Ericsson, HW/HiSi, Nokia, Futurewei, Lenovo (Suggested change), Qualcomm, Xiaomi, MediaTek, ZTE, InterDigital** |
| Objecting companies |  |

**Please provide your view Proposal 1-4-3, if any.**

|  |  |
| --- | --- |
| Company | Comments |
| FL | The intention of **proposal 1-4-3** is to define UE trajectory model. We can further discuss which one to use for generation and or performance evaluation. Therefore, FL modified option #4 as above.  @Nokia, please check whether it is OK with you. |
| NTT DOCOMO | Option 4 seems sufficient to validate the performance. |
| CAICT | We can support FL’s proposal. |
| CATT | Support this proposal and prefer Option 2. |
| LGE | OK |
| HW/HiSI | Support and our preference would be Opt 4 |
| Nokia | @FL, yes ok with modified Option 4. Also Ok with keeping other options 2/3. |
| Lenovo | Prefer Option #2. We suggest the following change to the second bullet in the proposal:  **Generalization issue is FFS ~~including generation from the same trajectory model but different drops, or generation from different trajectory models~~** |

Moreover, please provide update of the following options.

1. **For option 2:**
   * UE moving trajectory: UE will move straightly 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 move straightly within the time interval with the fixed speed.

**Please provide your view for description of option 2, if any.**

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Provided in earlier comment. |
| CATT | Generally fine. |
| vivo | We still prefer UE trajectory modeled as in 37.885 with random direction change or smooth direction change described in option 2 and option 3.  One modelling example is shown as below:    UEs are dropped on predefined straight roads with some crossroads. The dropped UE moves with a random direction in a straight road, while an action is randomly selected from 4 operations, such as go ahead, turn back, turn left and turn right, occurred for a UE moving across a crossroad. |
| MediaTek | Considering the deployment scenario (e.g., 21 cells), UE may change its direction upon hitting the bouncing circle surrounding the cells. |
| FL | Please provide necessary modification of option 2, if any |
| Qualcomm | Nether for Option 2, nor for Option 3 the prospect of confining UE movement within a cell has not been explained. For Option 4, it has been discussed in “for training data generation” section. |

1. **For option 3:**
   * 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 move straightly within the time sub-interval with the fixed speed.

**Please provide your view for description of option 3, if any.**

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Provided in the first table. |
| CATT | There may be a typo, i.e. the above c) is for Option 3 but not Option 2. |
| vivo | We still prefer UE trajectory modeled as in 37.885 with random direction change or smooth direction change described in option 2 and option 3.  One modelling example is shown as below:    UEs are dropped on predefined straight roads with some crossroads. The dropped UE moves with a random direction in a straight road, while an action is randomly selected from 4 operations, such as go ahead, turn back, turn left and turn right, occurred for a UE moving across a crossroad. |
| FL | Please provide necessary modification of option 3, if any |
| Qualcomm | Nether for Option 2, nor for Option 3 the prospect of confining UE movement within a cell has not been explained. For Option 4, it has been discussed in “for training data generation” section. |

1. **For option 4:**

* 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 geographic based.
    - During the simulation, inter-cell handover or switching should be disabled.

**For training data generation**

* For each UE moving trajectory: the total length of the UE trajectory can be set as T second if it is in time, of set as D meter if it is in distance.
  + The value of T (or D) can be further discussed
  + The trajectory sampling interval granularity depends on UE speed and it can be further discussed.
* UE can move straightly along the entire trajectory, or
* UE can move straightly during the time interval, where the time interval is provided by using an exponential distribution with average interval length
  + 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 hit 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.
  + At the current stage, the length of observation window + prediction window is not fixed and the companies can report their values.

**Please provide your view for description of option 4, if any.**

|  |  |
| --- | --- |
| Company | Comments |
| FL | Only keep the part for training data generation. How to test the performance can be discussed together with generalization issue. |
| Nokia | Yes “the part for training data generation” should be sufficient. |

### 1.2.3 Others aspects for data generation or evaluation

The following aspects were discussed and proposed:

* Samsung [9]: For evaluation of beam prediction in the time domain, in addition to the spatially-consistent mobility modelling and UE trajectory modelling, the selection of UE speed, blockage [Section 7.6.4 in TR 38.901], and/or UT rotating [Section 7.6.7 in TR 38.901] should be considered.
* Lenovo [18]: The beam management AI/ML model evaluation methodology should support evalutations with realistic modeling of UE mobility and rotation, spatially consistent channel models, different UE speeds, and single-beam/panel and multi-beam/panel scenarios for evaluating a model's robustness and adaptability.
* NVIDIA [21]: Additional simulation methodology for generating synthetic data, such as digital twins, should be explored for the study of AI/ML based algorithms for beam management.

Based on the above views, the following questions can be discussed for other assumptions:

#### 1st round: FL1 Low Priority Question 1-5

**Question 1-5:**

1. What other assumptions or parameters need to be defined for SLS based dataset generation and evaluation for beam management?

Note: Mixed scenario(s) for generalization can be discussed in section 2.2.1. This question only focuses on single scenario case for dataset and performance evaluation.

|  |  |
| --- | --- |
| Company | Comments |
| Apple | We suggest adding UE rotation with speed of 360 degree per second |
| Nokia, NSB | UE rotating could be considered as an additional evaluation assumption and should be considered with static UE. |
| vivo | Share same view as apple, UE rotation should be considered for temporal domain beam prediction, and we prefer 50 r/m (round per minute) |
| Intel | OK to consider UE rotation, although 360 degrees per second seems very fast. |
| AT&T | Ok to consider UE rotation |
| CATT | Ok to optionally consider UE rotation but should be in lower priority. |
| LGE | UE rotation can be optionally considered, if needed. |
| Ericsson | We are ok with adding a UE rotation. It should be clarified around what UE axis the rotation is made. Also defining reasonable numbers for such rotation. 360 degree per second sounds very fast. |
| ZTE, Sanechips | Ok to consider UE rotation. It is suggested that the change of UE rotation (if needed) shall follow a simple or fixed pattern, as stated by Apple and vivo. Excessive random rotation during movement would cause the adopted AI model to require huge samples to converge. |
| Samsung | UE rotation, blockage, and random UE speed over time can be considered. We shared the similar view as Intel that 360 degree per second could be too fast. |
| CMCC | Open to consider UE rotation |
| MediaTek | UE rotation may be considered as an option. |
| InterDigital | Fine to consider UE rotation if is optional. |
| Lenovo | UE rotation modelling as in TR 38.901can be considered. |
| Qualcomm | Suggest adding UE rotation for temporal and spatial + temporal beam prediction use cases. |
| Futurewei | We think it is sufficient for dataset generation for the study. System level simulation is not needed for performance evaluation. |
| PML | UE rotation should be considered. |

Summary of Question 1-5:

Most of companies suggest to model UE rotation for time domain beam prediction. Some companies think 360 degree per second is too fast.

#### 2nd round: FL2 Medium Priority Question 1-5a

**Proposal 1-5:**

* **UE rotation is optionally modeled for SLS at least for time domain beam prediction.** 
  + **FFS the speed 50 r/m**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, OPPO, CATT, CAICT, PML, ZTE, vivo, Ericsson, Spreadtrum, MediaTek, NVIDIA, Lenovo, Qualcomm, InterDigital** |
| Objecting companies |  |

**Question 1-5:**

1. Please provide your views for proposal 1-5

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Ok as optional modelling. Companies can report the speed in the next meeting. |
| LGE | Fine in principle. |
| ZTE, Sanechips | Open to consider more rotation speed candidates. |
| Ericsson | Companies can report speed and rotation axis in next meeting. |
| Samsung | 50r/m could be too fast. We are fine with the modification  **Proposal 1-5:**   * **UE rotation is optionally modeled for SLS at least for time domain beam prediction.**    + **~~FFS the speed 50 r/m~~**   + **Rotation speed: [X] r/m** |
| HW/HiSi | Fine to have UE rotation reported by companies |
| Lenovo | Open to further discussion |
| Qualcomm | To have the ability of training and testing over different UE rotation speeds, we suggest not limiting to a single rotation speed. |
| InterDigital | Fine as it is optinal. |

#### 3rd round: FL3 Medium Priority Question 1-5b

**Proposal 1-5b:**

* **UE rotation is optionally modeled for SLS at least for temporal beam prediction. The speed is reported by companies.**

|  |  |
| --- | --- |
| Supporting companies | **DCM, OPPO, CMCC, CATT, Fujitsu, LGE, Samsung, Ericsson, HW/HiSi, Nokia, Lenovo, Qualcomm, Xiaomi, MediaTek, ZTE, InterDigital** |
| Objecting companies |  |

**Question 1-5b:**

1. Please provide your views for proposal 1-5b

|  |  |
| --- | --- |
| Company | Comments |
|  |  |
|  |  |

## 1.3 Dataset generation and evaluation assumptions with LLS (on hold)

Two companies proposed to use LLS for the evaluation of the beam prediction in time domain or for spatial domain beam prediction.

* Samsung [9]: Link-level simulation can be used for the evaluation of beam prediction in the time domain.
  + For the evaluation of beam prediction in the time domain, the CDL extension used in the Rel-17 HST-SFN evaluation should be a good starting point in link-level evaluation.
* Samsung [9]: Consider Table A.2.5-2 (for SLS) and Table A.1.6.4 (for LLS) of TR 38.802 as the starting point for Rel-18 AI/ML for beam management evaluation, based on which necessary modifications/simplifications can be further discussed for the specific evaluation purpose and/or sub use case.
* Intel [20]: For spatial domain beam prediction, CDL channel models should be used for dataset generation and RSRP can be used as the beam specific parameter for the dataset.
* Intel [20]: Assumptions on gNB and UE antenna arrays and beamforming should be aligned across companies for common dataset generation
* Intel [20]: Dataset normalization based on specific sub-use case should be reported by companies

Based on the above views, the following questions can be discussed for LLS for AI/ML-based beam management.

#### 1st round: FL1 Medium Priority Question 1-6 (temporary closed)

**Question 1-6:**

1. Whether LLS can be used as a complementary evaluation methodology for AI/ML in beam management?
2. If the answer is yes, whether Table A.1.6.4 (for LLS) of TR 38.802 can be used as the starting point for Rel-18 AI/ML for beam management evaluation?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | N | At least SLS should be the baseline. LLS may cause overfitting problem. |
| Nokia | N | Disagree that LLS are needed for this SI. The BM use case requires mainly beam measurements data (L1-RSRP) for multiple beams and UEs in different locations of the sector. We don’t see the advantage of using LLS for this use case since LLS will simulate the BS-UE transmission link with too many details (down at the bit-level), which is too much simulation burden for the BM study, and it can be avoided. On the other hand, we believe that SLS enables us to generate a large amount of data for Ues in different positions for a single network drop and enables us to diversify the data to improve the ML performance during training while enabling to test the ML model generalization capabilities during the evaluation phase. |
| Vivo |  | We are open to discuss |
| Intel | Y | LLS channel models i.e., CDL models can be used to generate RSRP data for spatial domain beam prediction. LLS for performance evaluation may not be needed |
| NVIDIA |  | Interested companies can present the results with sufficient level of description. |
| OPPO |  | SLS is the baseline. LLS seems not necessary. Anyway, companies can bring up LLS evaluation results if they are willing to. |
| CATT | N | We don’t need to duplicate the evaluation effort since SLS evaluation is sufficient. |
| LGE | N | Prefer to have SLS as the baseline. |
| Ericsson | N | No need to address LLS. |
| ZTE, Sanechips |  | SLS should be the baseline and LLS can be optional provided for preliminary evaluation. |
| CAICT | N | SLS is preferred. |
| Samsung | Y | We share an opposite view with Nokia. In our discussion paper, we proposed reusing the CDL-extension used in Rel-17 HST-SFN to get L1-RSRP data for multiple beams from different UE locations considering UE trajectory. **The advantage is that this LLS does not require the spatial consistent modeling described in TR 38.901, so we can reduce our workload for simulation.** Also, we can avoid the overfitting issue by adopting random trajectory modeling, random UE’s boresight, random UE speeds and so on. Moreover, if we study and discuss the beam management for high speed users including HST, highway in the future, this LLS modeling would be useful. Thus, reusing the existing LLS can be adopted as a simpler metric for evaluation at least for Phase 1 evaluation (e.g., to evaluate Top-N accuracy, RSRP gap, etc.), while FFS Phase 2 evaluation (to evaluate UPT, etc.). |
| Fujitsu | Y | 1. Yes 2. Yes |
| CMCC |  | Open to use LLS for spatial domain beam prediction. |
| MediaTek | N | Beam management is to deal with UE mobility, which is usually studied using SLS. |
| HW/HiSi | Y | 1. LLS shall be considered. Especially for spatial domain BM 2. The table can be used as a starting point |
| InterDigital |  | Do not support LLS as an evaluation methodology as LLS does not accurately show the actual impact of beam prediction. |
| Lenovo | Y | 1. Yes, at least for the beam prediction evaluation. 2. Yes |
| Qualcomm | Y | We are open to discussing the prospect of optional LLS but prefer SLS since the channel models cover a broader range of scenarios. With LLS there’s a concern that the dataset may not be generic enough, and therefore there’s a risk of overfitting. |
| Futurewei | N | We do not see the benefit of using LLS here. |
| PML |  | SLS should be the baseline and LLS can be optional provided for preliminary evaluation. |

Summary of Question 1-6:

LLS for spatial domain beam prediction for initial phase evaluation:

* Supported by: Intel, Samsung, HW/HiSi
* Supported as optional by: OPPO, ZTE/Sanechips, Fujitsu, CMCC, Lenovo, Qualcomm

Not needed LLS:

* Apple, Nokia, CATT, LGE, Ericsson, CAICT, MediaTek, InterDigital, Futurewei

Based on the above summary, moderator suggest to focus on SLS first, and come back to it later.

## 1.4 AI/ML model related aspects(on hold)

Some companies suggested to define reference AI/ML model for calibration, while some companies believed no need to introduce a reference AI/ML model:

* Huawei/HiSi [1]: The calibration of the AI/ML model and dataset for beam management evaluations can be achieved by aligning simulation assumptions and calibrating intermediate results such as beam prediction accuracy.
* Ericsson [4]: No need to introduce a reference AI/ML model for calibration
* Vivo [7]: Fully-connected neural network with a limited number of model parameters for beam management case is considered as the basic model. Other models can also be considered if found beneficial.
* Apple [15]: During the use case study phase, it is not necessary to define a common AI architecture.
* NVIDIA [21]: Baseline AI model(s) should be identified for the purpose of calibration in the study of AI/ML based algorithms for beam management.
* Fujitsu [24]: Calibrate the performance of the AI/ML method, a common reference model is recommended, and its generation procedure needs to be studied.

Based on the above discussion, it is better to discuss whether a reference AI/ML model needs to be defined.

#### 1st round: FL1 Medium Priority Question 1-7 (temporary closed)

**Question 1-7:**

1. Whether a reference AI/ML model needs to be defined, and why?
2. If the answer is yes, please explain the purpose to define the reference AI/ML model.

|  |  |
| --- | --- |
| Company | Comments |
| Apple | a) At current stage, no. |
| Nokia, NSB | 1. No, only AI/ML model inputs/output need to be defined but ML model details will be up to companies’ implementation. |
| Xiaomi | No. companies can report the NN architecture, the input/output of the AI/ML model. |
| Vivo | For cross check purposes, we should support reference AI/ML model for calibration or companies should open the details as much as possible. |
| Intel | At this stage, no. Meaningful non-AI/ML baselines should be considered for fair comparison |
| NVIDIA | Yes, a baseline model would facilitate calibration. |
| OPPO | We are open to it. However, it may be difficult to define a reference AI/ML model. Companies are encouraged to share their models used in the evaluation for cross check and calibration. |
| CATT | We are open to consider it, at least for the purpose of calibration. |
| LGE | No, companies can provide there assumption on AI/ML model. |
| Ericsson | Not needed in case the model training methodology and model description are properly defined |
| ZTE, Sanechips | Rather than defining a reference AI/ML model, more importantly each company may provide a general and detailed description of the AI/ML models adopted for cross-validation. |
| CAICT | It might be hard to directly define common reference model. It is proposed that AI/ML model structure description is provided along with simulation results for double check. |
| Samsung | No. we don’t see the need, at least in this stage. Especially in this stage, due to the use case also being studied, it is hard to provide and justify a certain reference AI/ML model is suitable. |
| Fujitsu | Yes. The purpose to define the reference AI/ML model is to easily calibrate the simulation results |
| CMCC | We support to define a reference AI/ML model for calibration. If no, we have no idea how to carry out calibration. |
| MediaTek | 1. At this stage, no. |
| HW/HiSi | No, at least not in the starting phase. Companies could provide a general description of their model. |
| InterDigital | No. |
| Lenovo | A reference AI/ML model can be considered for the calibration purpose. |
| Qualcomm | a) No, generating data based on TR 38.901 and an agreed set of EVM assumptions is sufficient. There should be no need for further calibration of the data. Also, there is no need to align the AI model used by companies. |
| Futurewei | 1. No, we think by aligning simulation parameters and EVM should be ok for the study. However, for performance comparison and avoiding potential misunderstanding in the result discussion, it is recommended for companies to include results from multiple runs to show the performance distribution or via CDF. |
| NTT DOCOMO | Given a lot of workloads are required for reference AI/ML models, we are reluctant to define reference AI/ML models. |
| PML | No |

Summary of Question 1-7:

Need a reference AI/ML model

* Supported by (6): Vivo (for cross check), OPPO(Open), CATT(Open, for calibration), Fujitsu(for calibration), CMCC, Lenovo

No need to defined a reference AI/ML model

* Supported by (17): Apple, Nokia/NSB, Xiaomi, Intel, LGE, Samsung, MediaTek, InterDigital, ZTE/Sanechips, HW/Hisi, CAICT, Qualcomm, Futurewei, NTT DOCOMO

Based on the above summary, moderator suggests to not spend time to define a reference AI/ML model for now. Moreover, this topic is general for all three use cases. Moderator suggests to discuss this issue in agenda 9.2.1.

On the other hand, the following aspects related to AI/ML models and input/output of AI/ML models were proposed:

* Huawei/HiSi [1]: For AI/ML-based spatial domain beam prediction evaluation, adopt the RSRP for sparse beams and the optimal beam ID as the training inputs.
* Ericsson [4]: Evaluation should provide a description of ML/AI model, model input/output, along with the training methodology
* Samsung [9]: For AI/ML training and inferring, the detailed AI/ML model, and loss/reward function design should be decided by companies, while the relevant information should be explained by companies:
  + AI/ML model selection: e.g., DNN, CNN, LSTM with the number of layers, and the number of nodes in each layer, and some necessary description for the node connection, etc.
  + Input of AI/ML model.
  + Output of AI/ML model.
* LGE [13]: Consider following information as input data for AI/ML based DL Tx beam prediction in time domain.
  + For gNB side AI/ML, gNB measurement (e.g., UE position/trajectory, UL measurement) and UE beam related reporting.
  + For UE side AI/ML, UE own measurement (e.g., UE position/velocity, UE orientation/rotation, DL beam/CSI measurement).
* Lenovo [18]: Any additional side information (e.g., measurements from non-3GPP technologies) needed for a proposed beam management AI/ML model should be stated.
* Ericsson [4]: Model validity area should be described, if the AI/ML model is trained for a cell (cell-specific), multiple-cells, or for the entire scenario (valid for all cells).
* Ericsson [4]: Models are trained offline (no sequential update of the model)

Besides, the following training methodology were proposed:

* Ericsson [4]: Training methodology could for example include the training optimization function, loss function and/or number of training/test samples
* Vivo [7]: Training dataset and validation dataset should be collected from different drops to keep data independence.

#### 1st round: FL1 Medium Priority Question 1-8 (temporary closed)

**Proposal 1-8:**

* **Each company should provide a description of ML/AI model, [model input/output], along with the training methodology.** 
  + **FFS on the details**

**Question 1-8:**

1. Whether proposal 1-8 can be adopted? Why?
2. What parameter(s)/aspect(s) of AI/ML model(s) need to be reported by each company?
3. Whether to define model input(s)/output(s) subjected to each sub-use case or the model input(s)/output(s) of each sub-use case can be reported by each company for AI/ML in BM?
4. What aspects need to be reported or defined for training methodology?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | Y | Companies can report the NN architecture |
| Nokia, NSB | Y | a) Agree to specify the ML model input and output, since the exchange of the input and output data may have a standard impact, especially when UE model inference is done at the UE side. The ML model complexity may also be reported by each company.  b) Description of ML/AI model input/output including extra information (e.g., measurements not considered in 3GPP) needed for ML model input, model validity (single sector/multi sectors).  c) ML model input may differentiate between subcases and therefore should be specified.  d) Dataset size (e.g. number of Ues used for training/validation/testing), model trained for single sector or multi sectors. |
| Xiaomi | Y | For b), Companies can report the NN architecture, and the parameters such as number of layer etc..  For c), Also the model input/output need to be reported by each company and need to be specified if have a standard impact.  For d), For training methodology, for example, dataset size and model trained for single cell or all cells can be reported. |
| Vivo | Y | 1. Support, for calibration purpose. 2. The detail of AI Model architecture should be reported, such as model type, layer number, quantization and loss function. 3. Parameter type and corresponding number of model input/output should be reported.   Data independence should be defined in dataset construction between training data and validation data. |
| Intel | Y | Q1-8.a: Yes  Q1-8.b: In addition to description of AI/ML model, input/output, companies should also report dataset normalization  Q1-8.c: Yes input/output and model description should be provided for each sub-use-case |
| NVIDIA | Y | Yes, description of AI/ML model should be provided. Details can be FFS. |
| OPPO | Y | a) Support in principle.  b) At least the high-level description for AI/ML model should be reported. Detailed information is up to each company. Companies are encouraged to disclose more details.  c) Model input/output should be reported.  d) It is up to each company. |
| CATT | Y | a) Yes  b) The input(s)/output(s) of AI/ML model for each sub-use case can be reported by each company.  c) The output may be specified. While at the first stage, we are open to see different input(s) reported by companies.  d) At least the details of training data set should be reported, i.e. channel model, dataset size. |
| LGE | Y | a) Yes.  b) NN architecture can be provided.  c) Either way is fine. However, there is similar ongoing discussion in AI 9.1.3.2. |
| Ericsson | Y | 1. Agree. This allows for some degree of cross checking of results among companies and the possibility to assess the complexity, memory consumption, FLOPS etc. 2. Model description (type of model, parameters), Model input description, Model output description. The method used in e.g. IEEE papers on ML can be a guideline. 3. Agree – the input(s)/output(s) should depend on each subuse case 4. Loss function, optimization function, Dataset description (Training/Test data), Number of training/test samples, Model validity area |
| ZTE, Sanechips | Y | Parameters to be reported by each company at least include model input, model output, dataset size, and other general description of the employed AI/ML model. |
| CAICT | Y | The detail of AI model should be mainly focus on the model structure. |
| Samsung | Y | a) Yes for verification of each companies AI-model.  b) at least, the structure of AI/ML model (including type of neural network, number of layers, number of nodes in each layer, connections, etc), input/output information should be reported. Providing details such as post/pre-processing, training strategy, and so on can be up to each company.  c) model input/output should be reported, to study specification impact.  d) generation method of training data set should be provided from each company. Also, model scalability of each company should be reported. Furthermore, the loss function should also be encouraged to be reported for companies’ training. |
| Fujitsu | Y | Companies need to report AI/ML model structure, input/output, and training methodology |
| CMCC | Y | a) Yes  b) Besides input/output, companies are encouraged to report the NN architecture and network parameters.  c) Even for one sub use case, the input/output may different, thus it can be reported by company. |
| MediaTek | Y | 1. Companies can report the NN architecture (which can be generated by AI/ML tools) 2. Input/output format should be reported   for training methodology, companies may report data set size and the scope of trained model (generic, cell-specific, UE-specific, etc.)   1. Companies are encouraged to provide more detailed parameters for training such as batch size, learning rate, optimization technique, etc |
| HW/HiSi | Y | 1. Yes 2. Requires more discussion 3. Model input(s)/output(s) of each sub-use case can be reported by each company for AI/ML |
| InterDigital | Y | 1. High level model description 2. Input(s)/output(s) of each sub-use case can be reported by each company 3. This can be optional and up to each company. |
| Lenovo | Y | 1. Yes. Having the details of the AI/ML model helps, understanding the merits and merits and demerits of the proposed AI/ML method and the generic applicability of different ML methods for the BM use case. 2. We consider that following Model Characterization Card (MCC) (presented in [R1-2204416](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204416.zip)), would be an effective way of capturing different aspects of an AI/ML method. More details about the model (such as NN structure (e.g., CNN or RNN), input/output, hyper-parameters etc.) may be reported as additional details.   **Proposed AI Model Characterization Card**   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **AI/ML Proposal** | **Model Training/Validation Phase** | | | | **Model Deployment /Inference Phase** | | **Model Monitoring/Update Phase** | | | | **Model Training** | **Learning Paradigm** | **Data Set** | **Data Collection** | **Deployment** | **Inference Data collection** | **Model Monitoring** | **Model update paradigm** | **Update Data collection** | | **The Name of the proposed scheme** | Offline (simulation) | Centralized | Simulated data | Only simulated data | In network | Legacy signaling – no spec impact | No monitoring needed | Centralized | No field data needed | | Pre-trained (simulation) + fine-tuned (field) | Federated | Offline field data | Legacy signaling – no spec impact | In UE | Collaboration b/w a UE & gNB | At corresponding nodes | Federated | Offline field data | | Field | Distributed | Online field data | Collaboration b/w a UE & gNB | Split b/w network and UE | Across multiple nodes | At another node | Distributed | Online field data | |  |  |  | Across multiple nodes |  |  | Initiated periodically |  |  |  1. Yes, the model inputs and outputs need to be specified for the use case of BM 2. Details of Training paradigm: Such as offline or online, or initial offline training plus online finetuning, Centralized/Federated/Distributed training etc. |
| Qualcomm | Y | a) Yes, in principle, with the following description  b) A high-level description of AI/ML model can be provided. Providing more detailed description should be voluntary.  c) The input and output to the AI/ML model can be voluntarily provided by companies. The pre- and post-processing for AI/ML model input and output can be up to implementation. In our view, reporting the KPIs is sufficient, and the explicit input and output of AI/ML model can be up to companies to provide.  d) Can be voluntarily provided by each company. Candidates: dataset size, training on a given set of Ues, testing on another set, whether model is trained for single sector or multiple sectors |
| Futurewei | Y, but | 1. This proposal needs clarification on what additional information to be included in the description of AI/ML model, or just input/output. 2. AI/ML model parameters are implementation details while companies are welcome to provide but this should not be required. A brief description of the model like model type (e.g., CNN, RNN, statistical model) can be reported. 3. The exact model input belongs to implementation choice and companies are welcome to provide, but this should not be mandatory. A high-level description of the input can be provided, like wide beam is used to predict narrow beam. Whether the output should be provided/reported depends on the sub-use case. If the output has impact on the interface, then at least some aspects should be reported. Companies are welcome to share this information. 4. Training methodology can be reported, examples like:    * Assumptions    * # of samples used in training and # of samples used in validation    * Using cross validation or not |
| NTT DOCOMO | Y | Input/output of AI/ML models are better to be specified for calibration purposes to some extent and for the reference in the potential specification impact study (e.g., assistance data signaling). |
| PML | Y | 1. Agree to specify the ML model input and output, 2. The number of AI/ML model parameters and the inference speed should be reported, 3. It is optional 4. Dataset size (e.g. number of Ues used for training/validation/testing), UE type ( edestrian, on-board passengers, etc.), training type (offline/online, centralized/decentralized). |

Summary of Question 1-8:

Most of the companies are fine with the proposal 1-8 in general. However, consider this issue is general for all three use cases, moderator suggests to discuss this issue in agenda 9.2.1 in general.

A short summary for this issue:

* Description of AI/ML model, including NN architecture, number of layers, number of nodes in each layer, connections
  + At least report NN architecture of the model is reported.
* Model inputs/outputs can be reported by companies per sub-use case
  + FFS: Measurement outside of 3GPP
* Training methodology can be reported by companies
  + Loss function, optimization function
  + Training/testing dataset:
    - Dataset size, number of training/test samples
    - Post/pre-processing of the dataset
    - Number of training/test samples
    - Model validity area: e.g., whether model is trained for single sector or multiple sectors

## Others (closed)

### HST in FR2

Two companies mentioned beam management enhancement for high-speed train in FR 2.

* ZTE [2]: Consider predictable mobility for beam management as an enhancement aspect for improving UE experience in FR2 high mobility scenario (e.g., high-speed train and high-way).
  + Study and evaluate the feasibility and potential system level gain on predictable mobility for beam management based on the identified scenario(s).
* PML [3]: Consider predictable mobility for beam management as an enhancement aspect for improving UE experience in FR2 high mobility scenario (e.g., high-speed railway and high-way) in a Rel-18 WI.
  + Study the implementation and design of predictable mobility for beam management in various scenarios.
  + Evaluate the performance gain and cost of predictable mobility for beam management in a more concrete and comprehensive manner.

Based on the above views, the following questions can be discussed for high-speed train scenario in FR 2 for AI/ML for beam management.

#### 1st round: FL1 Medium Priority Question 1-9 (temporary closed)

**Question 1-9:**

1. Whether HST can be considered as one of the scenarios for AI/ML for beam management? If the answer is yes, which shall be the baseline tool for dataset generation and performance evaluation, e.g., LLS or SLS?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | N | We think current scenario is enough. At least HST should not be the baseline scenario. |
| Nokia, NSB | N | a) No need to include HST scenario in the set of simulations assumptions. We believe that our focus should concentrate on the Dense Urban scenario, which is supported by most companies |
| vivo |  | Open to discuss |
| Intel | N | Agree with Nokia |
| NVIDIA |  | Interested companies can present the results with sufficient level of description. |
| OPPO |  | Low priority |
| CATT | N | No need to include HST scenario. |
| LGE | N | Similar view as Nokia. |
| Ericsson | N | No need to study HST at this stage. |
| ZTE, Sanechips | Y | HST can be considered as one of the scenarios for AI/ML for beam management. As analyzed in our companion contribution R1-2203250, the high speed mobility and short beam dwelling time in HST lead to huge RS overhead for beam tracking and large latency for beam indication, which makes it imperative to introduce AI/ML technology for time-domain beam prediction. Besides, according to our preliminary simulation results, RS overhead and latency can be significantly reduced with AI/ML based beam prediction. Meanwhile, cell-edge UE UPT and mean UPT are also improved obviously. Regarding the dataset generation and performance evaluation, SLS can be adopted as the baseline tool.  Additionally, the scenario related problem may be discussed together in ‘FL1 High Priority Question 1-2’ instead of discussing it individually. |
| CAICT |  | Low priority but open to discuss. |
| Samsung |  | We are open to discuss this scenario. But general scenarios with low and medium UE speeds should be prioritized. |
| Fujitsu | N | To limit the workload, HST scenario is not recommended in initial stage. |
| CMCC | Y | We think HST can be considered as one of the scenarios. The baseline tool should be aligned with time domain beam prediction. |
| MediaTek | N | Dense Urban scenario should be our focus. |
| HW/HiSi | N | We think that scenarios with lower UE speed have higher priority. |
| InterDigital | N | No need to include HST scenario. |
| Lenovo | N | HST is a very special scenario of BM and need not be given a separate consideration. |
| Qualcomm | N | a) No need to consider HST |
| Futurewei | Y | HST may be considered as an optional scenario for beam prediction in time domain (but may be considered as lower priority). As we stated above, no LLS or SLS is needed for performance evaluation/comparison here. |
| PML | Y | HST can be considered as a typical scenario for beam prediction in temporal domain, featured by high-speed Ues and fixed trajectories. |

Summary of Question 1-9

Most of companies prefer to treat this as low priority. Some proposals were proposed in section 1.2. HST related discussion can be carried on in simulation assumption parts, as potential optional scenario.

### 1.5.2 Other consideration for evaluations

Several companies propose to define two phases for evaluations:

* CATT [6]: For AI/ML based beam management, the following evaluation can be considered:
  + Intermediate evaluation: Evaluate the result of beam selection from the AI model, or the overhead reduction due to AI/ML-based approach;
  + Final evaluation: Evaluate the system-level transmission performance based on the output of AI model.
* Vivo [7] Intermediate results for performance comparison across companies can be considered.
* Samsung [9]: The following two-stage approach is adopted for gNB/UE beambook design:
  + Stage-1: Alignment on the number of beams (as input/output for AI/ML beam prediction)
  + Based on the initial evaluation results, and to be concluded by RAN1 #110.
  + Stage-2: Based on the agreed number of beams (as input/output for AI/ML beam prediction), companies provide the simulation results:
    - Companies shall disclose the detailed beambook design: beam directions/beamwidth.
    - Companies shall disclose the detailed beam measurement and report configuration.

This can be discussed together with performance KPIs.

# KPIs on AI/ML in beam management

Two types of KPIs were proposed by companies for evaluation. One is performance related KPIs, the other is AI/ML model capability related KPIs including size of the models, computation complexity, generalization, etc.

## Performance KPIs

### Beam measurement related KPIs

Beam measurement or selection accuracy were proposed by most of the companies, including:

* ZTE [2]: Top-K candidate beams with higher predicted RSRP can be filtered out for refined small-range beam sweeping, resulting in a relatively good trade-off between training overhead and performance.
* ZTE [2]: Beam prediction accuracy can be used as the performance indicators at the early stage, which may include top-1/top-K beam prediction accuracy, average RSRP difference, and CDFs of RSRP difference between the AI-predicted beam and ideal beam.
* Ericsson [4]: Use case performance metrics could include metrics defined in Rel-17 EVM for BM including a potential energy saving metric, for example using the models defined in [4].
* InterDigital [5]: The following parameters should be considered to accurately evaluate benefits of AI/ML aided beam management.
  + Difference between estimated qualities and actual qualities
  + Optimal beam selection accuracy (%)
  + System performance based on the selected optimal beams
* CATT [6]: Intermediate KPI: Probability of identifying the best beam (pair), average power loss between the selected beam (pair) and the optimal beam (pair), and the ratio of overhead reduction;
* Vivo [7]: The 4 proposed RSRP-related KPIs should be considered for performance evaluation and comparison among different selected algorithms.
  + RSRP difference 1 for all predicted beam
  + RSRP difference 2 for predicted beam set
  + beam pair prediction deterioration
  + beam pair prediction accuracy
* xiaomi [8]: KPI:
  + KPI#1: The probability of right best Tx beam predicted by AI.
  + KPI#2: The L1-RSRP gap between the predicted best Tx beam and the real best Tx beam.
* Samsung [9]: For the performance-related KPI for AI/ML based beam prediction (in both time and spatial domains), the following two KPIs can be utilized, especially for Phase-I:
  + Accuracy of predicted best beam within the Top-N from genie-aided beam measurement.
  + Performance gap from the genie-aided beam measurement.
* Samsung [9]: In this SI, study and evaluate the performance of AI/ML beam prediction in the time domain in terms of the top N beam prediction accuracy and the overhead and latency reduction.
* OPPO [10]: Adopt L1-RSRP as performance metric for AI/ML beam prediction as a starting point.
* OPPO [10]: Study and evaluate the correct beam prediction rate for AI/ML beam prediction in spatial and time domain as one of the key performance metrics.
* Beijing Jiaotong University [11]: Beam selection accuracy, mean square error (MSE), throughput and system capacity, need to be considered as the KPI for the evaluation of beam selection.
* Beijing Jiaotong University [11]: Overhead, latency and beam selection accuracy of existing L1-RSRP measurement scheme, need to be considered as the benchmark of AI-based beam selection.
* Futurewei [12]: Include Top-1 prediction accuracy (Top1\_acc) as one of the evaluation metrics for AI/ML-based beam management use case.
* Futurewei [12]: Include Top-K (e.g., Top-3) prediction accuracy as one of the evaluation metrics for AI/ML-based beam management use case.
* Futurewei[12]: Include measured RSRP as one of the evaluation metrics for AI/ML-based beam management use case.
* CAICT [14]: The success rate of selecting best link quality beam pair(s) under a given number of measurements is used for performance comparison between AI/ML based algorithm and non-AI/ML based algorithm.
* CAICT [14]: The performance of the optimal beam pair(s) prediction by AI/ML model(s) could also be considered.
* CAICT [14]: Inference accuracy should be the main KPI for AI/ML based beam management algorithm.
* Apple [15]: The KPI for AI based beam prediction could be the beam prediction accuracy and the L1-RSRP distribution for the AI predicted beam.
* Lenovo [18]: KPIs for the AI/ML beam management performance evaluation should include beam alignment success rate, effectiveness (in terms of improvement in L1-RSRP or L1-SINR relative to legacy schemes), and beam failure rate.
* Nokia/NSB [19]: RAN1 shall consider the following KPIs for the ML-based beam management use case,
  + Beam prediction accuracy (Top-1 Prediction, Top-K Prediction, Top-1 and Top-K Prediction with 1 dB margin)
  + RSRP error/difference
* Intel [20]: For beam management use cases, hard metric KPIs like accuracy of best beam index or top K beam index prediction can be considered. Additionally, RSRP of predicted beams should also be considered as a key KPI for performance evaluation.
* NVDIA [21]: Define a KPI which measures beam management accuracy with and without AI/ML based algorithms.
* Qualcomm [23]: The KPIs for temporal beam prediction can be trade-off between reference signal overhead reduction (and/or UE power consumption) and a measure for beam prediction accuracy (such as RSRP prediction accuracy and/or top-M beam selection accuracy) and/or overall system performance (e.g., throughput).
* Qualcomm [23]: The KPIs for spatial (+time) domain beam prediction can be trade-off between reference signal overhead reduction (and/or UE power consumption) and a measure for beam prediction accuracy (such as L1-RSRP prediction accuracy and/or top-M beam selection accuracy) and/or overall system performance (e.g., throughput).
* Fujitsu [24]: The following KPIs are recommended for performance evaluation of beam prediction.
  + Probability of correct prediction
  + Average L1-RSRP difference
* MediaTek [25]: Inter-cell beam management (ICBM) can be considered.
  + KPI can be the accuracy of Cell ID(s) which the predicted best-N beam(s) belong to.
  + Note: ICBM does not necessarily mean mobility. ICBM introduced in Rel-17 feMIMO WI actually does not support mobility (i.e., no serving cell change). Therefore, ICBM should be considered in the scope of AI for BM.

Based on the proposals, the following proposal can be considered.

#### 1st round: FL1 High Priority Question 2-1

**Proposal 2-1:**

* The following beam prediction accuracy related KPIs for AI/ML in BM can be considered as a starting point:
  + L1-RSRP related KPIs:
    - Top-1/Top-K predicted beams:
      * Average L1-RSRP difference
      * CDF of L1-RSRP difference
      * CDF of L1-RSRP
  + Beam selection accuracy (%) without margin or with 1dB margin.
    - Top-1
    - Top-N
  + Note: Top-K beams are the Top-N from genie-aided beam measurement

**Question 2-1:**

1. Whether proposal 2-1 can be adopted? If no, what else is necessary to be considered and why?
2. Which KPI(s) are preferred as basic KPI(s)?
3. Which KPI(s) can be optional reported by each company?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | Y |  |
| Nokia | Y | a) Support.  b) Average L1-RSRP difference, Top-1 beam selection accuracy  c) CDF of L1-RSRP difference, CDF of L1-RSRP, Top-N beam selection accuracy |
| Xiaomi | Y | Support a)  For b), Average L1-RSRP difference and Top-1/K beam selection accuracy.  For c), CDF of L1-RSRP difference and CDF of L1-RSRP. |
| Vivo | Y | 1. Support 2. For RSRP related-KPI, we prefer average L1-RSRP difference and CDF of L1-RSRP difference as basic KPI, and both Top-1 and Top-N beam selection accuracy without margin or with 1dB margin can be considered as basic KPI.   For RSRP difference issue, at least three types of RSRP difference can be defined:  Type 1: Predicted RSRPs of top-k beams in predicted set – actual RSRPs in labelled set with the same K-th beam IDs;  Type 2: Predicted RSRPs of top-k beams in predicted set – actual RSRP of best beam in testing set;  Type 3: Actual RSRPs in labelled set of Top-k beams ID selected from predicted set -actual RSRP of best beam in testing set;  Thus, we believe the details of RSRP difference should be discussed further.  Moderator: In my understanding the for Top-K beams, RSRP difference is the predicted RSRP – actual RSRP of each target beam, where Top-K beams are the Top-K from genie-aided beam measurement |
| Intel | Y | a. Support the proposal  b. Top-1/N accuracy and Average L1-RSRP difference can be baseline  c. CDF of L1-RSRP difference can be optionally reported |
| NVIDIA | Y | a) Support  b) CDF of L1-RSRP difference, Top-K beam selection accuracy |
| OPPO | Y | a) Support  b) Average L1-RSRP difference, CDF of L1-RSRP difference, Top-1 beam prediction accuracy  c) any other KPIs |
| CATT | Y | a) Support the proposal.  b) Average L1-RSRP difference of the Top-K beams can be set as the basic KPI.  c) All other KPIs can be optionally reported by companies. |
| LGE | Y | a) Support.  b) Average L1-RSRP difference and Top-1/K beam selection accuracy.  c) CDF of L1-RSRP difference and/or CDF of L1-RSRP. |
| Ericsson | Y | 1. Agree 2. Average L1-RSRP difference and Top-1/K beam selection accuracy. |
| ZTE, Sanechips | Y | 1. Support. 2. Average L1-RSRP difference, CDF of L1-RSRP difference, and Top-1/K beam selection accuracy can be baseline. 3. CDF of L1-RSRP can be optionally reported. Besides, does the L1-RSRP here corresponding to the beam measurement results of different UEs or that of the same UE at different times?   Moderator: both can be considered depends on the simulation of each company. |
| CAICT | Y | a) Support  b) Average L1-RSRP difference, CDF of L1-RSRP difference, Top-1 beam prediction accuracy |
| Samsung | Y | a) support  b) Average L1-RSRP difference, Top-N beam prediction accuracy (N=1, and 3 can be selected firstly).  c) CDF of L1-RSRP difference: optionally reported because it is hard to align and compare among companies, and only provide additional information. |
| Fujitsu | Y | Basic KPIs:   * Average L1-RSRP difference and CDF of L1-RSRP difference * Top-1/N beam selection accuracy without margin |
| CMCC | Y | a) Yes  b) Average L1-RSRP difference, Top-N beam selection accuracy  c) CDF of L1-RSRP difference |
| MediaTek | Y | b) Average L1-RSRP difference and Top-1/N beam selection accuracy can be baseline  c) CDF of L1-RSRP and cell selection accuracy for inter-cell beam management case |
| HW/HiSi | [Y] | It should be clarified that the average L1-RSRP difference can also be calculated from difference beams sets. For example if the gain of narrow beams over wide beams should be evaluated. Or if the gains from super resolution non-orthogonal beams vs DFT beams should be evaluated  To capture this, we prefer to add note to the proposal how to understand the calculation of the L1-RSRP difference.  **Proposal 2-1:**   * The following beam prediction accuracy related KPIs for AI/ML in BM can be considered as a starting point:   + L1-RSRP related KPIs:     - Top-1/Top-K predicted beams:       * Average L1-RSRP difference         + Note: l1-RSRP difference can be obtained across different sets of beams       * CDF of L1-RSRP difference       * CDF of L1-RSRP   + Beam selection accuracy (%) without margin or with 1dB margin.     - Top-1     - Top-N   + Note: Top-K beams are the Top-N from genie-aided beam measurement   Moderator: Hope the Note 2 can address your concern. The intention is to calculate the difference of the L1-RSPB of the best beam in the set for beam selection, which can be same or different from the beam set of AI model input. |
| InterDigital | N | a) We prefer to discuss system performance and L1-RSRP together. We propose to include system performance in this proposal.  b) Average L1-RSRP difference, Top-N beam selection accuracy  c) CDF of L1-RSRP difference  Moderator: System performance related KPIs are discussed separately in section 2.1.2 |
| Lenovo |  | 1. Yes. 2. We think it is important to consider Latency incurred (i.e., time required for Tx-Rx beam selection) as a KPI for evaluating the performance of a proposed BM method and we discussed this in detail in our response to Question 2-3. For example, a scheme may achieve very high beam prediction accuracy, but it may need a long time in finding the beam-pair, rendering it practically useless.   Further, we suggest considering “Beam Failure Rate” as a KPI to evaluate the effectiveness of the AI/ML method’s beam tracking ability (if the AI/ML method also addresses the beam tracking). If the AI/ML model's beam tracking is not good, there would be more instances of beam failure. It can be computed as the number of beam failure events over a long time-period.  All the KPIs need to be reported across a range of SNR/SINR values covering low, moderate and high SNR/SINR regimes.  Moderator: Latency is discussed separated in section 2.1.3 |
| Qualcomm | Y | a) Support  b) top-1/top-N beam selection accuracy and average L1-RSRP difference  c) CDF of L1-RSRP and CDF of L1-RSRP difference |
| Futurewei | Y | 1. Y 2. We think both beam selection accuracy and L1-RSRP difference/gap are good KPIs to start with: Top-1/Top-N prediction accuracy and CDF of L1-RSRP difference 3. Average difference and CDF of L1-RSRP can be optionally reported. |
| NTT DOCOMO | Y |  |
| PML | Y | 1. Support 2. top-1/top-N beam selection accuracy, average L1-RSRP difference 3. CDF of L1-RSRP and CDF of L1-RSRP difference |

Summary of Question 2-1

Most of the companies agree on the proposal 2-1. One company suggested to discuss system performance as well.

One company suggest to consider Latency incurred and Beam Failure Rate. One company propose to have cell selection accuracy for inter-cell beam manage case.

The following are the summary of the L1-RSRP related KPIs:

* L1-RSRP related KPIs:
  + Top-1/Top-K predicted beams:
    - Average L1-RSRP difference
      * As basic KPI supported by (18): Nokia/NSB, Xiaomi, vivo, Intel, OPPO, CATT, LGE, Ericsson, ZTE/Sanechips, CAICT, Samsung, Fujitsu, CMCC, MediaTek, InterDigital, Qualcomm,
      * As optional KPI supported by (1): Futurewei
    - CDF of L1-RSRP difference
      * As basic KPI supported by (8): Vivo, NVIDIA, OPPO, ZTE/Sanechips, CAICT, Fujitsu, Futurewei
      * As optional KPI supported by (10): Qualcomm. InterDigital, CMCC, Samsung, ZTE/Sanechips, LGE, Intel, Xiaomi, Nokia,
    - CDF of L1-RSRP
      * As optional KPI supported by (4): Qualcomm, MediaTek, Xiaomi, Nokia
* Beam selection accuracy (%) without margin or with 1dB margin.
  + Top-1
    - As basic KPI supported by (14): Nokia/NSB, xiaomi, vivo, Intel, OPPO, LGE, Ericsson, CAICT, Samsung, Fujitsu (w/o margin), MediaTek, Qualcomm, Futurewei
  + Top-K
    - As basic KPI supported by (14): Xiaomi, vivo, Intel, NVIDIA, CATT, LGE, Ericsson, Samsung (N=3), Fujitsu(w/o margin), CMCC, MediaTek, InterDigital, Qualcomm, Futurewei
    - As optional KPI supported by (1): Nokia
* Note: Top-K beams are the Top-K from genie-aided beam measurement

Some clarification questions were asked or proposed by some companies. Comments from moderator can be found in previous table. Besides, moderator found out that different companies may have different assumption on Top-1 and/or Top-K shall be used. Therefore, the proposals for next round try to split the discussion.

Based on the summary and to address the concerns, the following proposals can be considered.

#### 2nd round: FL2 High Priority Question 2-1-1

**Proposal 2-1-1:**

* **At least the following beam prediction accuracy related KPIs for AI/ML in BM can be considered as basic KPIs:**
  + **Average L1-RSRP difference of Top-1 predicted beam**
  + **Beam selection accuracy (%) without margin for Top-1 and Top-K [K=3] beams**
    - **FFS: Beam selection accuracy for Top-K beams is the % if the Top-K beam set is correct.**
* **Note 1: Top-1/K beams are the Top-1/K from genie-aided beam measurement**
* **Note 2: L1-RSRP difference is the difference between the predicated L1-RSRP and L1-RSRP from genie-aided beam measurement of the best beam in the set for beam selection.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, OPPO, CATT, CAICT, Xiaomi, PML, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel** |
| Objecting companies | **InterDigital (Propose to combine L1-RSRP related KPIs with system performance related KPIs. We strongly believe that although L1-RSRP could be an intermediate KPI, but L1-RSRP is not enough to measure actual benefits from AI/ML based beam prediction.)** |

**Question 2-1-1:**

1. Please provide your view on proposal 2-1-1

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | “FFS: Beam selection accuracy for Top-K beams is the % if the Top-K beam set is correct” is not fully clear. Is the plan to agree with FFS or define the text inside FFS ?  FL: the sub bullet with FFS is try to define what does Beam selection accuracy (%) for Top-K beams means. Since no one provide any definition, and I feel there are several ways to define it therefore, I put FFS here. For example, some company may think the selection accuracy may be defined as only if the order of Top K beam is correct. However, current wording is try to make Top K beam accuracy regardless the order. If this definition is OK for everyone. We can remove “FFS” later. |
| NTT DOCOMO | We prefer to align the terminology of ‘beam selection accuracy’ and ‘beam prediction accuracy’ in the proposal.  FL: In my understanding, beam prediction accuracy includes whether the beam is correctly selected, and with the selected beam, the accuracy of L1-RSRP. |
| LGE2 | Generally fine. We think beam selection accuracy with 1 dB margin can also be basic KPIs. Also, further discussion is needed for the definition of beam selection accuracy for Top-K beams.  FL: If most companies support it, we can make it as basic KPIs as well. |
| CATT | Generally fine. Is the FFS trying to define: Beam selection accuracy for Top-K beams is the percentage of ‘the genie-aided best beam belongs to the Top-K predicted beam’?  FL: My original thinking was to ensure that all top K beams are correct regardless the order. But hope company can provide their preference on definition. |
| Xiaomi | Prefer to clarify the FFS |
| ZTE, Sanechips | Prefer to clarify the FFS. Per our understanding, the beam selection accuracy for Top-K beams can be the percentage of the samples that the Top-K likely predicted beams include the optimal beam. In this case, a refined small-range beam sweeping needs to be performed to obtain the optimal beam. |
| vivo | We prefer to add another average RSRP difference: the RSRP (not predicted) of the predicted Top1/K beam – the Top1/K RSRP through genie aided measurement |
| Ericsson | Suggest removing the FFS since it is not clear. Also add the beam selection accuracy with 1 dB margin as a KPI. Rename to prediction accuracy instead of selection accuracy. |
| HW/HiSi | The FFS is difficult to understand, do you mean that all inferred top-K beams are the true top-K beams, or is it mean that the optimum beam is included in the top-K beams?  “**FFS: Beam selection accuracy for Top-K beams is the % if the Top-K beam set is correct**.” |
| CMCC | The wording "the Top-K beam set is correct " is confusing, suggest the following updates:  **Proposal 2-1-1:**   * **At least the following beam prediction accuracy related KPIs for AI/ML in BM can be considered as basic KPIs:**   + **Average L1-RSRP difference of Top-1 predicted beam**   + **Beam selection accuracy (%) without margin for Top-1 and Top-K [K=3] beams**     - **FFS: Beam selection accuracy for Top-K beams ~~is the % if the Top-K beam set is correct.~~** * **Note 1: Top-1/K beams are the Top-1/K from genie-aided beam measurement** * **Note 2: L1-RSRP difference is the difference between the predicated L1-RSRP and L1-RSRP from genie-aided beam measurement of the best beam in the set for beam selection.** |
| MediaTek | The “Top-K beam” may be considered optional. Usually, UE is configured to perform L1 measurements on several neighboring beams, and thus it can guess the Top-K beams. However, UE will be indicated to only one beam, and that should be the goal of AI/ML-based beam prediction. |
| Futurewei | We are ok with the proposal. However, the average L1-RSRP difference of Top-1 predicted beam may not provide full picture view of the beam prediction performance. CDF of L1-RSRP difference of Top-1 predicted beam may help performance comparison across approaches. We provide our view in our response for proposal 2-1-2. |
| Lenovo | Both KPIs in this proposal and important to be considered as basic KPIs |
| Qualcomm | Suggest the definition of Beam selection accuracy for Top-K beams either elaborated or the definition left for FFS. |
| Intel | The FFS should be removed since it is not clear. |
| InterDigital | We suggest to remove the FFS bullet. |

Based on the above comments, **Proposal 2-1-1** is updated to **Proposal 2-1-1a.** companies are invited to provide the comments and explain the definition of “**Beam prediction accuracy (%) for Top K beams**”

#### 3rd round: FL3 High Priority Question 2-1-1a

**Proposal 2-1-1a:**

* **At least the following beam prediction accuracy related KPIs for AI/ML in BM can be considered as basic KPIs:**
  + **Average L1-RSRP difference of Top-1 predicted beam**
  + **Beam prediction ~~selection~~ accuracy (%) without margin for Top-1 and Top-K [K=3] beams**
    - **FFS: definition of beam prediction ~~selection~~ accuracy (%) for Top-K beams ~~is the % if the Top-K beam set is correct.~~**
* **Note 1: Top-1/K beams are the Top-1/K from genie-aided beam measurement**
* **Note 2: L1-RSRP difference is the difference between the predicated L1-RSRP and L1-RSRP from genie-aided beam measurement of the best beam in the set for beam selection.**

|  |  |
| --- | --- |
| Supporting companies | **DCM, OPPO, CAICT, CMCC, CATT, Fujitsu, LGE, Samsung, Ericsson, Nokia, Futurewei, Lenovo, Qualcomm, MediaTek, ZTE** |
| Objecting companies |  |

**Question 2-1-1a:**

1. Please provide your view on proposal 2-1-1a. And please provide your definition of beam prediction accuracy (%) for Top-K beams

|  |  |
| --- | --- |
| Company | Comments |
| CMCC | The definition is related to whether traditional P2 are performed after AI based BM prediction.  For example, if AI/ML is used for select the top-N1 DL beams during P1. During P2, UE would measure the predicted top-N1 DL beams and report the measured RSRP to gNB. gNB indicates the transmission beam based on the measured RSRP of top-N1 DL beams. In such case, beam prediction accuracy for the top-N1 beam means the probability of best beam among all beams belongs to the top-N1 predicted beam.  If AI/ML is used for select the top-N1 DL beams during P1, no traditional P2 is performed, then gNB indicates the transmission beam based on the predicted RSRP of top-N1 DL beams. In such case, beam prediction accuracy for the top-N1 beam means the probability that best beam among all beams is the same as the best beam among the top-N1 predicted beams. Beam prediction accuracy of P1 may be smaller than that of P1 and P2. |
| CATT | We see different understanding:  (1) The percentage of ‘the genie-aided optimum beam is included in the top-K predicted beams’.  (2) The percentage of ‘the genie-aided K best beams are exactly the same with the top-K predicted beams’.  Our initial understanding is (1), but we are open to either one as long as the definition is clear to all. |
| Fujitsu | from our understanding, the beam prediction accuracy for Top-K beams can be defined as  the percentage of beam with best predicted L1-RSRP is included in the Top-K beams from genie-aided beam management. |
| LGE | Regarding the FFS part, it is better to clearly define the definition in this meeting. We have similar view as CATT with (1). |
| Ericsson | Our understanding is CATT (1). Suggest updating the FFS text with CATT (1). |
| HW/HiSi | Beam prediction accuracy (%) for Top-K beams is defined by the accuracy that the optimal beam from genie-aided BM is in included in the set of the predicted Top-K beams. |
| Nokia | Ok with the proposal.  Definition : the beam selection accuracy for Top-K beams is the percentage of the samples that the Top-K likely predicted beams include the optimal beam (top-1 beam) from genie-aided beam measurement |
| Lenovo | The KPI “Beam prediction accuracy (%) for Top-K beams” should be the “Percentage of samples (or, equivalently, the percentage of the beam prediction instances) that the predicted beam is among the top-K beams given by the genie-aided/exhaustive search method”. The mathematical expression given by Nokia in R1-2204573 may be adopted. |
| Xiaomi | For the definition of beam prediction accuracy, we share same view as CATT (1). While for ‘without margin’ and note 2, does it mean the RSRP must be the output of the AI/ML model? We prefer to define it as the L1-RSRP-difference obtained by genie-aided beam measurement between the predicted best beam and the genie-aided beam measurement of the best beam. If the predicted best beam is same as the genie-aided beam measurement of the best beam, the L1-RSRP difference will be 0. |
| ZTE, Sanechips | We prefer to define the beam prediction accuracy as the percentage that the Top-K likely predicted beams include the genie-aided best beam, as mentioned in CATT(1). According to preliminary simulation results provided by some companies, the beam prediction accuracy can be significantly improved by inferring Top-K candidate beams for refined small-range beam sweeping. Regarding the definition of beam prediction accuracy that all top K beams are correct regardless the order, we doubt if gNB can always select a optimal beam among the K beams to guarantee a best performance, even with a well-trained AI model. Besides, this kind of definition may complicate the model training and inference process. |

#### 2nd round: FL2 High Priority Question 2-1-2

**Proposal 2-1-2:**

* **Further study whether any of the following beam prediction accuracy related KPIs for AI/ML in BM can be considered as basic KPIs or optional KPIs:**
  + **CDF of L1-RSRP difference for Top-1 predicted beam**
  + **CDF of L1-RSRP for Top-1 predicted beam**
  + **Average L1-RSRP difference for Top-K [K=3] predicted beam**
    - **FFS on the definition**
  + **CDF of L1-RSRP difference for Top-K [K=3] predicted beam**
    - **FFS on the definition**
  + **CDF of L1-RSRP for Top-K [K=3] predicted beam**
    - **FFS on the definition**
  + **Beam selection accuracy with 1dB margin (%) for Top-1 beam**
  + **Beam selection accuracy with 1dB margin (%) for Top-K [K=3] beams,** 
    - **FFS: Beam selection accuracy with 1dB margin(%) for Top-K beams is the % if the Top-K beam set is correct**
  + **Beam Failure Rate (Sub-use specific)**
  + **Cell selection accuracy inter-cell beam manage case (Sub-use specific)**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel, InterDigital** |
| Objecting companies |  |

**Question 2-1-2:**

1. Please provide your view on proposal 2-1-2. Please provide the definition if you support any of the KPIs as optional or basic

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | We support following two items to be used as basic KPI and others could be optional:   * CDF of L1-RSRP difference for Top-1 predicted beam * Average L1-RSRP difference for Top-K [K=1/3] predicted beam |
| Fujitsu | * 1. The following optional KPIs are supported   **CDF of L1-RSRP difference for Top-1 predicted beam** |
| CATT | We think the following can be basic:   * **CDF of L1-RSRP difference for Top-1 predicted beam** * **Beam selection accuracy with 1dB margin (%) for Top-1 beam**   Meanwhile, we are not sure ‘**CDF of L1-RSRP for Top-1 predicted beam**’ is meaningful since it is not compared to legacy mechanism. |
| PML | 1. CDF of L1-RSRP difference for Top-1 predicted beam, Average L1-RSRP difference for Top-K [K=3] predicted beam |
| ZTE, Sanechips | We have a similar concern with CATT about whether it is necessary to evaluate CDF of L1-RSRP for Top-1 predicted beam. |
| Samsung | We are open to discuss although we think KPIs in Proposal 2-1-1 are sufficient. |
| HW/HiSi | We support the following as basic KPIs:   * **CDF of L1-RSRP difference for Top-K [K=1/3/5] predicted beam** * **Beam selection accuracy with 1dB margin (%) for Top-K [K=1/3/5] beams** |
| CMCC | We think Average L1-RSRP difference for Top-K [K=3] predicted beam can be basic, others can be optional. |
| MediaTek | Rel-17 inter-cell beam management should be considered in the scope of AI for BM. In this case, the KPI can be cell selection accuracy instead of beam prediction accuracy. |
| Futurewei | We prefer including CDF of L1-RSRP difference for Top-1 predicted beam as one of the KPIs to help better compare the performance across approaches. Average value may be mis-leading. Beam selection accuracy with 1dB margin (%) for Top-1 beam cam be considered as optional KPI.  We suggest not to specify many optional KPIs while companies may still report if they see the needs. |
| Lenovo | We recommend “Average L1-RSRP difference for Top-K [K=3] predicted beam” and “Beam selection accuracy with 1dB margin (%) for Top-K [K=3] beams” as an optional KPIs. |
| Intel | OK to study |
| InterDigital | We are fine to study. |

#### 3rd round: FL3 High Priority Question 2-1-2a

Summary of the supporting companies based on the inputs for question 2-1-1 and question 2-1-2:

* + **CDF of L1-RSRP difference for Top-1 predicted beam**
    - **Supported by as basic (2): CATT, Futurewei**
    - **Supported by as optional (3): DCM, Fujitsu, PML**
  + CDF of L1-RSRP for Top-1 predicted beam
  + Average L1-RSRP difference for Top-K [K=3] predicted beam
    - FFS on the definition
    - Supported by as basic (1): CMCC
    - Supported by as optional (2): DCM, PML
  + CDF of L1-RSRP difference for Top-K [K=3] predicted beam
    - FFS on the definition
    - Supported by as basic (1): HW/HiSi
    - Supported by as optional (1): Lenovo
  + CDF of L1-RSRP for Top-K [K=3] predicted beam
    - FFS on the definition
  + **Beam selection accuracy with 1dB margin (%) for Top-1 beam**
    - **Supported by as basic (5): CATT, HW/HiSi, LGE, Ericsson**
    - **Supported by as optional (1): Futurewei**
  + Beam selection accuracy with 1dB margin (%) for Top-K [K=3] beams,
    - FFS: Beam selection accuracy with 1dB margin (%) for Top-K beams is the % if the Top-K beam set is correct
    - Supported by as basic (3): HW/HiSi (Top 1/3/5), LGE, Ericsson(?)
    - Supported by as optional (1): Lenovo
  + Beam Failure Rate (Sub-use specific)
  + Cell selection accuracy inter-cell beam manage case (Sub-use specific)
    - Supported by(1): MediaTek

Based on the summary, the following proposal can be considered:

**Proposal 2-1-2a:**

* **The following beam prediction accuracy related KPIs for AI/ML in BM can be considered as optional KPIs:**
  + **CDF of L1-RSRP difference for Top-1 predicted beam**
  + **Beam ~~selection~~ prediction accuracy (%) with 1dB margin (%) for Top-1 beam**
  + **Other KPIs are not precluded and can be reported by companies.**

|  |  |
| --- | --- |
| Supporting companies | **OPPO, CAICT, CMCC, CATT, Fujitsu, LGE, Samsung, Ericsson, [HW/HiSi] (with updates), Nokia, Futurewei, Lenovo, Qualcomm, MediaTek, ZTE, InterDigital (if we also agree system performance as well)** |
| Objecting companies |  |

**Question 2-1-2a:**

* + - * 1. Please provide your view on proposal 2-1-2a

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | In addition to the KPI the proposal covers, average L1-RSRP difference for Top-K [3] predicted beam can be optional KPI as well. |
| OPPO | We are also fine with DCM’s suggestion.  One minor suggestion for wording. It is better to align the same terminology: beam prediction accuracy in main bullet and beam selection accuracy in the 2nd sub-bullet |
| CAICT | We are fine with FL’s proposal and some updates. |
| FL | Proposal 2-1-2a is updated to align the description with Proposal 2-1-1a, by changing “Beam selection accuracy” to “beam prediction accuracy” |
| CATT | Generally fine.  Regarding other KPIs, we think the sub-bullet is clear that they are not precluded. |
| Fujitsu | We prefer the first bullet as one of optional KPIs |
| LGE | OK |
| HW/HiSi | The performance varies a lot dependent on different values of Top-K. In some cases, a negative gain may be observed for Top-1. Thus, we suggest to include different candidate values for Top-K, for example, Top-1, Top-3, and Top-5.   * **The following beam prediction accuracy related KPIs for AI/ML in BM can be considered as optional KPIs:**   + **CDF of L1-RSRP difference for Top-1/3/5 predicted beam(s)**   + **Beam selection accuracy (%) with 1dB margin (%) for Top-1/3/5 beam(s)** |
| Xiaomi | Same comments as for proposal 2-1-1a |
| ZTE, Sanechips | We agree with DCM that average L1-RSRP difference for Top-K [1/3] predicted beam can be optional KPI. Besides, we would like to check if the Top-1 predicted beam in the subbullet represents that: 1) one beam is predicted by AI and adopted as the optimal beam; or 2) K candidate beams are predicted by AI and scanned again by brute-force search to obtain the optimal beam. |
| InterDigital | We are also fine with Docomo’s suggestion and prefer to support system performance as well. |

### 2.1.2 System performance related KPIs

Other than beam measurement related KPIs, several companies mentioned that the system performance shall be also evaluated:

* Huawei/HiSi [1] Consider a super-narrow codebook (e.g., with 256 Tx beams) for the evaluation of the AI/ML-based spatial domain beam prediction to improve the system performance (e.g., coverage, throughput) from the network perspective without increasing the maximum number of CSI-RS resources.
* Ericsson [4]: Use case performance metrics could include metrics defined in Rel-17 EVM for BM including a potential energy saving metric, for example using the models defined in [4].
* Vivo [7]: Throughput performance for space/time domain beam prediction are also considered.
* Samsung [9]: For Phase-II, user-perceived throughput (UPT) can be utilized as the KPI to evaluate the performance benefits obtained by AI/ML-based beam measurement.
* Samsung [9]: Shannon capability based simplified model for UPT can be employed in the EVM of AI/ML-based beam management.
* Beijing Jiaotong University [11]: Beam selection accuracy, mean square error (MSE), throughput and system capacity, need to be considered as the KPI for the evaluation of beam selection.
* Nokia/NSB [19]: RAN1 shall consider the following KPIs for the ML-based beam management use case,
  + Beam management measurement overhead
  + Cell throughput (average, 5%ile, 50%ile)
* Qualcomm [23]: The KPIs for temporal beam prediction can be trade-off between reference signal overhead reduction (and/or UE power consumption) and a measure for beam prediction accuracy (such as RSRP prediction accuracy and/or top-M beam selection accuracy) and/or overall system performance (e.g., throughput).
* Qualcomm [23]: The KPIs for spatial (+time) domain beam prediction can be trade-off between reference signal overhead reduction (and/or UE power consumption) and a measure for beam prediction accuracy (such as L1-RSRP prediction accuracy and/or top-M beam selection accuracy) and/or overall system performance (e.g., throughput).

Based on the proposals, the following proposal can be considered.

#### 1st round: FL1 High Priority Question 2-2

**Proposal 2-2:**

* **System performance is considered as one of the general KPIs for AI/ML in beam management. FFS on the following details:**
  + **UE throughput: CDF of UE throughput, avg. and 5%ile UE throughput**

**Question 2-2:**

1. Whether proposal 2-2 can be adopted? If not, why?
2. Which KPI(s) are preferred as basic KPI(s)? Are they common for all the sub-use cases or subject to some of sub-use case(s)?
3. Which KPI(s) can be optional reported by each company?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | N | We are open to consider throughput as an optional metric. Usually L1-RSRP should be sufficient for BM related evaluation. |
| Nokia | Y | a) Yes,  b) average cell throughput, 5%-percentile and 50%-percentile UE throughput  c) Packet delay (for the sub-use case of spatial domain beam prediction for throughput and latency reduction) |
| Xiaomi | N | We prefer to consider throughput as an optional metric and we share same view as Apple. |
| vivo |  | Support at least in SI-phase 2 stage for further performance evaluation. |
| Intel | N | The KPIs related to beam measurement should be the baseline and are enough to evaluate AI/ML model performance. System performance KPIs should be optional if at all needed. |
| NVIDIA | Y | a) Yes,  b) CDF of UE throughput, avg. and 5%ile UE throughput |
| OPPO |  | It can be an optional KPI  Average cell throughput, 5%-percentile UE throughput |
| AT&T | Y | 1. Prefer CDF of UE throughput and 5% UE throughput 2. Packet delay |
| CATT | Y | a) Yes  b) CDF of UE throughput shall be the basic one. |
| LGE | N | Prefer to have throughput as optional metric. |
| Ericsson | Y | a) Agree  b) CDF of UE throughput, avg. and 5%ile UE throughput  c) CDF of UE beam failures, Note that time-based beam predictions could be used to mitigate such occurrences |
| ZTE, Sanechips |  | Throughput related metrics such as 5%-edge, 95%-ile, and mean UPT can be evaluated for time-domain beam prediction. |
| CAICT | N | It may depend on the operation mode for AI/ML based BM. We think Proposal 2-1 should be baseline. |
| Samsung |  | We think throughput need to be considered in the end. But for phase I study, this is not necessary. |
| Fujitsu | N | In initial stage, the UE throughput is not necessary since KPIs of proposal 2-1 are sufficient to show the gains of AI/ML-based method. |
| CMCC |  | We prefer to consider throughput as an optional metric. |
| MediaTek | N | L1-RSRP should be sufficient for BM evaluation. UE throughput can be considered as an optional metric. |
| HW/HiSi |  | We are open to discuss system performance |
| InterDigital | Y | As we commented, L1-RSRP is not enough for BM evaluation. We strongly prefer to discuss system performance together with L1-RSRP in a same proposal. |
| Lenovo | N | 1. We think the resulting L1-RSRP/L1-SINR after beam alignment (or, beam selection/pairing) should serve as a good and sufficient metric. However, we are open to having throughput as an optional metric. 2. Overhead and latency, along with beam prediction accuracy metrics of Proposal 2-1, should be considered as basic KPIs. |
| Qualcomm | Y | a) Yes,  b) CDF of UE throughput  Beam selection accuracy and L1-RSRP difference do not capture the full picture and benefit of AI/ML on their own, as they are not representative of the overhead needed to achieve the respective performance, and therefore may lead to misinterpretation of evaluation results. |
| Futurewei | N | We agree with Apple that L1-RSRP KPIs should be sufficient in evaluating the performance for beam prediction and UE throughput can be optional. |
| PML | Y | a) Yes,  b) 5%-edge, 95%-ile, and mean UE throughput  c) Overhead and latency |

Summary of Question 2-2

Companies have different view on whether the system performance, i.e., UE throughput can be the basic KPIs or not. The summary is as below:

* Supported by (10): Nokia, vivo, NVIDIA, AT&T, CATT, Ericsson ZTE/Sanechips(?), InterDigital, Qualcomm
* Not supported by (11): Apple, Xiaomi, Intel, OPPO, LGE, CAICT, Samsung, Fujitsu, MediaTek, Lenovo, Futurewei

Based on the summary, the following proposal can be considered.

#### 2nd round: FL2 High Priority Question 2-2a

**Proposal 2-2a:**

* **Beam measurement related KPIs is used for sub-use case selection.**
* **For the selected representative sub-use case for BM, the system performance is considered as the general KPIs:** 
  + **UE throughput: CDF of UE throughput, avg. and 5%ile UE throughput**

|  |  |
| --- | --- |
| Supporting companies | **Nokia (second bullet only), DCM, PML, vivo, Samsung, HW/HiSi (second bullet only), Lenovo (first bullet only), InterDigital** |
| Objecting companies | **Fujitsu, Xiaomi, MediaTek, Futurewei, Qualcomm, Intel** |

**Question 2-2a:**

1. Please provide your view on proposal 2-2a

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | First bullet is not needed at this stage. |
| DCM | How to conduct the system performance for each representative sub use cases should be further studied. |
| Fujitsu | For the first bullet, we don’t fully understand  For the second bullet, we think system performance is not necessary in initial stage |
| LGE | The performance related KPIs can be optionally considered. |
| OPPO | We prefer to keep system performance as optional KPI. But we can live with it. |
| CATT | Although we understand the motivation, it is unclear to us how these KPIs will be used for sub-use case selection. In different sub-use cases, the KPIs may or may not be the same. |
| CAICT | We are OK with the first bullet. However, if BM is only used to measurement overhead reduction, system performance might not be necessary. |
| Xiaomi | Throughput is not necessary |
| FL | Please provide your view on the two bullets separately. |
| ZTE, Sanechips | We are fine with first bullet. For the second bullet, we think the system performance can be considered as an optional KPI. |
| Ericsson | Unclear first bullet. Ok with second bullet |
| Samsung | In the Phase I evaluation (beam measurement related KPIs), a simpler metric is preferred for sub-use case selection. The Phase II evaluation (general KPIs) is encouraged to show the benefit of the AI-based solutions in RAN1 perspectives. |
| Spreadtrum | The performance of UE throughput can be an optional KPI. |
| HW/HISi | The first bullet is not needed at the stage |
| CMCC | Does general KPI mean basic KPI? |
| MediaTek | For beam management study purpose, we believe that L1-RSRP distribution is enough. |
| NVIDIA | How to perform sub-use case selection can be FFS, i.e., it does not need to be tied to KPIs at this stage. |
| Futurewei | We are ok with the first bullet. The 2nd bullet (throughput) is not needed. |
| Lenovo | Support the proposal, in general. We agree with the first point “Beam measurement related KPIs is used for sub-use case selection”. KPIs for the sub-use cases should be discussed after selecting the sub-use cases, as applicable to the sub-use case being considered. |
| Qualcomm | We do not agree with the two-phase approach and believe both beam measurement related KPIs and system performance (throughput) should be considered for both use case selection and further evaluation. Relying solely on beam measurement related KPIs may lead to exaggerated gains of AI/ML without incorporating the underlying costs (RS overhead, etc.) needed to achieve those gains. Therefore, we believe both beam measurement related KPIs and throughput should be considered at both stages (use case selection and further evaluation) |
| Intel | End-to-end system level simulation while good to have, should not be mandated since the AI/ML performance can easily be determined by beam prediction related KPIs. Suggest to make throughput or full simulation related metrics optional. |
| InterDigital | As we mentioned several times, we strongly believe that system performance should be a final KPI to evaluate actual benefits of proposed specification enhancements considering optimal beam selection, RS overhead reduction, beam selection latency reduction and etc. |

#### 3rd round: FL3 High Priority Question 2-2b

**Proposal 2-2b:**

* **For the selected representative sub-use case for BM, the system performance is considered as one of KPIs:** 
  + **UE throughput: CDF of UE throughput, avg. and 5%ile UE throughput**
  + **FFS whether UE throughput is a basic KPI or an optional KPI based on the selected representative sub-use case for BM.**

|  |  |
| --- | --- |
| Supporting companies | **DCM, OPPO, CAICT, CMCC, CATT, Samsung, Ericsson, Nokia, Futurewei, Lenovo (partially, see comments), Qualcomm, ZTE, InterDigital** |
| Objecting companies | **Fujitsu, MediaTek** |

**Question 2-2b:**

1. Please provide your view on proposal 2-2b

|  |  |
| --- | --- |
| Company | Comments |
| CMCC | We prefer to consider throughput as an optional KPI at initial evaluation phase. |
| Fujitsu | we think system performance is not necessary in initial stage. |
| LGE | Similar view as Fujitsu. |
| HW/HiSi | We think that throughput is not needed at this stage. The RSRP evaluation should be sufficient. However, as a compromise, we could remove the FFS from 2-2b:   * **For the selected representative sub-use case for BM, the system performance is considered as one of KPIs:**    + **UE throughput: CDF of UE throughput, avg. and 5%ile UE throughput**   + **~~FFS whether~~ UE throughput is a ~~basic KPI or an~~ optional KPI based on the selected representative sub-use case for BM at this stage.** |
| Nokia | To understand the benefits of AI/ML solutions for beam management, it is not adequate to look only ML model performance. In MIMO BM related studies, it is hard to identify any gain without observing the system level performance, and we are bit puzzled by company views that suggesting throughput as Optional KPI.  RAN1 shall use general KPIs that used in past MIMO discussions, and system throughput is one main KPI that allows us to see performances of the ML solutions vs baselines.  We do not think this can be avoided or delayed in RAN1, as the work will be incomplete without a good investigation. Therefore, we suggest stating this already as a basic KPI and we do not really see technical justification to do otherwise. |
| Lenovo | We should be discussing about the KPIs for the representative sub-use case of BM only after finalizing the sub-use case of BM. We prefer having throughput only as an optional KPI. |
| Qualcomm | Agree with Nokia’s update that system performance (throughput) should be a basic KPI from beginning to truly assess the benefits of AI/ML-based solutions. |
| Xiaomi | Same view as Fujitsu. |
| MediaTek | Share the same view with Fujitsu, LG, HW, Xiaomi. As a compromise, fine with HW’s suggestion. |
| InterDigital | In our view, L1-RSRP related KPIs possibly evaluate beam prediction as an intermediate measure, however, we strongly believe that final decision should be based on system performance. For example, X dB higher L1-RSRP does not guarantee actual system performance gain considering inter-cell interference, MU interference, actual CQI and etc. In addition, we also agree with Nokia that system performance was used for MIMO related discussion even in beam management. Finally, we don’t think that RAN1 will separately discuss KPIs for the initial stage and the final stage, so we strongly prefer to agree system performance as a KPI. |

### 2.1.3 Other performance KPIs

Overhead reduction and latency were proposed as one of the KPIs for AI/ML in beam management:

* Huawei/HiSi [1]: Consider the evaluation of the AI/ML based spatial domain beam prediction with the target to obtain accurate narrow beams for CSI-RS beam sweeping to reduce the UE’s overhead and power consumption.
* ZTE [2]: AI/ML based solutions are expected to be studied and evaluated to do beam prediction so as to reduce beam tracking latency and RS overhead in high mobility scenarios.
* Ericsson [4]: The study item should investigate how beam predictions can improve robustness and reduce overhead associated to beam management
* CATT [6]: Intermediate KPI: Probability of identifying the best beam (pair), average power loss between the selected beam (pair) and the optimal beam (pair), and the ratio of overhead reduction;
* Samsung [9]: Reference signal overhead (SSB or CSI-RS) and reduced latency for the specific beam management procedure should be considered as performance-KPI for beam prediction in both time and spatial domains.
* Samsung [9]: In this SI, study and evaluate the performance of AI/ML beam prediction in the time domain in terms of the top N beam prediction accuracy and the overhead and latency reduction.
* Beijing Jiaotong University [11]: Overhead, latency and beam selection accuracy of existing L1-RSRP measurement scheme, need to be considered as the benchmark of AI-based beam selection.
* Lenovo [18]: Beam acquisition/selection latency including Tx/Rx beam training should be evaluated for a proposed AI/ML
* Nokia/NSB [19]: RAN1 shall consider the following KPIs for the ML-based beam management use case,
  + Beam management measurement overhead
* NVIDIA [21]: Define a KPI which measures the reference signal overhead for beam management with and without AI/ML based algorithms.
* NVIDIA [21]: Define a KPI which measures the latency for beam management with and without AI/ML based algorithms.
* Qualcomm [23]: The KPIs for temporal beam prediction can be trade-off between reference signal overhead reduction (and/or UE power consumption) and a measure for beam prediction accuracy (such as RSRP prediction accuracy and/or top-M beam selection accuracy) and/or overall system performance (e.g., throughput).
* Qualcomm [23]: The KPIs for spatial (+time) domain beam prediction can be trade-off between reference signal overhead reduction (and/or UE power consumption) and a measure for beam prediction accuracy (such as L1-RSRP prediction accuracy and/or top-M beam selection accuracy) and/or overall system performance (e.g., throughput).

Based on the above proposals, the following question can be discussed.

#### 1st round: FL1 Medium Priority Question 2-3

**Question 2-3:**

1. Whether the reference signaling overhead reduction ratio can be considered as one of the KPIs for AI/ML in BM (when applicable)? If yes, how to define the metric?
2. Whether latency can be considered as one of the KPI for AI/ML in BM (when applicable)? If yes, how to define the metric?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | Y | We think both overhead and latency can be considered as optional KPIs, which depend on the use cases. For overhead, metric can be number of required resources for BM, and for latency, the metric can be beam update delay. |
| Nokia, NSB | Y | 1. signaling overhead reduction ratio can be computed as   1-N/M, where N is the number of beam measurements for a subset of beams with size N and M is the number of all beams. When UE specific measurements are needed, N should be specific for each UE, and the metric should account for the number of UEs per sector.   1. Latency may be specific to the packet delay defined as the one-way PDCP layer delay between gNB and UE. |
| Xiaomi | Y | At least the reference signal overhead reduction ratio can be considered as one of the KPIs. And the metric can be the number of RS resource for beam management. |
| vivo | Y | Overhead from beam sweeping and UCI report should be considered as basic KPI. The metric of beam sweeping overhead can be the number of resources for BM in both non-AI algorithm and AI algorithm. The overhead of UCI report can also be reported by companies.  The necessity of considering latency is unclear since we already have RSRP difference as a metric. The necessity and details on how to define latency should be clarified. |
| Intel | Y | Both overhead and latency reduction are important metrics to consider along with beam prediction accuracy and are more important that system performance metrics in the previous section. |
| NVIDIA | Y | 1. Signaling overhead can be measured as the ratio of required number of beams for a given scheme over the number of all beams. With this, signaling overhead reduction can be computed accordingly. 2. AI/ML model inference latency, i.e., the time it takes for the model to make its prediction once it is fed its input. |
| OPPO | Y | RS overhead reduction and latency can be optional KPIs. |
| AT&T | Y | Support overhead reduction and latency metrics. The proposals from Nokia and vivo are good starting points |
| CATT | Y | a) Overhead reduction ratio can be considered as a KPI.  b) Latency reduction seems not applicable to all sub use cases. |
| LGE | Y | Prefer to have overhead reduction ratio as basic KPI. Generalized equation for the ratio can be decided in this meeting. |
| Ericsson | Y | 1. Yes, but the overhead needs to be compared to a state-of-the-art non-ml baseline approach. 2. Unclear what is meant by latency. The latency could comprise of the time to find the strongest beam, however, such information should be visible in the RSRP performance statistics. |
| ZTE, Sanechips | Y | a) At least for the spatial-domain beam prediction, the reference signaling overhead reduction ratio can be considered as one of the KPIs for AI/ML in BM. Otherwise, it may be hard to align performance from different companies since different number of measured partial beams are used as model input. Besides, the number of employed RS resources and corresponding partial beams would also significantly impact the reporting overhead if AI model is deployed at gNB. Intuitively, there should be a trade-off between RS overhead and inference accuracy.  b) Latency shall be clearly defined. For example, the inference latency is strongly dependent on the computing power and software/hardware implementation of gNB/UE, which may be hard to be defined or quantified. |
| CAICT | Y | The detail KPI for latency and overhead reduction could be fixed after baseline performance of non-AI algorithm(s) with comparable accuracy. |
| Samsung | Y for a) | RS overhead is an important KPI. Each company can provide some analysis on the RS overhead. alternatively, we can agree on some reduced RS number for spatial domain prediction, and compare the performance.  The latency here is not very clear. whether this is the reduced latency of measurement/report, or this is latency of AI model inference. Some clarifications are needed. |
| Fujitsu | Y | At least the overhead reduction ratio should be an optional KPI. For the overhead reduction, metric can be the number of measurement resources on DL and reports on UL.  For the latency, it involves more implementation issues and is not recommended as KPI |
| CMCC |  | a) Yes. Nokia's definition is fine.  b) It can be discussed in AI 9.2.1. |
| MediaTek | Y | * Signaling overhead can be considered. * Latency should be defined as the interval between beam indication and UE using the new beam (TCI state). Such latency is usually quite short for intra-cell case (~5ms) but may be much longer for inter-cell beam management due to the need of synchronization. We suggest that latency be considered for inter-cell beam management. |
| HW/HiSi |  | 1. Yes. 2. Open to discuss |
| InterDigital | Y | a) Yes, but RS overhead reduction should be compared with implementation based AI/ML prediction without specification enhancement.  b) Yes, but latency reduction should be compared with implementation based AI/ML prediction without specification enhancement. |
| Lenovo | Y | 1. Yes. Signaling overhead incurred by the AI/ML method, which may include the following, need to be considered as one of the KPIs:    1. Number of reference signals (e.g., CSI-RS, SRS, SS blocks etc.) configured for a beam management procedure.    2. Number of measurement reports and the corresponding report content.    3. Any other signals that need to be exchanged between UE and gNB to support the AI/ML model, such as signaling in another carrier (e.g., FR1), UE location information, spatial/visual features of the environment etc.   Further, the signaling overhead incurred during every phase in the lifecycle of the AI/ML model (training-in case of online training, inference, model update, as applicable) should be reported.  The number of time-frequency resources needed for the signaling required for beam management could be a measure of the signaling overhead.   1. Yes. Beam acquisition/selection latency should be considered as a KPI for a proposed AI/ML model. It should include the following.    1. Tx beam training: The average time required for the UE to acquire/select a gNB Tx beam with a measured L1-RSRP/L1-SINR larger than a threshold among a set of configured Tx beams.   Rx beam training: The average time required for the UE to acquire/select a Rx beam with measurements on the same gNB Tx beam and measured L1-RSRP/L1-SINR larger than a threshold among a set of Rx beams. |
| Qualcomm |  | Yes, to both a) and b). As a representative use case for which these metrics are useful, we can consider wide to narrow beam prediction. Through measurements of wide beams (e.g., SSBs over multiple measurement occasions), we can reduce the search space over narrower beams (e.g., CSI-RS) and therefore reduce the CSI-RS *overhead* as well as beam refinement *latency,* due to sweeping over a smaller number of beams. As we see, for this use case, a metric for overhead as well as latency can appropriately capture the benefits of AI/ML. We can discuss the prospects of exact metric definition in later phases of the study. |
| Futurewei | 1. Y 2. optional | 1. RS overhead reduction ratio can be considered as one of the KPIs, e.g., CSI-RS reduction ratio, or CSI-RSRP measurement reduction ratio. 2. We think latency may be hard to define and comparably compare across companies in the SI while companies are welcome to provide such information. |
| NTT DOCOMO | Y | Payload of UCI report should be considered as basic KPI for AI/ML beam management operation at gNB. |
| PML | Y | Yes, to both a) and b). |

Summary of Question 2-3:

The original intention of this question is to discuss on the performance KPIs related to overhead reduction, e.g., RS overhead, UCI report overhead, or beam prediction latency reduction. The signaling overhead of model transfer, inference latency is not part of the performance KPIs, but will be discussed as part of capability related KPIs in section 2.2.

The summary of the above two questions:

Overhead reduction as one of the KPIs for AI/ML in BM:

* Supported by (25): Apple, Nokia/NSB, Xiaomi, vivo Intel, NVIDIA, OPPO, AT&T, CATT, LGE, Ericsson, ZTE/Sanechips, CAICT, Samsung, Fujitsu, CMCC, HW/HiSi, InterDigital, Lenovo, Qualcomm, Futurewei, NTT DOCOMO

Latency reduction for beam management as one of the KPIs for AI/ML in BM:

* Supported by (10): Apple, Nokia/NSB, Intel, OPPO, AT&T, CATT, Lenovo, Qualcomm, Futurewei

Model inference latency as one of the KPIs for AI/ML in BM:

* Supported by (4): NVIDIA, ZTE/Sanechips, CAICT(？)

**For the overhead reduction**, there were several proposed definitions:

* Option #1: RS overhead reduction for spatial domain prediction
  + 1-N/M,
    - where N is the number of beams with reference signal (SSB or CSI-RS) for measurement
    - M is the number beams in the target output set
  + Supported by (14): Apple, Nokia/NSB, Xiaomi, OPPO, AT&T, ZTE/ Sanechips, CAICT, Samsung, CMCC, MediaTek, InterDigital, Lenovo
* Option #2: The overhead number of UCI report
  + Supported by (4): vivo, AT&T, Lenovo, NTT DOCOMO

**For latency reduction**, the following options were proposed by companies:

* Option 1: Latency should be defined as the interval between beam indication and UE using the new beam (TCI state) for inter-cell beam management.
  + Supported by MediaTek
* Option 2: Tx beam training: The average time required for the UE to acquire/select a gNB Tx beam with a measured L1-RSRP/L1-SINR larger than a threshold among a set of configured Tx beams.
  + Supported by Lenovo
* Option 3: Rx beam training: The average time required for the UE to acquire/select a Rx beam with measurements on the same gNB Tx beam and measured L1-RSRP/L1-SINR larger than a threshold among a set of Rx beams.
  + Supported by Lenovo

Based on the above summary, the following proposals can be considered.

#### 2nd round: FL2 High Priority Question 2-3-1

**Proposal 2-3-1:**

* **At least for spatial domain prediction in AI/ML for BM, RS overhead reduction is considered as one of the KPIs. The RS overhead reduction is defined as:** 
  + **1-N/M,** 
    - **where N is the number of beams with reference signal (SSB or CSI-RS) in the input beam set for measurement**
    - **where M is the number of beams with or without reference signal in the target output beam set**
  + **FFS on whether to define a proper number of N and M for evaluation.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, Fujitsu, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo(M can be reworded as the RS overhead to achieve similar performance with non-AI schemes), Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi(with updates) , CMCC, MediaTek, NVIDIA, Futurewei, Lenovo (with suggested modification), Qualcomm, InterDigital** |
| Objecting companies |  |

**Question 2-3-1:**

1. Please provide your view if any.

|  |  |
| --- | --- |
| Company | Comments |
| LGE | I’m not sure the definition of M is correct. M can be the number of all beams or all configured beams as reference signal, if exhaustive beam search is the baseline scheme.  FL: The intention is to cover the case that M = number of all the beams. |
| CATT | This seems reasonable. At the first stage we may not need to limit the input number, i.e. N. |
| CAICT | RS overhead reduction should combine the accuracy constraint. |
| FL | If some other suggestion on the definition of M/N, please provide your suggested wording |
| vivo | **M can be reworded as the RS overhead to achieve similar performance with non-AI schemes** |
| Samsung | We are fine with following modification.  **Proposal 2-3-1:**   * **At least for spatial domain prediction in AI/ML for BM, RS overhead reduction is considered as one of the KPIs. The RS overhead reduction is defined as:**    + **1-N/M,**      - **where N is the number of measurement beams with reference signal (SSB or CSI-RS) for the input of the AI/ML ~~in the input beam set for measurement~~**     - **where M is the number of measurement beams with or without reference signal in the target ~~output~~ beam set of the baseline scheme**   + **FFS on whether to define a proper number of N and M for evaluation.** |
| HW/HiSi | For N, we would like to include a more generic approach where the N could also be the sum of SSB and CSI-RS beams. This is for the case when the AI model e.g. would use SSB beams as input and infers top-K beams (out of e.g. 64). In that case, N would be the number of SSB beams plus the top-K beams.  **Proposal 2-3-1:**   * **At least for spatial domain prediction in AI/ML for BM, RS overhead reduction is considered as one of the KPIs. The RS overhead reduction is defined as:**    + **1-N/M,**      - **where N is the number of beams with reference signal (SSB and/or CSI-RS) in the input beam set for measurement**     - **where M is the number of beams with or without reference signal in the target output beam set**   + **FFS on whether to define a proper number of N and M for evaluation.** |
| Lenovo | a) We welcome the proposal of having the overhead reduction as a KPI.   * It would be more reasonable to consider the overhead in terms of the number of “measurements” to be performed for beam prediction, rather than the number of SSB or CSI-RS signals as the gNB will be transmitting the SSBs (including those that the UE did not perform measurements on) for other UEs (including legacy UEs) in the cell. For CSI-RS, the reduction in number of measurements may translate to a reduction in the CSI-RS overhead depending on whether the CSI-RS is configured exclusively for the UE or shared by multiple UEs. So, the KPI can be generally considered as UE measurement overhead reduction and whether the measurement reduction translates to RS overhead reduction is dependent on the use-case and configuration. * We are open to agree on a value for **M** (the total number of beams) for evaluation purposes and find what would be the required value of **N** for each AI/ML method. We do not see the purpose of defining a value for **N**.   We suggest modifying the proposal as follows:   * **At least for spatial domain prediction in AI/ML for BM, ~~RS~~ measurement overhead reduction is considered as one of the KPIs. The ~~RS~~ overhead reduction is defined as:**    + **1-N/M,**      - **where N is the number of beams (with reference signal (SSB or CSI-RS)) ~~in the input beam set~~ required for measurements**     - **where M is the total number of beams ~~with or without reference signal in the target output beam set~~**   **FFS on whether to define a proper ~~number~~ ~~of N and~~ value for M for evaluation.** |
| Qualcomm | Agree with Proposal in principle but believe the description of RS overhead reduction metric should be further clarified.   * **At least for spatial domain prediction in AI/ML for BM, RS overhead reduction is considered as one of the KPIs. The RS overhead reduction is defined as:**    + **1-N/M,**      - **where N is the number of beams measured with AI/ML approach to produce the predicted best set of beams ~~with reference signal (SSB or CSI-RS) in the input beam set for measurement~~**     - **where M is the number of beams measured with non-AI/ML approach to output the best beams ~~with or without reference signal in the target output beam set~~**   + **FFS on whether to define a proper number of N and M for evaluation.** |
| Intel | Definition of M should be improved. We think M can be total number of beams. Then this metric can be used to compare AI/ML approach and non-AI/ML approach which will have different number of measurement beams N. |
| InterDigital | We are fine to consider RS overhead reduction as a KPI for spatial domain prediction, however, we believe that RS overhead reduction can be included as a part of evaluation assumption of system performance. |

#### 3rd round: FL3 High Priority Question 2-3-1a

Based on the input from companies, the proposal 2-3-1 is updated as below:

**Proposal 2-3-1a:**

**At least for spatial-domain beam prediction in AI/ML for BM, RS overhead reduction is considered as one of the KPIs. The RS overhead reduction is defined as:**

* **1-N/M,** 
  + **where N is the number of beams (with reference signal (SSB and/or CSI-RS)) ~~in the input beam set~~ required for measurement**
  + **where M is the total number of beams ~~with or without reference signal in the target output beam set~~**
    - **Note: the total number of beams M may require measurement for non-AI/ML approach as baseline scheme**
* **FFS on whether to define a proper value for ~~number of~~ ~~N and~~ M for evaluation.**

|  |  |
| --- | --- |
| Supporting companies | **DCM, CAICT, CMCC, CATT, Fujitsu, LGE, Samsung, Ericsson, [HW/HiSi] (with small update for clarity), Nokia, Futurewei, Lenovo, Qualcomm, Xiaomi, MediaTek, ZTE, InterDigital** |
| Objecting companies |  |

**Question 2-3-1a:**

1. Please provide your view if any.

|  |  |
| --- | --- |
| Company | Comments |
| OPPO | Generally, we are fine with the proposal. But the note seems confusing and not needed. One possible way to modify the note is as below:  **Note: Non-AI/ML approach based on the measurement of these M beams may be used as a baseline** |
| LGE | OK |
| HW/HiSi | We suggest to have following modification (in blue) for clarity:  **At least for spatial-domain beam prediction in AI/ML for BM, RS overhead reduction is considered as one of the KPIs. The RS overhead reduction is defined as:**   * **1-N/M,**    + **where N is the number of beams (with reference signal (SSB and/or CSI-RS)) ~~in the input beam set~~ required for measurement and for determination of the final beam used for data transmission**   + **where M is the total number of beams ~~with or without reference signal in the target output beam set~~**     - **Note: the total number of beams M may require measurement for non-AI/ML approach as baseline scheme** |
| Lenovo | We think there is no need for the **Note** in the proposal. Recommend to either delete it or modify it as suggested by OPPO to avoid any possible confusion. |
| Xiaomi | Share same view as OPPO on the note. |

#### 2nd round: FL2 High Priority Question 2-3-2

**Proposal 2-3-2:**

* **At least for time domain prediction in AI/ML for BM, the number of UCI report can be considered as one of the optional KPIs reported by company.**

|  |  |
| --- | --- |
| Supporting companies | **DCM, Fujitsu, PML, vivo, Samsung, MediaTek, Lenovo (with further discussion)** |
| Objecting companies | **Nokia, CATT, Futurewei, Qualcomm, InterDigital** |

**Question 2-3-2:**

1. Please provide your view if any.

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Not fully clear why this is needed. |
| NTT DOCOMO | The time domain prediction can achieve accurate beam management with low-frequent beam measurement reports. For commercial perspective, it is beneficial to reduce the number of uplink transmission for CSI report in terms of spectrum efficieny. |
| LGE | Open to discuss, but not clear enough. |
| OPPO | Not sure whether it is number of UCI report or the payload of UCI. In our understanding, the payload of reporting seems more important |
| CATT | This KPI, if adopted, will have to explore in detail on how the number of UCI is determined and counted. This somewhat related to the report configuration. For example, if the same periodicity is configured to both legacy UCI report and AI based UCI report, it may show no difference. |
| ZTE, Sanechips | More details about UCI report or payload reduction are needed. |
| Vivo | The motivation is to use fewer beam report to efficiently predict more accurately. For example, originally it needs 40ms to track the beam accurately. But with proper beam prediction, the beam report can be reduced to once per 160ms. This would help to save UE power and also save UL resources.  Payload size can also be reduced since it is possible that some prediction needs more input while other prediction needs few.  **Proposal 2-3-2:**   * **At least for time domain prediction in AI/ML for BM, the number of UCI report and UCI payload size can be considered as one of the optional KPIs reported by company.** |
| Ericsson | Open to discuss, but the number of UCI reports should anyway be reflected in the RS overhead reduction KPI. Or throughput KPI. In case it could save UE power as vivo mentions. We should first agree to support UE energy consumption as a KPI. |
| Spreadtrum | The number of UCI reports cannot fully reflect the UL resource overhead. |
| HW/HiSi | Open to discuss |
| CMCC | The total payload of UCI report may be more precise than the number of UCI report. |
| Futurewei | Not clear the need of this KPI, need discussion/clarification. We agree NTT DOCOMO’s view that potentially less frequent beam measurement reports would be required with accurate time domain prediction. |
| Lenovo | We are open to further discussion on this proposal. UCI overhead considerations should include the relative change (compared to Rel-16/17) in overhead per UCI report, as well as the frequency at which UCI reports are fed back. |
| Qualcomm | The proposal needs to be elaborated as the number of UCI reports only is not necessarily representative. |
| Intel | Too early to agree to such proposals without concrete sub-use case schemes. Open to discuss more in future. |
| InterDigital | Not clear why this is needed. If needed, we can include the reporting periodicity and offset for system performance evaluation. |

#### 3rd round: FL3 Medium Priority Question 2-3-2a

Based on the inputs from companies, **proposal 2-3-2** is updated to the following

**Proposal 2-3-2a:**

* **At least for ~~time~~ ~~domain~~ temporal prediction in AI/ML for BM, the number of UCI report and UCI payload size can be ~~considered as one of the~~ ~~optional KPIs~~ reported by company.**

|  |  |
| --- | --- |
| Supporting companies | **DCM, OPPO, CAICT, CMCC, Fujitsu, Samsung, Ericsson, Futurewei, Lenovo, Qualcomm, MediaTek, ZTE** |
| Objecting companies | **Nokia, InterDigital** |

**Question 2-3-2a:**

1. Please provide your view on proposal 2-3-2-a if any:

|  |  |
| --- | --- |
| Company | Comments |
| NTT DOCOMO | Overall fine with the proposal.  However, what is difference between “can be reported” and “considered as one of the optional KPIs”?  We think both the number of UCI reports and UCI payload are important KPIs. It is beneficial to reduce the number of uplink transmissions for commercial aspects, which can be achieved by temporal prediction with maintaining the beam accuracy. |
| OPPO | We are still not convinced that the number of UCI report is an representative KPI. We are ok with Proposal 2-3-2a as it leaves it up to each company. |
| FL | For DCM’s question: what is difference between “can be reported” and “considered as one of the optional KPIs”?   * In FL’s understanding, optional KPIs a little bit stronger than “reported by companies”. Optional KPIs will be captured by TR, but whether some output reported by companies will be captured in TR may need further study. |
| CATT | OK if companies would like to report based on their interest. |
| Fujitsu | UL transmission overhead is also important. The number of UCI report and UCI payload size should at least as an optional KPI for both temporal prediction and predication in spatial domain. |
| HW/HiSi | We are fine that UCI report and UCI payload can be reported by companies but it should not be considered as KPI. |
| Nokia | Hard to see any general applicability or usefulness of this KPI. From our view, the main focus is beam measurement overhead and latency reduction so the focus should be on the KPIs related to that, and there can be multiple factors and assumptions with UCI reporting which complicates the comparison of feedback overhead. For example, when the prediction applied at the gNB, there will not be any reporting from the UE in the prediction time durations. As this does not seems to be generic KPI that used in past, we suggest not to go ahead with this, and companies can always report additional KPIs. |
| Lenovo | As it is up to each company whether to report it or not, we are OK with this proposal. |
| InterDigital | As commented in the previous round, reporting related assumptions can be reported by companies. We don’t think that this shouldn’t be an additional KPI. |

#### 3rd round: FL2/FL3 Low Priority Question 2-3-3

**Question 2-3-3:**

1. How to define latency reduction for beam prediction, if you think it can be considered as one of the KPI for AI/ML in BM (when applicable)?

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Our suggestion on packet delay defined as the one-way PDCP layer delay between gNB and UE is not captured anywhere, and we think it is also an important KPI. In the SLS, it is something that can be generated (similar as throughput). |
| MediaTek | Latency can be defined as  (1) the interval between beam indication and UE using new beam (TCI state)  (2) the interval between a different beam (pair) becomes the best one and UE using that beam  Both are reasonable KPI. |
| Lenovo | Latency should be considered as a KPI. It can be defined and measured as the average time required for beam prediction (as given in our response to Q2-3). As the time required for beam prediction is proportional the number of beam measurements, and it is reasonable to assume that the beam measurement time is relatively constant, the “average number of beam measurements required for beam prediction” for a given RS for BM configuration can be an effective and easier way of measuring the latency.  Another latency measure can be the average time required for beam-related measurement, prediction, and reporting, which can be related to the inference latency KPI for an AI/ML model. How to feasibly compute such metric is FFS. |
| FL3 | Companies are invited to provide further input for this question. |
| OPPO | One alternative to define the latency is the interval between the first RS (CSI-RS resource, or SSB) measured for the AI/ML input and the time gNB knows which is the best predicted beam(s). |
| CATT | Regarding ‘latency of inference’, the definition is well explained by Lenovo and OPPO.  Regarding ‘latency reduction for beam prediction’, we do not see why this is a good KPI… Does it mean the interval *dT* between time of reporting beam prediction and the predicted time, so that the BM can be planned in *dT* advance? |
| Samsung | Similar with overhead reduction KPI, we can consider following KPI for latency reduction.  (1 – [Total transmission time of N beams]/[Total transmission time of M beams]) where N is the number of beams (with reference signal (SSB and/or CSI-RS)) in the input beam set required for measurement and where M is the total number of beams |
| Qualcomm | Agree with Samsung that latency reduction can be quantified in a similar manner to overhead reduction. |
| InterDigital | As commented in the previous round, reporting related assumptions can be reported by companies. We don’t think that this shouldn’t be an additional KPI. |

Power consumption were proposed by three companies as the metric for evaluation.

* Huawei/HiSi [1]: Consider the evaluation of the AI/ML based spatial domain beam prediction with the target to obtain accurate narrow beams for CSI-RS beam sweeping to reduce the UE’s overhead and power consumption.
* Ericsson [4]: Use case performance metrics could include metrics defined in Rel-17 EVM for BM including a potential energy saving metric, for example using the models defined in [4].
* CATT [6]: Intermediate KPI: Probability of identifying the best beam (pair), average power loss between the selected beam (pair) and the optimal beam (pair), and the ratio of overhead reduction;
* Qualcomm [23]: The KPIs for temporal beam prediction can be trade-off between reference signal overhead reduction (and/or UE power consumption) and a measure for beam prediction accuracy (such as RSRP prediction accuracy and/or top-M beam selection accuracy) and/or overall system performance (e.g., throughput).
* Qualcomm [23]: The KPIs for spatial (+time) domain beam prediction can be trade-off between reference signal overhead reduction (and/or UE power consumption) and a measure for beam prediction accuracy (such as L1-RSRP prediction accuracy and/or top-M beam selection accuracy) and/or overall system performance (e.g., throughput).
* Ericsson [4]: Evaluation results could include ML-performance metrics related to beam predictions, both comprising classification and regression performance metrics

Based on the above proposals, the following question can be discussed.

#### 1st round: FL1 Medium Priority Question 2-4 (temporary closed)

**Question 2-4:**

1. Whether power consumption can be considered as one of the KPIs for AI/ML in BM? If the answer is yes, how to define the power consumption metric?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | Y | UE power consumption can be considered as an optional KPI, which depend on the use case. |
| Nokia, NSB | Y | Yes, discussion should continue to define more details about the UE power consumption model. |
| Vivo | Y | Support. Power consumption can be considered by defining a reference unit, e.g., define single unit power consumption as single resource reception with one RX beam. |
| Intel | N | This can be a secondary consideration once sub-use-cases with definitive performance gain are finalized. |
| NVIDIA | Y | More discussion is required to define a proper power consumption metric. |
| OPPO |  | Not sure how to evaluate the power consumption for AI-based solution. In general, the implementation of AI is device-specific. |
| CATT | N | Actually, power consumption can be reflected by RS measurement (overhead) reduction. It does not have to be a standalone metric. |
| LGE | N | Similar view as Intel. |
| Ericsson | Y | Using the models in Ericsson [4] |
| ZTE, Sanechips |  | We share similar view with Intel and OPPO that more details are needed for evaluating power consumption. |
| CAICT |  | Power consumption is hard to measure. |
| Samsung |  | Need to discuss whether a proper UE power consumption model can be easily found and agreed.  We are open to have some qualitative analysis or observation in general. |
| Fujitsu | N | It’s difficult to get power consumption results through simulation only. |
| CMCC |  | The method to evaluate the power consumption needs to be specified. It can be discussed in AI 9.2.1. |
| MediaTek | N | Can be an optional metric. |
| HW/HiSi |  | We are open to discuss. The issue will be how to model the power consumption and how to align on a common understanding. |
| InterDigital |  | We are fine with the proposal if it is optional. |
| Lenovo | Y | Yes. Power consumption is an important consideration, especially, for UE and it is tightly coupled to computational complexity. It can be measured as the average power consumed for beam alignment/finding procedure. |
| Qualcomm | Y | The metric can be defined as a function of number of measurements that the UE needs to perform for BM. For the use case in which UE only measures a down-sampled set of SSBs to predict strongest SSB ID, the benefit cannot be captured properly through overhead reduction as the overhead remains fixed due to legacy SSB. The benefit can be quantified properly through less UE measurements and hence UE power saving. This illustrative use case exemplifies why we need to consider the UE power saving aspect *in addition to* RS overhead reduction, as there is no overhead reduction in this example. We can discuss the prospects of exact metric definition in later phases of the study. |
| Futurewei | N | We do not see the need to have UE power consumption as a KPI here. And it requires a lot of extra effort from the companies. |
| PML |  | We share similar view with ZTE, Intel and OPPO that more details are needed for evaluating power consumption. |

Summary of Question 2-4:

Power consumption as a KPIs:

* Supported by (7): Apple Nokia/NSB, vivo, Ericsson, Lenovo, Qualcomm
* No or Secondary (12): Intel, NVIDIA, OPPO, CATT, LGE, ZTE/Sanechips, CAICT, Samsung (open to qualitative observation), Fujitsu, MediaTek, Futurewei

Most of companies think power consumption can be secondary considered or hard to model. Moderator suggests to discuss this issue later.

## Capability-related KPIs

### Generalization

Generalization is one of the important aspects to verify the performance of AI/ML model. The following proposals were proposed:

* Huawei/HiSi: [1] For AI/ML-based beam management evaluation, study how to evaluate the generalization of the AI/ML model in simulation.
* Vivo [7]: Generalization performance should be considered as performance-related KPIs.
* Vivo [7]: Different number of Tx beam and Rx beam should be considered for construction of the data set for generalization performance evaluation.
* Samsung [9]: For the use case of AI/ML based beam management, at least the following capability-related KPI shall be considered:
  + Generalization of AI/ML model by considering the performance degradation for test case with mixed scenarios.
* Lenovo [18]: Inference accuracy of a proposed beam management AI/ML model (without model updates) should be reported for different channel models including Uma, Umi (with various parameters), UE speed, UE orientations, and beam codebook design.
* Nokia/NSB [19]: For training/testing the supervised learning ML model, the number of scenarios/deployments and configurations of other simulation parameters can be extended and generalized beyond those detailed in Table 2.1 2.

#### 1st round: FL1 Medium Priority Question 2-5

**Question 2-5:**

1. Whether generalization should be one of the KPIs for AI/ML in BM?
2. If the answer is yes, how to define or test the generalization performance? For example, how to mix or extend the simulation parameters?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple |  | We are open, but we have the same question as b) |
| Nokia, NSB | Y | Based on table 1 and 2, the ML model trained for one specific scenario can be valid for single sector or multiple sectors. Discussion should continue to define more details and establish a procedure to test the ML mode generalization capabilities. |
| Xiaomi |  | Open to discuss. |
| Vivo | Y | Support generalization as a basic KPI in BM.  It should not be forced to realize the same Rx beam number for all accessed Ues, thus model design should consider the output target of an AI model used for beam prediction probably used for different number of Tx beams and Rx beams. Similarly, different drops, scenarios and UE trajectory can also be considered in generalization.  Generalization performance should be one of the basic KPIs for AI/ML in BM.  To define and test generalization performance, it can be easily verified as following:   * Step1: Using a first set of parameters (including e.g., Tx beams, Rx beams, drops, scenarios and UE trajectories) to generate training data set A; * Step2: Using a second set of parameters different from those in step 1 (including e.g., Tx beams, Rx beams, drops, scenarios and UE trajectories) to generate testing set B; * Step3: Testing the performance of the model trained in step1 with the dataset generated in step2. |
| Intel |  | More discussion is needed for how to define generalization. Is training across different channel models and inferencing in one of the models used for training an example of generalization? |
| NVIDIA | Y | Similar to the discussion in 9.2.2.1, a list of configuration parameters and a list of scenarios can be formulated for companies to discuss further. |
| OPPO |  | We are open to discuss this issue. It seems difficult to define an KPI in terms of generalization. But the generalization performance can be evaluated e.g., by using data sets of mixed scenarios. |
| AT&T | Y | This is important, but will require additional scenario definitions (venue, indoor hotspot, etc.) |
| CATT | Y | For generalization evaluation, we can simulate the AI model performance where the training data and testing data are from different scenarios, different gNB/UE antenna configurations, different UE distributions… |
| LGE |  | Open to discuss, but it could be later after the assumption on AI/ML model for BM is stabilized. |
| Ericsson | Y | 1. Yes, this is very important 2. By defining a mix of simulation parameters. For example, training on Ues moving at 60 km/h, and evaluate on Ues moving on 120 km/h. In another example, a model trained from one drop is tested on another UE drop. |
| ZTE, Sanechips |  | Open to discuss. |
| CAICT |  | The generalization of AI/ML model for BM is hard to measure. |
| Samsung |  | Need more discussion on how the generalization is required, e.g, if a different gNB beambook is used, seems it is hard to use existing neural network to be applied in the new case, and anyway the new training is required. Here are several cases, in which generalization should be needed, based on our understanding:   * Different scenario, in which channel modeling is changed. * Different UE trajectory and mobility model. |
| Fujitsu |  | We are open. But at least in initial stage, generalization is not necessary as one of the KPIs. |
| CMCC | Y | We support to discuss it. We believe vivo’s suggestion is a good starting point. The performance of a generalized model (can be used in different parameter settings) should also be evaluated. |
| MediaTek |  | We believe that the trained model should be “generally applicable”, but we would like to have some discussion on what “generalization” means. |
| HW/HiSi |  | Generalization is important and should be studied. But at this stage we think it will be difficult to quantify the KPI. |
| InterDigital |  | We believe that further discussion is needed. |
| Lenovo | Y | We should consider generalization as one of the KPIs to find out whether the model adapts to dynamically changing network environment (and corresponding changes in the statistical characteristics of the data). Some of the different network conditions are indicated below (please note that this is not an exhaustive list).   * 1. Different channel conditions      + Channels with single dominant path vs. multipath   2. Different UE speeds and rotation patterns      + Different possible orientations of the UE, Ues with different speeds etc.   3. Does the AI/ML model work with any generic beam design?   It can be tested by computing all the performance KPIs (e.g., beam prediction accuracy, latency, overhead etc. that are discussed before) of a proposed beam management AI/ML model under different channel models (with various parameters), UE speeds, and different beam designs etc. |
| Qualcomm |  | a) Yes. There are two different ways to address generalization. One approach is to develop a single (potentially more complex) AI/ML model that works across a more diverse set of scenarios *or* develop several (smaller, less complex) AI/ML models and perform model switching for different scenarios.  b) Assuring that the training data is rich and diverse enough is an important aspect, which needs to be ensured for proper generalization performance. There are multiple ways/levels to look into generalization performance. First example is to train on a first set of Ues and test on a second set of Ues without changing simulation parameters across Ues. Another option is to change parameters of a deployment across training and test dataset (within a cell) and evaluate the performance (such as different trajectories and speeds for UE movement for train and test dataset). A third example is to train in a first cell and test on a second cell. As mentioned before, the premise for good generalization is good training data coverage. If we train based on a first set of simulation assumptions and test based on a totally different set of assumptions and the model does not perform well, it is hard to argue against the generalization capability, as the training and test data have totally different distributions. |
| Futurewei | Y | In general, generalization should be considered for all AI/ML based approaches. Depending on solution deployment options (e.g., scenario-based solution or generalized solution). At this stage, we should at least consider generalization in the scenario-based solution option.  Using spatial domain beam prediction as an example.   1. Option 1:    1. Generate the dataset for a defined scenario using agreed-upon parameters (from many realizations)    2. Set-aside a subset of the overall data.    3. Train the AI/ML model using the remaining data samples (note: training may include model validation to tune the hyper-parameters).    4. Once the model is trained, use the saved-aside data (unseen during training) as input to the AI/ML model and report the model performance on the unseen data (from the same scenario) 2. Option 2 (preferred):    1. Generate the training dataset from a set of realizations for the scenario using agreed-upon parameters.    2. Train the AI/ML model using the training dataset (may include model validation to tune the hyperparameters).    3. Generate a new dataset from a separate set of realizations    4. Once the model is trained, use the new dataset as input to the AI/ML model and report the model performance on the new dataset.   For model generalization in generalized solution deployment option, the high-level idea is to understand how well the AI/ML model (e.g., trained using data from scenario 1) performs when using data generated from a different scenario, e.g., scenario2 as input. There are various data availability situations / assumptions in the new scenario (i.e., scenario 2) to consider (e.g., sufficient data is available, only a small number of data is available, or no data is available). For this generalized solution deployment scenario, depending on how similar/dis-similar between the training data (data from scenario 1 from which the AI/ML model is trained) and the new data (data from scenario 2), in general, we should not expect the trained model (using data from scenario 1) to perform well in scenario 2 if the two scenarios (i.e., scenario 1 and scenario 2) are very dis-similar and NO data is available from that scenario.  In summary, this generalized deployment option is more complicated and should be discussed among companies to agree on its priority in the study first. If companies agree to pursue including this deployment option, then the discussion regarding what scenarios to be considered for generalization, various data availability situations for those different scenarios, and the expectations should be further discussed. |
| NTT DOCOMO | Y | 1. We prefer considering generalization related KPI. 2. Study is necessary to define it. This discussion can be treated in AI 9.2.1, as it could be the common KPI for all use cases. |
| PML | Y | 1. Generalization is a significant KPI for AI/ML model evaluation. 2. Test the AI/ML model in a different scenario with a separate set of realizations. |

Summary of Question 2-5:

Most of companies agreed that generation is one of the KPIs or open to discus it.

* Supported by(12): Nokia/NSB, vivo, NVIDIA, AT&T, CATT, Ericsson, CMCC, Lenovo, Qualcomm, Futurewei, NTT DOCOMO
* Open for discussion (9): Apple, Xiaomi, Intel, OPPO(?), LGE, ZTE/Sanechips, Samsung, Fujitsu

Most of companies propose to training with mixed scenarios in general.

Based on the summary, the following proposal can be discussed:

#### 2nd round: FL2 Medium Priority Question 2-5a

**Proposal 2-5a:**

* **Further study AI/ML model generalization in BM, considering the performance for beam prediction under a single scenario, with training dataset generated with mixed scenarios or set of parameters with different values as a starting point. The mixed scenarios or set of parameters can be considered at least:** 
  + **Different scenarios/models, e,g, Umi, Uma, indoor hotspot, etc.**
  + **Different distributions/set of the general channel parameters in a single scenario/model, e.g., ISD, gNB height, delay spread, angle spread, etc.**
  + **Different number of Tx beams and/or Rx beams**
  + **Different drop with different UE trajectory**
  + **Different UE speeds**
  + **Different UE rotation patterns**
  + **Different gNB/UE antenna configurations**
  + **Different UE distributions**
  + **Different number of cell/sectors**
  + **Other options are not precluded.**
* **NOTE: the selection among different AI/ML models in different scenarios are not precluded.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, OPPO, CATT, CAICT, ZTE, vivo, Ericsson, Samsung, Spreadtrum, CMCC, MediaTek, NVIDIA, Lenovo (with changes), Qualcomm, InterDigital** |
| Objecting companies | **Fujitsu, Futurewei (description not clear)** |

**Question 2-5a:**

1. Please provide your views.

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Among the set of parameters that we would like to prioritize for the generalization study there are different scenarios/models and different number of Tx and/or Rx beams |
| NTT DOCOMO | Since the performance of generalization will be highly related to the features of training and testing dataset, the selection on the above scenarios or set of parameters to construct the dataset requires careful study. |
| Fujitsu | In initial stage, generalization is not necessary as one of the KPI |
| LGE2 | I think it is too early to have discussion on this proposal. |
| OPPO | We support to evaluate the generalization performance of AI/ML models. |
| CATT | We think this is a good list. But the group may need to down-select to limit the work load.  Among all alternatives, we think (1) Different scenarios/models, (2) Different number of Tx beams and/or Rx beams, (3) Different UE speeds should have higher priorities. |
| Xiaomi | Prefer to modify ‘**The mixed scenarios or set of parameters can be considered at least**’ to ‘**The mixed scenarios or set of parameters can be considered at least one of the following**’ to make the workload controllable. |
| PML | Open to discuss.  We prefer Different distributions/set of the general channel parameters in a single scenario/model, e.g., ISD, gNB height, delay spread, angle spread, etc., Different UE speeds, Different UE rotation patterns, Different gNB/UE antenna configurations, Different UE distributions, Different number of cell/sectors as changing issues for generalization.  Meanwhile, the model can be greatly changed with Different scenarios/models, e,g, Umi, Uma, indoor hotspot, etc., Different number of Tx beams and/or Rx beams, and Different drop with different UE trajectory. |
| FL | The intention of this proposal is to provide a list for down selection. So, if possible, please provide a short list for down selection. |
| Ericsson | Support. We think that it is good to list potential generalization parameters. However, we should prioritize among the parameters based on simulation results for upcoming meetings. |
| Samsung | Support the proposal 2-5a as the starting point, and further down-selection can be discussed since it is obviously not possible to evaluate generalization for all parameters. Therefore, we suggest to update the proposal as:   * **The mixed scenarios or set of parameters can be considered at least the following for down-selection:**   For the short list, we think for beam prediction use case, if the training is at gNB side, the training may base on a certain scenario, gNB configuration. However, the UE in the cell may have different antennas configuration, different speed, and channel conditions, e.g., different delay spread, angle speed, etc.  If the training is at UE side, different scenarios/model may need to be considered, while the UE antenna configuration is fixed. We are not sure whether UE vendors can have multiple AI/ML models for different gNB antenna configurations or not.  Therefore, we are open to discuss on that parts for training at UE side.  In all, we think different UE speeds, delay spread, and even UE trajectory can be considered. Others parameters/values for generalization evaluation can be discussed per sub-use case or training/inference assumption. |
| HW/HiSi | Different sub use cases may have different demands on generalization. The listed aspects should be carefully selected based on initial evaluations. We think it may be difficult to quantify the KPI at this early stage. |
| CMCC | The priority of the listed mixed scenarios and parameter settings should be considered. Xiaomi’s update is fine to us. |
| Futurewei | We support studying generalization (the first part of the first sentence) while the rest part of the first sentence is confusing and needs clarification.  “**under a single scenario, with training dataset generated with mixed scenarios or set of parameters with different values as a starting point.”**  We the above means the following:  Supporting a single scenario (with data generated from that scenario), and  Supporting mixed scenarios (with data generated from the identified scenarios with different parameter settings)  We suggest separate the single scenario and mixed scenarios in the proposal as follows.  **Proposal 2-5a) Further study AI/ML model generalization in BM, and consider model generalization for the following solution deployment options.**   1. **Scenario-based solution deployment option: in this option, a dataset is generated from the identified scenario.** 2. **Generalized solution deployment option: in this option, a dataset with mixed scenarios/parameters may be generated for AI/ML model training.**   **FFS on what scenarios/parameters are used in generating the dataset.**  For mixed scenarios, the list is too long. We suggest only including few scenarios like the first 2 bullets. Companies should strive to use one main AI/ML model to support different settings/configurations like # of antennas, # of Tx/Rx beams. |
| Lenovo | Generalization is an important metric for an AI/ML model and appreciate the moderator for the proposal. In the SI, conclusions for the beam prediction use-case should only be drawn after comparing performance over multiple scenarios/configurations. So, we suggest the following modification to the first paragraph of the proposal:  **~~Further~~ Study AI/ML model generalization in BM, considering the performance for beam prediction under a ~~single~~multiple scenarios/parameter configurations, or equivalently by testing the AI/ML model with ~~training~~ multiple datasets, each dataset generated ~~with~~ ~~mixed~~ by considering a different scenario or ~~set of parameters with~~ different values for the set of parameters as a starting point. The ~~mixed~~ different scenarios or set of parameters can be considered at least:**  Generalization of an AI/ML model is a measure of its ability to adapt to new, previously unseen data. There are different ways/techniques in the field of AI/ML to achieve this ability. While “training with mixed datasets” is one way to generalizability, companies should be allowed to explore and employ a training technique that they think is suitable for the AI/ML model that’s being developed. |
| Qualcomm | For SLS simulations also consider training on a given set of UEs and testing on another set of UEs as an option. |
| Intel | OK to list options |

#### 3rd round: FL3 Medium Priority Question 2-5b

Most of companies agree that generalization is important for AI/ML. However, it seems some further study is needed. FL suggests to simply the proposal for generalization issue.

**Proposal 2-5b:**

* **Further study AI/ML model generalization in beam management considering the following options:**
  + **Option 1: The AI/ML model training is based on multiple scenarios/configurations, and the testing/inference is performed for a single scenario/ configuration.**
  + **Option 2: The AI/ML model training is based on a single scenario #A/ configuration #A, and the testing/inference is performed for a different single scenario #B/configuration #B.**
  + **Companies report the scenarios/configurations, considering the assumption of AI/ML training location**

|  |  |
| --- | --- |
| Supporting companies | **DCM,OPPO, CAICT, CMCC (with modifications), CATT, Fujitsu, Samsung, Nokia, Qualcomm, MediaTek, ZTE, InterDigital** |
| Objecting companies | **Lenovo (Please see comments for suggested modification)** |

**Question 2-5b:**

1. Please provide your views.

|  |  |
| --- | --- |
| Company | Comments |
| CMCC | **Proposal 2-5b:**   * **Further study AI/ML model generalization in beam management considering the following options:**   + **Option 1: The AI/ML model training is based on multiple scenarios/configurations, and the testing/inference is performed for a different single scenario/ configuration.**   + **Option 2: The AI/ML model training is based on a single scenario #A/ configuration #A, and the testing/inference is performed for a different single scenario #B/configuration #B.**   + **Companies report the scenarios/configurations, considering the assumption of AI/ML training location**   **FL: the intention of original wording is using mixed scenarios for training while use single scenarios for testing. Therefore, no need to add “different” since there is not single scenarios to compared with.** |
| Fujitsu | We support both option 1 and 2. Companies need report which option is used for their evaluation about AI/ML model generalization. |
| LGE | OK for study. |
| Samsung | We believe Option 1 is for including mixed scenarios and/or different general parameters in a single scenario, but current statement in Option 1 looks only for mixed scenarios. To clarify of the terminology of multiple scenarios in this proposal, we think following note is needed.  **Note: Multiple scenarios refers mixed scenarios or scenarios with different general channel parameter sets (e.g., ISD, gNB height, delay spread, angle spread, etc.) in a single scenario.** |
| Ericsson | We suggest the following rewording and alternatives for option 1:   * **Option 1: The AI/ML model training is based on multiple scenarios/configurations in set A, and the testing/inference is performed for scenario(s)/configuration(s) in set B.**  1. **Set B is a subset of A** 2. **Set B is not a subset of A**   Supportive of the multiple-scenario definition by Samsung. |
| HW/HiSi | We generally support option 1. It up to companies that what scenarios/configurations are mixed for training, and what single scenario is used for test/inference. |
| Nokia | Support option 1 as baseline.  The performance of Option 2 will be dominated by the data distributions in A and B. . If the data distribution from A and B are way different, we do not expect simply train the model in A and test the model in B can promise any good performance. The option 2 needs more elaboration about how it will work. |
| Futurewei | Scenario-based solution deployment option should be considered as BL. In such case, the AI/ML model is trained using data from one scenario and the testing is performed using different dataset from the same scenario. This is to verify how well the trained AI/ML model can generalize to data unseen during training phase from the same scenario. Option 1 and Option 2 specified in the proposal can be optionally evaluated. |
| Lenovo | We think some clarification is needed on “Generalization” for AI/ML models.  1. When we are given AI/ML model, we test for its generalization ability, by testing the performance of AI/ML model under different possible scenarios/configurations and/or under possible changes in the statistical properties of the data. The testing for generalization should be across many different scenarios/configurations, but not limited to one scenario/configuration.  2.We only test the AI/ML model given to us considering different scenarios/configurations. We do not see any need to mention how the AI/ML model should be trained. Companies can describe and report how the proposed AI/ML model was trained (just to aid re-producibility of proponent conclusions during the evaluations). While “training with mixed datasets” is one way to generalizability, companies should be allowed to explore and employ a training technique that they think is suitable for the AI/ML model that’s being developed. (Please also refer to our response to FL2:Question 2-5a.)  3.As per the above discussion, consider having the proposal as follows:   * **Further study AI/ML model generalization in beam management ~~considering~~ evaluating the ~~following options:~~ inference performance of beam prediction under multiple different scenarios/configurations. Discussion on different scenarios/configurations is FFS.**   + **~~Option 1: The AI/ML model training is based on multiple scenarios/configurations, and the testing/inference is performed for a single scenario/ configuration.~~**   + **~~Option 2: The AI/ML model training is based on a single scenario #A/ configuration #A, and the testing/inference is performed for a different single scenario #B/configuration #B.~~**   + **~~Companies report the scenarios/configurations, considering the assumption of AI/ML training location~~**   4. It is good to have an in-depth discussion and agreement on the exact definition of “Generalization of an AI/ML Model” and how it should be tested – This is particularly important as the aspect of generalization is common across all use cases for AI/ML. |
| Qualcomm | As mentioned before, the premise for good generalization is good training data coverage. If we train based on a first set of simulation assumptions and test based on a totally different set of assumptions and the model does not perform well, it is hard to argue against the generalization capability, as the training and test data have totally different distributions. That’s why Option 2 without any elaborations may be hard to interpret. If we train using scenario #A and configuration #A, and test on a totally different scenario #B and configuration #B and do not get a good performance using AI/ML, it is hard to argue against generalization capability of AI/ML model.  Also training over a subset of UEs in SLS and testing over another subset can be an option. |
| Xiaomi | Open to study. |
| InterDigital | We are open to both options and fine with the proposal. |

### 2.2.2 Model size and computational complexity

Several companies proposed to consider model size and computation complexity for AI/ML model.

* Vivo [7]: Beam sweeping overhead, AI processing latency, computational complexity, model size and power consumption can be considered are all relevant for assessment.
* Samsung [9]: For the use case of AI/ML based beam management, at least the following capability-realted KPI shall be considered:
  + Size of AI/ML model;
  + Complexity of training and inference of AI/ML operation.
* Futurewei [12]: Include model/space complexity as one of the KPIs to evaluate the complexity of AI/ML-based approach for beam management use case. Model/space complexity measurements include number of parameters in the model and memory usage.
* Futurewei [12]: Include computational complexity as one of the KPI list to evaluate the complexity of AI/ML-based approach for beam management use case. Computational complexity can be estimated using number of floating-point operations (FLOPs) or number of multiplies and accumulates (MACs).
* CAICT [14]: AI/ML model size should be controlled during the evaluation phase.
* Lenovo [18]: Computation complexity of the proposed AI/ML model should be evaluated at every phase in the model lifecycle-training, inference, update.
* NVDIA [21]: Provide information on the used computing platform (such as the GPU model) when reporting KPIs for AI/ML based beam management.
* Fujitsu [24] The following KPIs are recommended for complexity of AI/ML models.
  + Computational complexity of AI/ML model inference
  + Memory size for AI/ML model storage

#### 1st round: FL1 Low Priority Question 2-6 (temporary closed)

**Question 2-6:**

1. Whether AI/ML model size can be considered as one of the KPIs for AI/ML in BM? If the answer is yes, how to quantify it, e.g., reported by each company with model size in Bytes?
2. Whether computation complexity at least for inference can be considered as one of the KPIs for AI/ML in BM? If the answer is yes, how to quantify it, e.g., reported by each company with number of floating-point operations (FLOPs) or number of multiplies and accumulates (MACs)?

|  |  |  |
| --- | --- | --- |
| Company | Y/N | Comments |
| Apple | N |  |
| Nokia | Y | a) We may indicate the model size in Byte as well as the total number of trainable parameters.  b) Yes, we have some details in 9.2.1, FLOPs could be one way to proceed. |
| Xiaomi |  | Open to discuss. |
| vivo |  | Open to discuss |
| Intel | N | At this early phase, we should evaluate absolute gain available from AI/ML models. These should be considered at a later phase. |
| NVIDIA | Y | a) Number of trainable model parameters, model size in Byte  b) Yes, number of floating-point operations (FLOPs) |
| OPPO |  | Companies are encouraged to report the mode size and FLOPs. How to use them can be further studied. |
| CATT |  | Model size and computation complexity should be reported/evaluated anyway, thus natural to be KPI. Details can be further discussed. |
| LGE |  | Open to discuss. |
| Ericsson | Y | 1. Yes, for example number of parameters. We consider model complexity estimations are mainly relevant valid for UE sided models. 2. FLOPs and model execution frequency could be presented. |
| ZTE, Sanechips |  | AI/ML model size as well as the number of FLOPs/MACs can be intermediate metrics for complexity evaluation. Nevertheless, considering the impact of the software environment and hardware implementation, more discuss is needed for quantify the complexity when comparing the strengths and weaknesses of different AI models. |
| CAICT | N | AI/ML model size should be limited for performance comparison. The size and structure of AI/ML model should be reported. |
| Samsung |  | Company can report the model size in Bytes and FLOPs |
| Fujitsu | Y | Model size is reported by companies in Bytes. And the computation complexity is reported as FLOPs |
| CMCC |  | Open to discuss |
| MediaTek | N | AI/ML model size is important from implementation perspective. However, at this early stage we should focus on the gain of introducing AI/ML assistance for BM. |
| InterDigital |  | We are fine with it if it is optional. |
| Lenovo | Y | 1. It is important to take “model size” into consideration. However, we think it can be considered as “memory required for the AI/ML model” as a part of the “Complexity” KPI discussed below. 2. Yes. Computational complexity should be considered as a KPI. We suggest that the complexity KPI should consider detailed measures that capture the hardware & software complexity (including the memory footprint) as shown in the table below (reproduced here from [R1-2204416](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204416.zip)).  |  |  | | --- | --- | |  | **Parameters** | | **Hardware** | Peak floating-point operations per second (FLOPS), | | Peak bandwidth to access the memory (byte/sec) | | Memory for the AI/ML model and input/output data (byte) | | Energy consumption per operation (J/op) | | Penalty of interaction with bus | | Need for measurements from any auxiliary (non-3GPP) hardware components (e.g., sensors/actuators/GPS etc.)? | | **Software** | Number of multiply-accumulates (MACs) | | Number of weights of the neural network | | Number of memory accesses | | Number of bytes per memory access (byte) | | Interaction Operational Intensity (FLOPS/byte) | |
| Qualcomm | Y | a) Yes, model size can be a KPI and can be reported in terms of number of parameters, instead of bytes  b) Yes, in principle. It is important to note that both a) and b) are for information purposes and do not directly translate into the relevant complexity such as power consumption, latency, etc. The real complexity impact is determined by implementation and is merely loosely correlated with the reported KPIs here. |
| Futurewei | Y | For AI/ML-based algorithm, complexity (model/space and computational) impacts amount of memory needed, and number of operations needed (which impact inference time) and they help vendors to determine HW/SW requirements. Thus, we believe such information is useful and should be considered as KPIs in BM.  For a), we can use number of model parameters as the indicator. For b), we can use FLOPs as the indicator.  Note: for complexity related KPIs, alignment among use cases is needed. |
| NTT DOCOMO | Y | 1. Yes, the performance and complexity could be tradeoff. Especially, it should be considered for the case where AI/ML is deployed on UE. Model size can be indicated in Bytes. 2. Yes, FLOPs should be considered. |
| PML | Y | a) Number of trainable model parameters  b) Number of floating-point operations (FLOPs) |

### 2.2.3 Other KPIs

Several other KPs were proposed, including reporting/model management overhead, AI processing latency, scalability:

* Vivo [7]: Beam sweeping overhead, AI processing latency, computational complexity, model size and power consumption can be considered are all relevant for assessment.
* LGE [13]: Study whether the procedure for training/update/management of AI/ML model can be considered as overhead and latency of beam management or not, and how to quantify the overhead/latency of AI/ML model.
* Lenovo [18]: Beam management signaling (e.g., RS, measurement reports) overhead required for a proposed AI/ML model (at every phase in the model lifecycle) should be evaluated. This can be reported relative to state-of-the-art Rel-17 based baseline schemes.
* Lenovo [18]: Inference accuracy sensitivity of a proposed beam management AI/ML model should be evaluated for a range of noisy input data and delay constraints.
* Lenovo [18]: Scalability of a proposed beam management AI/ML model for different parameter settings, e.g., number of beams at gNB/UE, should be evaluated.
* Lenovo [18]: KPIs for the AI/ML beam management evaluation should at least include accuracy and effectiveness, beam measurement overhead, latency, training convergence time, model robustness, scalability, adaptability and complexity/power consumption.
* NVIDIA [21]: Define a KPI which measures the measurement reporting overhead for beam management with and without AI/ML based algorithms.
* Lenovo [18]: A proposed AI/ML model that is based on online learning (e.g., online training, model update/re-training) should evaluate the convergence time for the model to reach a valid inference state.

#### 1st round: FL1 Low Priority Question 2-7 (temporary closed)

**Question 2-7:**

1. Any other KPI/metric needs to be considered for AI/ML in BM?

|  |  |
| --- | --- |
| Company | Comments |
| Lenovo | The following relevant metrics may also be considered as KPIs for the use case of BM (as presented in [R1-2204416](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204416.zip)).   1. Side information from e.g., sensor(s) and hardware support   Does the AI/ML method require side information (e.g., measurements from non-3GPP technologies). For example, does the proposed beam management AI/ML method require measurements from additional sensors like GPS, LIDAR, Camera, or additional hardware like memory storage, GPU execution?   * 1. UE   2. gNB   For example, an AI/ML method may require the gNB to have powerful cameras (or equipping a vehicular UE with a LIDAR) so that the BM can be done based on the signals from these sensors. Such an AI/ML method can result in an additional cost and support for sensors, which need to be taken into account while comparing it with other methods.   1. Robustness: Sensitivity of the beam management AI/ML model to 2. Errors in the data (e.g., erroneous measurements exchanged between UE and gNB) 3. Latency (e.g., latency in generating and reporting the measurement reports)   Importance of this KPI may be described by considering the following scenario: Two methods might perform equally well under favorable conditions (such as, highly reliable and low latency reporting of L1-RSRP/L1-SINR measurements over the network). However, performance of one of the methods may degrade substantially with errors in the RSRP/SINR measurements or with an increased latency in the availability of measurement reports at the inference node. It is recommended to evaluate robustness by considering a range of signaling error probabilities and latency values in the low, moderate and high SNR/SINR regimes.  3. Scalability  This KPI reveals whether the model scales well if the network parameters change. AN indicative list of the relevant parameters to be considered here for beam management use case are  a. Number of beams at gNB and UE  b. Number of active UEs in a multi-beam scenario (when the gNB can simultaneously form more than one beam)  c. UE mobility  We think scalability needs to be included as a KPI due to the following reasons: The inference complexity of a method may increase linearly or exponentially with the cardinality of the set of the beams to be searched over. A method may maintain the same complexity but its accuracy may degrade significantly with the increase in the search space. Some methods might work well under stationary/slowly changing environments and may significantly underperform in a highly dynamic environment. |
| Qualcomm | Other KPIs can be considered such as overhead needed for model management (frequent model switching due to poor generalization), overhead needed for data collection at gNB, etc. Some of these KPIs may be difficult to quantify, but the possibility of considering other KPIs should not be precluded and can be up to companies. |

## Baseline performance

Some companies provided some analysis on baseline performance for benchmark.

* CATT [6]: On the simulations for AI/ML-based beam management, conventional beam management strategy (i.e. exhaustive beam sweeping) can be considered as baseline.
* InterDigital [5]: No collaboration framework: AI/ML algorithms purely implementation based and not requiring air-interface changes’ could be an appropriate baseline to accurately evaluate the benefits of AI/ML with specification enhancements.
* Samsung [9]: EVM on AI/ML based beam measurement feedback compression shall at least be able to evaluate the system performance while considering one or both of the following aspects
  + (1) the compressed beam measurement feedback has lower feedback overhead as compared to the legacy feedback for a given number of reported beams
  + (2) the number of reported beams in the compressed beam measurement feedback is larger than the legacy feedback for the same beam measurement feedback overhead.
* OPPO [10]: To make more meaningful comparison between traditional beam selection scheme and AI/ML beam prediction, study and decide the EVM and benchmark for comparison.
* CMCC [16]: Baseline of spatial domain beam prediction needs to be studied, the following three options of baseline can be considered:
  + Option 1: gNB performs exhaust beam sweeping, UE selects best beam pair among all beam pairs.
  + Option 2: gNB performs sparse beam sweeping with fixed sparse pattern, UE selects best beam pair among measured beam pairs.
  + Option 3: gNB performs sparse beam sweeping with variable sparse pattern, UE selects best beam among measured beam pairs.
* Nokia/NSB [19]: Baselines for supervised learning spatial-temporal domain beam prediction are needed. The following are possible candidates:
  + UE measures all the CSI-RS resources with an exhaustive search at all time instants and selects the best beam at each time instant.
  + UE selects the best beam based on the measurements of all the CSI-RS resources during the time instants within the observation window and maintains the selected beam during the time instants of the prediction window.
* Intel [20]: Baseline performance evaluation schemes for benchmarking the performance of AI/ML tools should be based on exhaustive beam search and more practical hierarchical beam search procedures.
* Qualcomm [23]: Based on the agreed KPIs, RAN1 should study and identify baseline prediction schemes for temporal beam prediction as a benchmark for AI/ML-based schemes to compare against
* Qualcomm [23]: Based on the agreed KPIs, RAN1 should study and identify baseline prediction schemes for spatial domain beam prediction as a benchmark for AI/ML-based schemes to compare against

The baseline performance is subject to each sub-use case. However, this is one of the important issues for evaluation, we can have some open discussion

#### 1st round: FL1 Medium Priority Question 2-8

**Question 2-8:**

1. For spatial domain beam prediction, what can be the baseline performance?
2. For time domain beam prediction, what can be the baseline performance?

Note: The baseline performance of other sub-use cases can be discussed after the sub-use cases are well defined.

|  |  |
| --- | --- |
| Company | Comments |
| Apple | a) L1-RSRP from ideal beam, beam selection from non-AI scheme (spatial correlation), and random beam  b) L1-RSRP from ideal beam, and the latest beam (assuming no beam change) |
| Nokia, NSB | * + For spatial domain beam prediction:   **Alternative 1a :**  UE measures all CSI-RS resources  **Alternative 2a :**  UE measures a subset of CSI-RS resources with given size  **Alternative 3a :**  UE measures all SSB resources   * + For time domain beam prediction   **Alternative 1b :** UE measures all the CSI-RS resources with an exhaustive search at all time instants and selects the best beam at each time instant.  **Alternative 2b :** UE selects the best beam based on the measurements of all the CSI-RS resources during the time instants within the observation window and maintains the selected beam during the time instants of the prediction window. |
| Xiaomi | For spatial domain, beam selection from measurement on sparse beams/wide beams can be the baseline. |
| vivo | Those best measured RSRP can be directly as baseline for comparison, as we have done for Rel-15/16/17 design. |
| Intel | The baselines are dependent heavily on sub-use-case definitions. Suggest considering this after sub-use-cases are finalized. |
| NVIDIA | 1. Upper bound: Genie (best beam); Lower bound: UE measures a (random/fixed) subset of beams 2. Upper bound: Genie (best beam); Lower bound: latest best beam in the observation window applied to the prediction window |
| OPPO | Since there is no common baseline for beam management, the baseline scheme can be reported by each company in their evaluation. In general, company can use any non-AI scheme as the baseline. |
| CATT | At least for spatial domain prediction, exhaustive beam sweeping scheme can be set as the baseline. |
| LGE | For spatial domain beam prediction, exhaustive beam search can be the baseline.  For time domain beam prediction, specific periodicity of beam reporting can be decided for baseline performance. |
| Ericsson | a) L1-RSRP from ideal beam, and beam selection from non-AI scheme such as selecting K closest beams in the spatial domain (adjacent beams)  b) Using the latest strongest measured beam in the prediction window could be used. |
| ZTE, Sanechips | We share similar view with Nokia. |
| CAICT | a) gNB performs exhaust beam sweeping, UE selects best beam pair among all beam pairs.  b) the latest beam could be used as baseline. |
| Samsung | a) Upper bound: Genie aided approach by assuming all beams being measured. Baseline: Only measure the restricted subset of beambook.  b) Genie assuming knowledge of the optimal beam pair in the predicted time. We are open to discuss the latest beam, but how to quantify top-N beam accuracy is should be discussed since it is unclear for the latest beam. |
| Fujitsu | For spatial domain beam prediction, the exhaustive beam search can be used to compare the gains of overhead reduction of AI/ML model. And the hierarchical beam search can be used to compare the performance gains of AI/ML model. |
| CMCC | a)   * Option 1: best beam pair among all beam pairs. * Option 2: best beam pair among a fixed subset of all beam pairs. * Option 3: best beam pair among a random subset of all beam pairs.   b) At least consider the followings   * Option 1: latest best beam pair with the same overhead with AI-based method. * Option 2: latest best beam pair with a frequent beam measurement and beam reporting. This can be viewed as the upper bound of traditional scheme. |
| MediaTek | The baseline performance depends largely on sub-use-cases. However, L1-RSRP can be considered as a general baseline. |
| HW/HiSi | Since there is not standardized baseline in legacy BM, we think it is up to company to report their baseline. One example for spatial BM could be to use the optimal beam from the SSB sweeping phase and then sweep its neighboring narrow beams. For time domain beam prediction, we are also open to discuss further. |
| InterDigital | For both time domain and spatial domain, optimal beam selection ratio, L1-RSRP difference and system performance should be considered. |
| Lenovo | a) The baseline scheme can be genie-aided ideal beam (equivalently, beam identified from exhaustive search). In addition to the ideal beam, each company be allowed to consider a state-of-the-art non-AI/ML scheme and report it while presenting their performance results.  b) Genie-aided ideal beam (equivalently, beam identified from exhaustive search). Additionally, each company be allowed to consider a state-of-the-art non-AI/ML scheme and report it while presenting their performance results. |
| Qualcomm | In our view, for both a) and b), it is important to identify state-of-the-art *competitive* baselines to compare against. Comparing AI/ML performance to exhaustive search or random beam selection may potentially lead to exaggerated gains (given the KPIs: top-K beam selection accuracy and/or overhead reduction) that may not highlight the actual benefit of AI/ML-based approaches and may lead to misinterpreted results/conclusions. This state-of-the-art baseline can be defined for each use case, and the prospect of other prediction-based baselines (non-AI/ML) could also be discussed. |
| Futurewei | For both a) and b), we can use true/ideal best beam (e.g., via exhaustive beam sweeping) as BL/reference/upper bound. |
| NTT DOCOMO | 1. For spatial domain beam prediction, performance achieved by beam management with beams used for beam measurement can be the baseline. 2. For time domain beam prediction, performance achieved by beam management without prediction can be the baseline. |
| PML | We share similar view with Nokia and ZTE. |

Summary of Question 2-8

Some companies proposed the L1-RSRP from the idea beam. Some companies proposed some conventional or upper bound with exhaustive beam sweeping. In moderator’s understanding, the difference between L1-RSRB from ideal beam can be covered and evaluated as part of KPs. For AI/ML in BM, some baseline performance with conventional scheme need to be compared.

Based on the discussion on Question 2-8, the following proposal can be considered:

#### 2nd round: FL2 Medium Priority Question 2-8-1

**Proposal 2-8-1:**

* **For spatial domain beam prediction, further study the following options as baseline performance:**
  + **Option 1: UE measures all RS resources of target beam Set A (exhaustive beam sweeping)** 
    - **FFS CSI-RS/SSB as the RS resources**
  + **Option 2: UE measures the subset of RS resources of target beam Set A** 
    - **FFS on conventional scheme to obtain performance KPIs**
  + **Other options are not precluded.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, LGE,OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HwHiSi, CMCC, MediaTek, NVIDIA, Futurewei (for Option 1 only), Lenovo, Qualcomm, InterDigital** |
| Objecting companies |  |

**Question 2-8-1:**

1. Please provide your view, or proposed modification if any.

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | What is meant by target is not clear.  Option 1: UE measures all RS resources of ~~target~~ beam Set A (exhaustive beam sweeping)  Option 2: UE measures the subset of RS resources of ~~target~~ beam Set A |
| NTT DOCOMO | Both Option 1 and Option 2 could be considered. Option 1 is the upper bound performance regardless of overhead/latency and Option 2 is a tradeoff solution. The subset of RS resources in Option 2 could be aligned with that for AI/ML model-based methods so as to fairly compare the performance |
| Fujitsu | At least option 1 should be supported. |
| LGE | Prefer option 1. |
| CATT | We think both Option 1 and Option 2 can be considered.  Note that Option 1 is the solid upper bound of performance and easy to compare. For Option 2, we have to put additional effort to define conventional scheme. |
| CAICT | The baseline performance should be based on UE measurements on target beam Set. |
| ZTE, Sanechips | We are fine with the FL proposal and prefer Option 1. |
| Ericsson | Support both options. A conventional scheme in option 2 could comprise using knowledge on neighboring beams. |
| HW/HiSi | Both Option 1 and Option 2 can be considered |
| CMCC | For option 2, companies may use different beam set B. The following FFS can be added.  **Proposal 2-8-1:**   * **For spatial domain beam prediction, further study the following options as baseline performance:**   + **Option 1: UE measures all RS resources of target beam Set A (exhaustive beam sweeping)**      - **FFS CSI-RS/SSB as the RS resources**   + **Option 2: UE measures the subset of RS resources of target beam Set A**      - **FFS on conventional scheme to obtain performance KPIs**     - **FFS：how to determine the subset of RS resources is reported by companies**   + **Other options are not precluded.** |
| Futurewei | For spatial domain beam prediction, option 1 (exhaustive beam sweeping) may be considered as the upper-bound. For conventional method, companies have different views, so we suggest leaving the entire option 2 as FFS. |
| Lenovo | Prefer Option 1 |

#### 3rd round: FL3 Medium Priority Question 2-8-1a

Based on companies’ inputs, the **proposal 2-8-1** is updated as **proposal 2-8-1a.** Moreover, in **proposal 2-8-1a**, the wording is updated to consider the AI/ML inference at both gNB and UE sides.

**Proposal 2-8-1a:**

* **For spatial-domain beam prediction, further study the following options and select one or both options as baseline performance** 
  + **Option 1: ~~UE~~ based on ~~measures~~ the measurement of all RS resources of ~~target~~ beam Set A (exhaustive beam sweeping)** 
    - **FFS CSI-RS/SSB as the RS resources**
  + **Option 2: ~~UE~~ based on ~~measures~~ the measurement of the subset of RS resources of ~~target~~ beam Set A** 
    - **FFS on conventional scheme to obtain performance KPIs**
    - **FFS: how to determine the subset of RS resources is reported by companies**
  + **Other options are not precluded.**

|  |  |
| --- | --- |
| Supporting companies | **DCM, OPPO, CAICT, CMCC, CATT, Fujitsu, LGE, Samsung, Ericsson, Nokia, Futurewei, Lenovo, Qualcomm, Xiaomi, MediaTek, ZTE** |
| Objecting companies |  |

**Question 2-8-1a:**

1. Please provide your view, or proposed modification if any.

|  |  |
| --- | --- |
| Company | Comments |
| Fujitsu | We prefer option 1. It’s better to leave option 2 as FFS. |
| LGE | We also prefer option 1. |
| HW/HiSi | We suggest that an upper boundary benchmark can also be considered:  Option 3: a genie-aided BM, where based on the measurement of all possible beams (e.g., 256 beams for super-resolution BM)  **Proposal 2-8-1a:**   * **For spatial-domain beam prediction, further study the following options and select one or ~~both~~ or two or all options as baseline performance**    + **Option 1: ~~UE~~ based on ~~measures~~ the measurement of all RS resources of ~~target~~ beam Set A (exhaustive beam sweeping)**      - **FFS CSI-RS/SSB as the RS resources**   + **Option 2: ~~UE~~ based on ~~measures~~ the measurement of the subset of RS resources of ~~target~~ beam Set A**      - **FFS on conventional scheme to obtain performance KPIs**     - **FFS: how to determine the subset of RS resources is reported by companies**   + **Option 3: A genie-aided BM, where the best beam is determined out of the set of all possible beams**   + **Other options are not precluded.** |
| Nokia | We think Option 3 suggested by HW is Option 1. Not clear what is the difference. |
| Lenovo | Prefer Option 1 |
| ZTE, Sanechips | We agree with the FL proposal and prefer Option 1. |

#### 2nd round: FL2 Medium Priority Question 2-8-2

Based on companies’ inputs, the **proposal 2-8-2** is updated as **proposal 2-8-2a:**

**Proposal 2-8-2:**

* **For time domain beam prediction, further study the following options as baseline performance:**
  + **Option 1: UE measures all the CSI-RS resources with an exhaustive search at all time instants and selects the best beam at each time instant.**
  + **Option 2: UE selects the best beam based on the measurements of all the CSI-RS resources during the time instants within the observation window and maintains the selected beam during the time instants of the prediction window.**
  + **Other options are not precluded**.

|  |  |
| --- | --- |
| Supporting companies | **Nokia (with updates), DCM, Fujitsu,OPPO, CATT, CAICT, Xiaomi, PML, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi (with updates), MediaTek, NVIDIA, Futurewei (with modification), Lenovo, Qualcomm, InterDigital** |
| Objecting companies |  |

**Question 2-8-2:**

1. Please provide your view, or proposed modification if any.

|  |  |
| --- | --- |
| Company | Comments |
| Nokia | Suggest following edits,  Option 1: UE measures all the ~~CSI-~~RS resources (from beam Set A or Set B) ~~with an exhaustive search~~ at all time instants and selects the best beam at each time instant.  Option 2: UE selects the best beam based on the measurements of all the ~~CSI-~~RS resources (from beam Set B) during the time instants within the observation window and maintains the selected beam during the time. |
| NTT DOCOMO | Both Option 1 and Option 2 could be considered. Similar reason to 2-8-1, and the observation window and prediction window should be aligned with those for AI/ML model-based methods to fairly compare the performance. |
| Fujitsu | At lease option 1 should be supported |
| CATT | We think both Option 1 and Option 2 can be considered.  Note that Option 1 is the solid upper bound of performance and easy to compare. But for Option 2, there might be some better legacy methods than this very simple one. |
| CAICT | Time domain beam prediction is implemented dependent. We are open to discuss the details further. |
| ZTE, Sanechips | We are fine with the FL proposal and prefer Option 1. |
| Ericsson | Support both options. Agree to the updated proposal by Nokia . |
| Samsung | We are also fine with Nokia’s update. |
| HW/HiSi | At this stage, we would like to be too restrictive. We suggest to change “CSI-RS” to “SSB or RS”. Then both option 1 and option 2 can be considered.  **Proposal 2-8-2:**   * **For time domain beam prediction, further study the following options as baseline performance:**   + **Option 1: UE measures all the SSB or CSI-RS resources with an exhaustive search at all time instants and selects the best beam at each time instant.**   + **Option 2: UE selects the best beam based on the measurements of all the SSB or CSI-RS resources during the time instants within the observation window and maintains the selected beam during the time instants of the prediction window.**   + **Other options are not precluded**. |
| CMCC | The definition of all time instants should be clarified, e.g., all time instants means the time instants within the observation window and the prediction window. And whether the interval of time instants of option 1 can be different with that of AI-based method? |
| Futurewei | For time domain beam prediction, option 1 (best beam in each of the time instances) may be considered as the upper-bound. For option 2, we are ok with Nokia’s rewording. |
| Lenovo | Prefer Option 1 |
| Qualcomm | Agree with both options and Nokia’s update. |

#### 3rd round: FL3 Medium Priority Question 2-8-2a

Based on companies’ inputs, the **proposal 2-8-2** is updated as **proposal 2-8-2a.** Moreover, in **proposal 2-8-2a**, the wording is updated to consider the AI/ML inference at both gNB and UE sides.

**Proposal 2-8-2a:**

* **For ~~time domain~~ temporal beam prediction, further study the following options as baseline performance:**
  + **Option 1: ~~UE measures~~ Select the ~~beast~~ best beam based on the measurements of all the ~~CSI-~~RS resources (from Set A or Set B of beams) ~~with an exhaustive search~~ at all time instants (i.e., the time instants within the observation window or the prediction window) ~~and selects the best beam at each time instant~~.**
  + **Option 2: ~~UE~~ Select~~s~~ the best beam based on the measurements of all the ~~CSI-~~RS resources (from Set B of beams)** **during the time instants within the observation window and maintain~~s~~ the selected beam during the time instants ~~of~~ within the prediction window.**
  + **Other options are not precluded**.
  + **Note: The observation window and prediction window are aligned with those for AI/ML model-based methods**

|  |  |
| --- | --- |
| Supporting companies | **DCM, OPPO, CAICT, CATT, Fujitsu, Samsung, Ericsson, Nokia, Futurewei, Lenovo (with changes), Qualcomm, Xiaomi, MediaTek, ZTE** |
| Objecting companies |  |

**Question 2-8-2a:**

1. Please provide your view, or proposed modification if any.

|  |  |
| --- | --- |
| Company | Comments |
| FL | FL has some question for the above Option 1. Current wording of Option 1 in proposal 2-8-2a, UE needs to measure the RS in both observation window and prediction window. But in FL’s understanding, we can directly use the measurement in prediction window. That is, there is no “prediction” but directly use the measurement result.  **Option 1a: Select the best beam based on the measurements of all the RS resources from Set A at time instants within the prediction window**  FL encourages companies to provide the view of the proposal 2-8-2a and the modified Option 1a. |
| NTT DOCOMO | Support the proposal. Just need to fix the typo as follows   * **Option 1: ~~UE measures~~ Select the ~~beast~~ best beam based on the measurements of all the ~~CSI-~~RS resources (from Set A or Set B of beams) ~~with an exhaustive search~~ at all time instants (i.e., the time instants within the observation window or the prediction window) ~~and selects the best beam at each time instant~~.** |
| OPPO | Generally, we are fine with the proposal.  One question for clarification: For Option 1, the RS resource is from Set A or Set B, whereas the RS resource is from Set B. Why they are different? It seems better to align them.  FL: In email discussion [06], there are some definitions of Set A and Set B. In FL’s understanding, for option 1, the measurement in observation window is based on Set A, and the measurement in prediction window is based on Set B. However, Set A and Set B may or may not be the same. For example, Set B may be wide beams, while Set A may be sharp beam. |
| CAICT | We are fine with FL’s proposal with some update. |
| CMCC | We prefer Option1a. Option 1a can be viewed as an upper bound performance of traditional method. |
| FL3 | Correct the typo as indicated by DCM. |
| CATT | While we are generally fine with the proposal, we have to point out that there are actually 3 Options:  Option 1-A: Select the beast beam **from set A** based on the measurements of all the CSI-RS resources **from Set A** at all time instances. 🡨 No prediction, low resource cost, probably with low performance.  Option 1-B: Select the beast beam **from set B** based on the measurements of all the CSI-RS resources **from Set B** at all time instances. 🡨 No prediction, high resource cost, probably with upper bound performance.  Option 2: the same as FL’s Option 2. 🡨 Simple non-AI/ML-based prediction, low resource cost, probably with low performance. |
| Fujitsu | Agree with FL’s modified option 1a. |
| Samsung | Our understanding is Option 1a. |
| Ericsson | Agree with FL’s option 1a. |
| Nokia | Option 1a also looks fine. |
| Lenovo | Option 1a is fine with us; However, we don't see the need to include the words “prediction window” and “observation window” in the proposal (Here, we further note that, there no exact meaning/definition provided about these words). We propose to modify the proposal as follows:  **Option 1: ~~UE measures~~ Select the ~~beast~~ best beam based on the measurements of all the ~~CSI-~~RS resources (from Set A or Set B of beams) ~~with an exhaustive search~~ at all time instants ~~(i.e., the time instants within the observation window or the prediction window)~~ ~~and selects the best beam at each time instant~~.** |
| ZTE, Sanechips | We are fine with the FL proposal and prefer Option 1a. |
| InterDigital | Fine |

# Others

Some companies suggest to consider multiple scenarios for evaluations.

* InterDigital [5]: Consider the following AI/ML aided beam prediction scenarios for evaluations.
  + Simple specification extension of UE reporting which enables AI/ML beam prediction
  + Partial beam measurement
  + Beam prediction in time domain
  + Association between beams with different beam widths
  + Handling of UE Rx beams
* Qualcomm [23]: Based on evaluations using the agreed KPIs, RAN1 should identify the deployments/scenarios/use cases for which AI/ML based temporal beam prediction may be beneficial.

# Stable proposals for GTW on Tue

Please directly indicate over email if you have strong concerns of the following proposals.

###### **Proposal 1-4-1:**

* **At least for spatial-domain beam prediction in initial phase of the evaluation, UE trajectory model is not necessarily to be defined.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTEk, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel, InterDigital** |
| Objecting companies |  |

###### **Proposal 1-4-2:**

* **At least for ~~time domain~~ temporal beam prediction in initial phase of the evaluation, UE trajectory model is defined. FFS on the details.**

|  |  |
| --- | --- |
| Supporting companies | **Nokia, DCM, Fujitsu, LGE, OPPO, CATT, CAICT, Xiaomi, PML, ZTE, vivo, Ericsson, Samsung, BJTU, Spreadtrum, HW/HiSi, CMCC, MediaTek, NVIDIA, Futurewei, Lenovo, Qualcomm, Intel, InterDigital** |
| Objecting companies |  |

# Appendix: Detailed evaluation assumptions

Table 1 Baseline assumptions for SLS

|  |  |
| --- | --- |
| Parameters | Values |
| Frequency Range | FR2 @ 30 GHz,   * SCS: 120 kHz * BW: 80 MHz |
| Scenarios | High speed @FR2:   * Dense Urban (macro-layer only, TR 38.913) @FR2, 200m ISD, 2-tier model with wrap-around (7 sites, 3 sectors/cells per site), 100% outdoor   One UE is dropped for each of the 21 sectors/cells (see mobility description below) |
| UE Speed | For Dense Urban: 60 km/hr and 120 km/hr |
| Transmission Power | Maximum Power and Maximum EIRP for base station and UE as given by corresponding scenario in 38.802 (Table A.2.1-1 and Table A.2.1-2) |
| BS Antenna Configuration | (M, N, P, Mg, Ng) = (4, 8, 2, 2, 2). (dV, dH) = (0.5, 0.5) λ. (dg,V, dg,H) = (2.0, 4.0) λ  Companies to explain TXRU weights mapping.  Companies to explain beam selection.  Companies to explain number of BS beams |
| BS Antenna radiation pattern | TR 38.802 Table A.2.1-6, Table A.2.1-7 |
| UE Antenna Configuration | Number/location of panels: 3 panels (left, right, and back)  Panel structure: 1x4x2 or (M, N, P) = (1, 4, 2), dH = 0.5 λ  Companies to explain TXRU weights mapping.  Companies to explain beam and panel selection.  Companies to explain number of UE beams |
| UE Antenna radiation pattern | TR 38.802 Table A.2.1-8, Table A.2.1-10 |
| Beam correspondence | Companies to explain beam correspondence assumptions (in accordance to the two types agreed in RAN4) |
| Link adaptation | Based on CSI-RS |
| Traffic Model | Full buffer |
| Inter-panel calibration for UE | Ideal, non-ideal following 38.802 (optional) – Explain any errors |
| Control and RS overhead | Companies report details of the assumptions |
| Control channel decoding | Ideal or Non-ideal (Companies explain how it is modelled) |
| UE receiver type | MMSE-IRC as the baseline, other advanced receiver is not precluded |
| BF scheme | Companies explain what scheme is used |
| Transmission scheme | Multi-antenna port transmission schemes  Note: Companies explain details of the using transmission scheme. |
| Other simulation assumptions | Companies to explain serving TRP selection  Companies to explain scheduling algorithm |
| Algorithm details (when applicable) | Companies to report:   * Beam reporting mechanism * Beam metric L1-RSRP * Number of active panels |
| Other potential impairments | Not modelled (assumed ideal).  If impairments are included, companies will report the details of the assumed impairments |

Table 2 Baseline assumptions for SLS: Additional simulation assumptions for Dense Urban scenario (FR2) mainly from TR 38.802 Table A.2.1-1, and TR 38.901.

|  |  |
| --- | --- |
| Parameters | Values |
| Carrier Frequency | 30 GHz |
| Scenario | UMa LOS |
| System BW | 80 MHz |
| BS Tx Power | 40 dBm |
| Maximum UE Tx Power | 23 dBm |
| BS receiver Noise Figure | 7 dB |
| UE receiver Noise Figure | 10 dB |
| Inter site distance | 200m |
| BS Antenna height | 25m |
| UE Antenna height | 1.5 m |
| Car penetration Loss | 38.901, sec 7.4.3.2: μ = 9 dB, σp = 5 dB |

# Reference

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| --- | --- | --- | --- |
| [1] | [R1-2203142](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203142.zip) | Evaluation on AI/ML for beam management | Huawei, HiSilicon |
| [2] | [R1-2203250](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203250.zip) | Evaluation assumptions on AI/ML for beam management | ZTE |
| [3] | [R1-2203255](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203255.zip) | Model and data-driven beam predictions in high-speed railway scenarios | PML |
| [4] | [R1-2203283](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203283.zip) | Evaluations on AI-BM | Ericsson |
| [5] | [R1-2203374](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203374.zip) | Discussion for evaluation on AI/ML for beam management | InterDigital, Inc. |
| [6] | [R1-2203453](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203453.zip) | Discussion on evaluation on AI/ML for beam management | CATT |
| [7] | [R1-2203552](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203552.zip) | Evaluation on AI/ML for beam management | vivo |
| [8] | [R1-2203810](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203810.zip) | Evaluation on AI/ML for beam management | xiaomi |
| [9] | [R1-2203899](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203899.zip) | Evaluation on AI ML for Beam management | Samsung |
| [10] | [R1-2204017](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204017.zip) | Evaluation methodology and preliminary results on AI/ML for beam management | OPPO |
| [11] | [R1-2204059](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204059.zip) | Evaluation methodology of beam management with AI/ML | Beijing Jiaotong University |
| [12] | [R1-2204102](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204102.zip) | Discussion on evaluation of AI/ML for beam management use case | FUTUREWEI |
| [13] | [R1-2204151](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204151.zip) | Evaluation on AI/ML for beam management | LG Electronics |
| [14] | [R1-2204182](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204182.zip) | Some discussions on evaluation on AI-ML for Beam management | CAICT |
| [15] | [R1-2204240](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204240.zip) | Evalulation on AI based Beam Management | Apple |
| [16] | [R1-2204297](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204297.zip) | Discussion on evaluation on AI/ML for beam management | CMCC |
| [17] | [R1-2204377](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204377.zip) | Discussion on evaluation on AI/ML for beam management | NTT DOCOMO, INC. |
| [18] | [R1-2204419](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204419.zip) | Evaluation on AI/ML for beam management | Lenovo |
| [19] | [R1-2204573](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204573.zip) | Evaluation on ML for beam management | Nokia, Nokia Shanghai Bell |
| [20] | [R1-2204795](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204795.zip) | Evaluation for beam management | Intel Corporation |
| [21] | [R1-2204842](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204842.zip) | On evaluation assumptions of AI and ML for beam management | NVIDIA |
| [22] | [R1-2204862](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204862.zip) | Evaluation methodology aspects on AI/ML for beam management | AT&T |
| [23] | [R1-2205026](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2205026.zip) | Evaluation on AIML for beam management | Qualcomm Incorporated |
| [24] | [R1-2205078](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2205078.zip) | Evaluation on AI/ML for beam management | Fujitsu Limited |
| [25] | R1-2205102 | AI-assisted Target Cell Prediction for Inter-cell Beam Management | MediaTek Inc. |