**3GPP TSG RAN WG1 #122 R1-250xxx**

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**Agenda item:**  11.6

**Source:** Samsung (Moderator)

**Title:**Moderator summary #1 on AI/ML for 6GR

**Document for:** Decision

# Framework and evaluation

## Evaluation and KPIs

Several companies discussed aspect on EVM and KPIs. Several companies proposed for comprehensive evaluation of AI/ML use cases by considering KPIs including system performance, system and model complexity, inter-vendor collaboration complexity, power consumption. In addition to intermediate and system KPIs that were adopted in 5G NR, companies proposed new KPIs such power consumption and inference latency to be considered in 6GR.

#### Proposal 1.1-1:

For evaluation of AI/ML use cases in 6GR, consider

* Performance related metrics, including intermediate (model) performance KPIs and system KPIs, e.g., throughput, overhead
* AI/ML Model related metrics, including model complexity, inter-vendor collaboration when applicable
	+ FFS: whether/how to measure power consumption, inference latency and training latency (when applicable)

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| Company | Comment |
| Google | Probably we can consider adding a note as follows. Different use case may choose different types of KPIs.Note: Whether to use intermediate KPI and/or system KPI is discussed per use case.  |
| Lenovo | At least for use cases, link level KPI can be considered, e.g., BLER for AI based channel estimation. |
| CATT, CICTCI | Support in general.For the FFS, we think training latency is not a critical issue for offline training. Is it only applicable for online training or continuous learning? |
| CMCC | Generally OK except for the inter-vendor collaboration part. For two-sided model, there is inter-vendor collaboration training complexity, but to quantify the complexity with specific metrics, we think it is not an easy way from the expertise in 5G-A AI study.And for training latency, we think it only occurs when online training is involved. |
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| **Company** | **Proposal**  |
| Ericsson  | Proposal 2 6GR AI/ML use cases should be selected considering their potential as per the following criteria: performance gain, implementation complexity, inter-vendor interoperability, AI/ML model training complexity, signalling overhead, and specification impact. |
| Huawei | Proposal 3: Comprehensive comparison between non-AI and AI/ML-based air-interface enhancement solutions is necessary to justify the advantages, at least in terms of system performance, system overhead, computational complexity, and power consumption. * Fallback from AI/ML-based solution to the corresponding non-AI solution should be supported.

Proposal 4: For the study of a use case with both one-sided and two-sided model solutions, comprehensive comparison between one-sided and two-sided models should be considered at least on system performance, system overhead, computational complexity, and power consumption. |
| AT&T | Proposal 6: For 6GR design, final performance metrics (e.g. throughput) are used for performance evaluation of AI/ML use casesProposal 7: For 6GR design, consider complexity and performance tradeoffs for evaluating AI/ML use cases |
| Xiaomi | Proposal 1: * Selected use cases should achieve an optimal trade-off among performance gain, complexity, and power consumption.
* Candidate use cases for selection can be categorized as: 5GA-supported use cases, extensions of 5GA use cases, and new use cases. Distinct approaches should be applied to handle each type.

Proposal 2: The following principles should guide framework extension studies:* Control UE Complexity and Cost:
* Mitigate the requirement for UEs to maintain excessive models or parameters.
* Minimize unnecessary on-device training.
* Maintain Excellent User Experience:
* Prioritize high energy efficiency.
* Ensure robust user privacy protection.
* Support Extended Enablers for Identified Use Cases:
* Extend the data collection framework to enable the acquisition of new data sample types (e.g., transmission data bits/symbols).
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| HONOR | Proposal 3: During the study on potential use cases of AI/ML in 6GR interface, three critical dimensions should be considered: performance improvements, sustainability initiatives, and the creation of new services. |
| vivo | Proposal 1: 6G AIML evaluation methodology need to be established for evaluating use case performance, complexity and power consumption.Proposal 3: Number of operations per second (OPS) and inference frequency are used as metric for evaluation of power consumption and complexity. Proposal 4: A magnitude level upper bound for complexity/power consumption can be set up/considered for feasibility observation of use cases, e.g., [1T] Ops as an upper bound for 6G AIML operations, with understanding that it corresponds to 100mw power consumption and 1% of total on device computation power.Proposal 5: For each use case companies are expected to report and cross check performance gain, number of operations per second for inference (OPS) and inference frequency per second. |
| Samsung | Proposal 5: For 6GR use-case studies, adopt intermediate and ultimate (eventual/system) KPIs as in the NR.* Intermediate KPIs to evaluate model-specific performance, e.g., model performance-complexity trade-off, generalization performance, monitoring accuracy, training and dataset aspects.
* Ultimate KPIs to assess overall performance benefits of AI/ML use cases.

Proposal 6: Adopt NR’s AI/ML evaluation methodology for model generalization performance evaluation for 6GR. The following cases for verifying the generalization performance of an AI/ML model over various scenarios/configurations:* Case 1: The AI/ML model is trained based on training dataset from one Scenario#A/Configuration#A, and then the AI/ML model performs inference/test on a dataset from the same Scenario#A/Configuration#A
* Case 2: The AI/ML model is trained based on training dataset from one Scenario#A/Configuration#A, and then the AI/ML model performs inference/test on a different dataset than Scenario#A/Configuration#A, e.g., Scenario#B/Configuration#B, Scenario#A/Configuration#B
* Case 3: The AI/ML model is trained based on training dataset constructed by mixing datasets from multiple scenarios/configurations including Scenario#A/Configuration#A and a different dataset than Scenario#A/Configuration#A, e.g., Scenario#B/Configuration#B, Scenario#A/Configuration#B, and then the AI/ML model performs inference/test on a dataset from a single Scenario/Configuration from the multiple scenarios/configurations, e.g., Scenario#A/Configuration#A, Scenario#B/Configuration#B, Scenario#A/Configuration#B.
 |
| SK Telecom | Proposal 2. For 6G system with AI/ML, performance gain with complexity/cost should be assessed/evaluated by comparing with that without AI/ML. FFS on details (e.g., metric).  |
| OPPO | 1. Consider the following principles to select AI/ML use cases for 6GR study
* Prioritization of AI/ML-Intrinsic design that significantly enhances the basic components of the transceiver chain of 6GR
* Significant performance benefits for intermediate metrics (e.g. SGCS, NMSE, or predication accuracy) and final metrics (e.g. BLER or throughput) over legacy non-AI schemes
* Well-balanced tradeoff among performance benefits, computation complexity and power consumption
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| Kyocera | 1. Companies should provide system-level simulation results to quantify the performance gains achievable using Neural Receivers. These evaluations should also assess the feasibility and practical considerations of implementing Neural Receivers on the UE side, considering computational complexity, power consumption, and real-time processing constraints.
2. During the study item phase, in addition to presenting performance gains for any considered use case, it is proposed that inference latency results also be reported. This will ensure a comprehensive evaluation of AI/ML-based solutions, particularly in scenarios where real-time responsiveness is critical.
 |

## Enhancement on LCM framework

Many companies proposed enhancement on NR’s LCM, encompassing aspects such as data and model management, including model transfer, applicability of the associated ID, support for localized models, advanced training methods, e.g., online and federated learning, meta-learning for handling network-side additional conditions. Moreover, a number of companies proposed to 5G NR’s LCM framework including functionality-based LCM as a starting point. Enhancement on AI/ML processing unit framework was proposed by a few companies, e.g., 1 company (Samsung) proposed to introduce AI/ML memory unit (MU) on the concurrently activated AI/ML feature/models

#### Proposal 1.2-1:

Consider the 5G NR LCM framework as a starting point. Strive to minimize changes by updating or revising the framework only when justified.

* Study potential enhancements for LCM at least including the following
	+ Data and model management, including model transfer
	+ Handling of network-side additional conditions, e.g., applicability of associated ID
	+ Advanced model training, e.g., online training/finetuning, federated learning, meta-learning
	+ Enhancement on the framework for AI/ML processing unit and memory

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| Company | Comment |
| Google | We suggest removing the sentence “Strive to minimize changes by updating or revising the framework only when justified.” The 5G LCM framework includes CSI framework. It is too early to say 6G will reuse 5G’s CSI framework.In addition, we failed to see the necessity to study “advanced model training”.  |
| Ofinno | Generally fine. Regarding advanced model training, the aspect related to at least online training needs to be studied. |
| Fainity | Fine with the proposal.   |
| Lenovo | We are generally fine with this proposal. For the last bullet, we want to clarify whether the computation/processing time issue for AI/ML operation is included? |
| CATT, CICTCI | Fine with the listed enhancement points. We also think ‘**Continuity of AI/ML features**’ can be studied since UE-side model may or may not fail when moving across cells.Nonetheless, we think the sentence ‘*Strive to minimize changes by updating or revising the framework only when justified*’ looks quite negative view on 6G study. 5G LCM is studied and established only in 2 releases. Unlike waveform/modulation, we cannot say 5G LCM is perfect, the golden rule and mature enough for future 10~15 years. Suggest removing this sentence. |
| SK Telecom | Generally fine but we also think ‘Strive to minimize changes by updating or revising the framework only when justified’ would be too conservative. Better to remove it. The editorial suggestion for the main bullet would be “For 6G LCM framework for AI/ML for air interface, consider the 5G NR LCM framework as a starting point.”  |
| CMCC | OK to take 5G NR AI LCM framework as starting point and study some 6G enhancements. For the last bullet, we suggest modifying to a more general wording, “Enhancement on the framework for AI/ML processing ~~unit~~ and memory criteria ”. |

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| **Company** | **Proposal**  |
| Huawei | *Proposal 6: The framework should be enhanced based on the legacy framework for AI/ML for air-interface at least in the following aspects:* * *Data collection and management, e.g., considering new data types.*
* *Model management, e.g., considering new UE capability of online fine-tuning, or management across multiple AI/ML enabled functions.*
* *UE management, e.g., scheduling of UEs for distributed model solutions.*
 |
| AT&T | Proposal 1: The following core principles are followed to design an AI/ML framework for 6GR air interface:* A unified flexible LCM framework for model management, model transfer, model training, and model testing
* A unified data collection framework to enhance management efficiency
* Network visibility to drive innovation while proactively addressing security and privacy concerns
* Network control over data collection to ensure network performance is not impacted while providing potential new value opportunities via hosting/routing/augmenting the data
* Scalability to accommodate various emerging and future use cases.
 |
| Xiaomi | Proposal 14: Consider the AI/ML framework defined in 5GA as baseline for 6GR AI/ML Proposal 15: Unique associated ID among multiple cells should be supported to ensure more efficient network condition check |
| Apple | Proposal 7: For the 6G SI on AI/ML Lifecycle Management (LCM) framework, use the 5G AI/ML LCM framework as the starting point for both one-sided and two-sided model architectures. Additional enhancements to be considered include:* Extending the Association ID to support multi-cell scenarios, applicable to both one-sided and two-sided models
* Study a simplified and scalable APU framework applicable to a wide range of AI/ML use cases other than AI based CSI report.
 |
| LGE | Proposal#12: Study 6GR LCM framework in a dedicated agenda considering at least the following aspects:* Training data reduction for NW/UE-side data collection
* Reduced signaling/configuration overhead for LCM operation
* Support of fast and dynamic LCM operation considering localized model implementation
* New PU framework to support various AI/ML use cases
 |
| Sharp | Proposal 6: RAN1 assumes Rel-19 functionality-based AI/ML LCM could be reusable as baseline for designing 6G AI/ML framework.  |
| Samsung | *Proposal 1:Take NR AI/ML framework as a starting point and support/adopt the following in 6GR AI/ML framework** Terminologies in TR 38.843
* UE-side and NW-side data collection
* Applicability report
* Associated ID to indicate additional conditions that may not be explicitly configured
* Fully specified reference two-side models to address interoperability
* Performance monitoring
* Dedicated AI/ML processing unit (APU) and timeline

*Proposal 2: Consider the following approaches to support site/scenario-specific models** Non-linear approaches: Parameter transfer for input/output adaptation layers of specified model structure
* Linear approaches: downloadable projection/basis matrices for input/output processing

*Proposal 3: Considering online training/fine-tuning in 6GR AI/ML study, at least for the use case that only requires lightweight model.**Proposal 4: Study the potential impact of AI/ML memory on the concurrently activated AI/ML features/models, including whether to introduce AI/ML memory unit (MU) taking the NR’s active CSI-RS resource and ports counting as a starting point* |
| OPPO | Proposal 3: Strive for unified LCM framework for 6GR, including at least the following aspects * Data collection for model training and fine-tuning
* UE-side and/or NW-side model monitoring
* Model paring (for two-sided model) and model identification
* LCM-related operation, e.g. model switch, fallback, activation/deactivation
 |
| CATT, CICTCI | Proposal 1: For 6G AI/ML framework, develop an enhanced LCM framework to enable future-proof framework applicable to emerging use cases, incorporating:* Advanced training techniques, e.g. online training, federated learning
* Unified management of AI/ML features
* Continuity of AI/ML features
 |
| Kyocera  | Proposal: RAN1 should further investigate the feasibility of implementing more robust solutions to address the network-side additional conditions problem. The study may include the technology enablers of advanced AI/ML methodologies, such as meta-learning, which enable models to dynamically adapt to varying data distributions encountered during inference.  |

## Data collection framework

A number of companies discussed data collection framework in their contribution. The following summarizes the discussion points

1. Enhancement in the data collection framework for future-proof and unified (across working groups) design.
2. Scope and restrictions, e.g., whether to restrict data collection to use cases or to support generic purpose data collection.
3. Whether to introduces a new AI/ML data management plane

Some of the proposals may not be under the realm of RAN1. However, RAN1 may identify requirements which may consequently suggest enhancement in the relevant working group. With this in mind, the RAN1 study may focus in identifying requirements that may lead to data collection framework enhancement.

#### Conclusion 1.3-1:

For AI/ML study in 6GR, RAN1 to study on the content and format for data collection for each use case.

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| Company | Comment |
| Google | OK in principle. We also want to clarify the measurement related aspects, e.g., DL-RS, CPU and so on should also be studied in RAN1. |
| Ofinno | Support |
| Sharp | Support |
| Fainity | Support. Most use cases correspond to channel conditions measured by the UE and it may be transmitted via L1 signalling. So, the content and format should be studied by RAN1.  |
| Lenovo | Support |
| CATT, CICTCI | OK. But just remind, RAN1 may participate in relevant LCM discussion, e.g. whether the CSI related data is collected in RAN1 CSI framework, or a dedicated AI/ML framework.BTW, this should be proposed as an agreement rather than conclusion? |
| SK Telecom | Support. |
| CMCC | Support. Also, the latency of data collection should be studied if some advanced model training, e.g., online training/finetuning, federated learning, meta-learning are involved. |
| NVIDIA | Support |

Companies’ proposals are captured below:

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| **Company** | **Proposal**  |
| AT&T | Proposal 2: AI/ML framework in 6GR should support multiple termination points for AI/ML data within the network with MNO visibilityProposal 3: 6GR is designed to differentiate AI/ML data management traffic from user plane traffic and control plane trafficProposal 4: for the AI/ML framework in 6GR, study the introduction of an AI/ML data management plane to manage data collection, model transfer/delivery and LCM aspects of different AI/ML use cases on 6GR interface |
| Xiaomi | Proposal 17: Consider data collection extension from the following aspects* Define dedicated data bit/symbol sequence for training data collection
* Establish the procedure for the dedicated data sample collection
 |
| HONOR | Proposal 4：Data collection framework in 6GR interface should be designed with forward compatibility, at least including* Capable of supporting diverse AI/ML use cases in 6GR.
* Support of a data collection framework that is open, standardized and accessible to OEMs and network operators.
* Strive for a common data collection framework across RAN and SA.

Proposal 5: AI/ML in 6GR interface should strive for a unified framework for LCM, including:* The LCM framework defined within the 5G specifications for AI/ML can serve as a valuable foundation for 6GR.
* Offline model training is at least supported in 6G day one.
* 6GR works towards establishing a unified framework for model exchange across both RAN and SA.
* It’s proposed to achieve a unified functionality management framework to support broader use cases.
* Non-AI solutions are always supported as fallback mechanisms.
* It is recommended to explore a more flexible UE capability and functionality reporting in the context of 6GR.
 |
| Kyocera | RAN1 should study enhancements to data collection and data management tailored to the specific new use cases.  |

## Others

Other proposals on various topics were raised. SK telecom proposed to include fallback mechanism for AI/ML solutions to non-AI/ML which was also supported by a number of companies. The monitoring mechanism defined in 5G NR serves as starting point to discuss this fallback mechanism. Companies may propose additional enhancement for 6GR, if any. Other proposals discuss on the expectations, requirements of 6GR for AI/ML service. InterDigital proposed to initially focus the discussion on AI/ML framework before potential use case identification.

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| **Company** | **Proposals** |
| InterDigital, Inc. | Proposal 1: For 6GR AI/ML, RAN1 should initially focus on AI/ML framework.Proposal 2: For 6GR AI/ML, RAN1 can start work on identification of use cases for selected use cases and enhancements once the work on the conventional baseline has progressed sufficiently. |
| Xiaomi | Proposal 16: Define Standardized Power States within the AI/ML Framework * Define mechanisms to synchronize power states between the network and UE.
* Define mechanisms to achieve an optimal balance between energy efficiency and service response delay.
 |
| HONOR | Proposal 1: For AI/ML in 6G Radio, two aspects should be considered: AI for 6G Radio and 6G Radio for AI.* AI for 6G Radio pertains to the application of AI technologies to assist networks and devices in delivering services defined by 3GPP.
* 6G Radio for AI emphasizes how the system can facilitate and empower AI applications by utilizing the functionalities of 6G to offer various services.

Proposal 2：For AI/ML in 6GR interface, study how to integrate the AI agent in the 6GR system at both UE and network, to improve network performance and user experience. |
| SK Telecom | 1. For 6G system with AI/ML, the unified fallback mechanism to non-AI/ML should be considered.
 |

# Use cases

## Principle for use case selection

Several companies mentioned to extend 5GA use case without duplicated evaluation, and selected new 6G use cases for both UE/NW side model, and shall considering the performance gain and complexity. Some companies want to prioritize one-sided use cases.

No need to have special conclusion for this.

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| Company | Proposal  |
| Nokia [1] | Proposal 2: RAN1 studies should focus on identifying promising new AI/ML-enabled use cases related to the physical layer for both UEs and the network, and on assessing the performance and complexity trade-offs of these use cases. * RAN1 shall coordinate with other WGs from the early stages of the study item to avoid misalignment of study outcomes across different WGs.
 |
| Ericsson [5] | Proposal 7 6GR Rel-20 study item should prioritize one-sided use cases which are easier to deploy and maintain in real life. |
| Huawei/Hisi [6] | As some selected use cases about AI/ML for air interface and NG-RAN have been studied in 5G NR, the following aspects can be considered for the study of use cases in 6GR to improve the performance of RAN at both NW side and UE side.* Time varying channel acquisition and prediction
* Burst interference prediction and handling
* Site-specific radio transmission optimization
* Low complex and high performance receiver
* Joint transceiver design across multiple L1 functions

Proposal 3: Comprehensive comparison between non-AI and AI/ML-based air-interface enhancement solutions is necessary to justify the advantages, at least in terms of system performance, system overhead, computational complexity, and power consumption. * Fallback from AI/ML-based solution to the corresponding non-AI solution should be supported.
* Proposal 4: For the study of a use case with both one-sided and two-sided model solutions, comprehensive comparison between one-sided and two-sided models should be considered at least on system performance, system overhead, computational complexity, and power consumption.

Proposal 5: AI/ML for air-interface enhancement in 6G should consider directions including AI/ML based CSI acquisition enhancement and data transmission enhancement. * Use case categorization can be considered for the use cases, e.g., from the perspective of one-sided model and two-sided model solutions, or the perspective of single function and multiple functions solutions.
 |
| Google [7] | Proposal 1: The following principles should be considered for AI/ML use case selection* The AI/ML use case should provide clear benefit compared to existing mechanisms in terms of the performance improvement, overhead reduction, power saving, and latency reduction
* The AI/ML use case does not rely on time-variance property
* The evaluation for the AI/ML use case is based on multiple types of channels from the system level simulation or channels from the field
* One-side model is prioritized with regard to the possibility for deployment
 |
| Vivo [9] | Proposal 1: 6G AIML evaluation methodology need to be established for evaluating use case performance, complexity and power consumption.Proposal 6: The first three meetings in RAN1 for AIML study should target for use case clarification and categorization.Proposal 24: Use cases already studied in 5G-A era do not need further study in Rel-20 6G SI, but can be directly considered during scoping of 6G WI.  |
| Xiaomi [10] | Proposal 1: * Selected use cases should achieve an optimal trade-off among performance gain, complexity, and power consumption.
* Candidate use cases for selection can be categorized as: 5GA-supported use cases, extensions of 5GA use cases, and new use cases. Distinct approaches should be applied to handle each type.
 |
| ZTE, Sanechips [12] | Proposal 1: 6G is envisioned as a Smart Radio capable of supporting native AI with the following design principles:* 6GR is designed with flexibility to accommodate both AI-based solution and non-AI-based solution
* 6GR prioritizes the AI/ML use cases with compelling trade-off between performance and complexity

Proposal. 2. RAN1 strives to deliver an AI enhanced Efficient, Green and Autonomous 6G air interface. |
| Samsung [14] | Proposal 7: Leverage the NR’s study outcome for 6GR study on AI/ML for the air interface with potential extensions for some of the use cases.Proposal 8: For the study on AI based CSI compression, the following should be considered:• UE complexity handling: e.g., NW-sided model, compatibility to non-AI/ML capable UEs• New UCI structure: e.g., for JSCM• Explicit channel feedback: e.g., full channel matrices, or eigenvectors and eigenvaluesProposal 9: Study CSI-RS overhead reduction with AI/ML based CSI prediction over the time/frequency/spatial and beam domains, including wide frequency range prediction.Proposal 10: AI/ML for PA nonlinearity handling can be studied as one use case which benefits from online training/finetuning.Proposal 11: Explore more use cases, e.g., PAPR reduction with two-sided model, especially with standardized (reference) model. |
| Lenovo [19] | Proposal 1: 6G PHY, from Day 1, should support the “possibility” of substituting/replacing conventional modules in the transmit-receive chain with AI models/modules (either with single-sided or two-sided AI modules). The substitution/standardization of different AI modules, however, can happen gradually during different releases. |
| OPPO[20] | Proposal 1: Consider the following principles to select AI/ML use cases for 6GR study• Prioritization of AI/ML-Intrinsic design that significantly enhances the basic components of the transceiver chain of 6GR• Significant performance benefits for intermediate metrics (e.g. SGCS, NMSE, or predication accuracy) and final metrics (e.g. BLER or throughput) over legacy non-AI schemes• Well-balanced tradeoff among performance benefits, computation complexity and power consumption |
| Interdigital [25] | Proposal 3: For R20 6GR AI/ML, focus on AI/ML use cases that show compelling benefits using a clear performance baseline including a 6GR non-AI/ML baseline when applicable.Proposal 8: RAN1 to determine a subset of AI/ML use cases for further study, based on potential performance/complexity trade-off and on the timing for defining a baseline.Proposal 9: RAN1 will down-select to a set of AI/ML use cases for study in Rel-20 based on the results of a full performance/complexity analysis using their respectively identified baseline. |
| Fujitsu [29] | Proposal 1:* For AI/ML in 6GR, the use cases supported in 5G-Adv should also be supported in 6G and the design in 5G-Advanced could be baseline for 6G
	+ If enhancement for certain use case is needed on top of the design in 5G-Adv, then it could be studied in 6G
	+ If enhancement is not needed on top of the design in 5G-Adv, then it could be specified in 6G
* For AI/ML in 6GR, new use cases on physical layer processing could be considered by RAN1
	+ Both one-sided model and two-sided model could be considered in 6G design
 |
| AT&T | Proposal 5: For 6GR design, consider use cases that provide high impact practical relevance to the operators |
| DCM [41] | Proposal 1* For the initial phase of 6G, prioritize the study of use cases with the one-sided model, considering the easy commercial deployment and commercial demands.
	+ New use cases for 6G and the use cases enhanced from 5GA can be studied based on the potential benefits of transmission efficiency, sustainability, and user experiences.

Proposal 2* Avoid duplicated work between 6G and 5GA AI/ML on the two-sided model.
	+ The complexity of practical deployments of the two-sided model should be investigated after the completeness of the Rel-20 5GA AI/ML work item. The study on use cases with the two-sided model can be deprioritized in this SI.
 |
| {Indian Institute of Tech (M), IIT Kanpur}\*[42] | Proposal 4: For all use cases considered for 6G study, parallel comparison with legacy non-AI/ML approaches should be included. Proposal 5: For all use cases considered for 6G study, appropriate signaling and configurations for fallback to non-AI/ML approaches should be included.  |

## 5GA use cases and extension

Most of companies suggest to consider 5GA use case with some extensions and avoid re-study.

#### Conclusion 2.2-1:

5GA use cases and the corresponding study outcome can be directly considered for 6GR system design, including: beam management, positioning, CSI prediction, and CSI compression.

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|  Company | Comment |
| FL | Please note that, only “study outcome”, which means observations/conclusions in SI phase, not 5GNR spec |
| Google | We do not see the need to consider positioning and CSI compression for 6G. |
| Ofinno | Fine |
| MTK | Suggest including “as baseline” in the wording as follows: “5GA use cases and the corresponding study outcome can be directly considered as baseline for 6GR system design, including beam management, positioning, CSI prediction, and CSI compression.” |
| Sharp | We wonder whether the conclusion would be applied for RAN2 use case, e.g. mobility. That is to say, does this conclusion preclude RAN2 use case? Furthermore, does “study outcome” refer to TR(38.843)? |
| Fainity | For the positioning use case, it may have more impact on RAN2 and RAN3. We don’t think this use case needs to be discussed in RAN1.  |
| Lenovo | Support |
| CATT, CICTCI | We notice that the current wording is soft, and hence no harm. Possibly, 6G non-AI/ML baseline will be improved so the value of each 5G-A use cases may be different. However, the proposal just mention ‘considered’, not ‘supported’.Perhaps the supplementary information from FL can also be captured in the conclusion:5GA use cases and the corresponding study outcome (e.g. observations, conclusions, etc. in TR 38.843) can be directly considered for 6GR system design, including: beam management, positioning, CSI prediction, and CSI compression. |
| SK Telecom | Since we do not see the huge need on some of 5GA use cases, we are not sure about the conclusion. I guess we need to make a decision on whether all 5GA use cases will be the scope of 6G AI/ML. If not, then the conclusion 2.2-1 needs to be somewhat revised.  |
| CMCC | We think whether to adopt these 5G-A use cases is also related to whether the corresponding non-AI technology is introduced in 6G. |
| NVIDIA | We support considering 5GA use cases for 6GR system including beam management, positioning, CSI prediction, and CSI compression. |

### Extension on AI/ML for beam management

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| New sub-use cases | Proposed companies  |
| inter-cell beam prediction/M-TRPorLTM | (5) Nokia, xiaomi, BJTU, ZTE/Sanechips, Qualcomm,(5) CATT/CICTCI \*, Samsung \*, NEC\*，Honor\*, DoCoMo\*(RAN 2-led), LGE |
| Tx-Rx beam pair prediction | (1) Nokia (1) NEC\* |
| RL-based beam prediction | (1) Nokia  |
| Cross-frequency beam prediction | (3) Futurewei, xiaomi, Apple，(4) CATT/CICTCI \*, China Telecom \*，LGE\*, Honor\*  |
| Beam selection during initial access | (9) CATT/CICTCI \*, vivo \*, ZTE/SANECHIPS\*, Samsung\*, LGE\*? , NEC\*,Qualcomm\*, DoCoMo\*, Ofinno |
| BFR  | (5) CATT/CICTCI \*LGE\*, Fujitsu \* NEC\*，Honor\* |
| Beam prediction with UEI | (1) Samsung \* |
| Fast TCI | (1) NEC\* |
| Beam management for HST | (1) BJTU \* |
| Beam management in hybrid beamforming and distributed MIMO | (1) NVIDIA\* |

\* without simulation results

Some extension on beam management were proposed, as summarized in above table. Some of them were specification design and no need to have additional evaluation, e.g., UEI, Fast TCI, while some of them may need some additional evaluations.

#### Conclusion 2.2.1-1:

In related study (e.g., MIMO, Initial access), AI/ML based beam management with DL Tx beam spatial/time domain prediction can be assumed as feasible.

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|  Company | Comment |
| Google | OK, we think we should clarify this also includes AI/ML based RSRP prediction. |
| Ofinno | Fine |
| Sharp | Generally support. In our understanding, we don’t think “In related study” is needed in the conclusion, since anyway if feasible, the use case would be incorporated in related aspect of 6GR. |
| Fainity | Support |
| Lenovo | It is too vague saying the related study. In Rel-18/19, RAN studied AI/ML based BM in connected mode only. At least the extension to initial access needs to be further studied with evaluation before we assume it is feasible. |
| CATT, CICTCI | Maybe not wrong, but we should be more careful on the assumption, for example, the conclusion is only hold when considering 6G in the same FR (FR2-1) as in 5G-A? Otherwise, performance evaluation may still be needed, such as in ~7 GHz. |
| CMCC | At least for AI/ML based beam management in initial access, the feasibility of it is much related with non-AI deign of 6G initial access. We suggest to discuss AI and non-AI methods together in initial access agenda. Here is suggested revised version:Conclusion 2.2.1-1: In related study (e.g., MIMO, Initial access), AI/ML based beam management with DL Tx beam spatial/time domain prediction can be considered. |

#### Conclusion 2.2.1-2:

Discussion on whether to support study on additional subcases/scenarios for beam management or directly extend the observations/conclusions from DL TX beam prediction, at least including:

* Inter-cell beam prediction/M-TRP beam prediction
* LTM
* BFR
* Inter-frequency beam prediction
* Tx-Rx pair prediction
* Beam management in hybrid beamforming and distributed MIMO

|  |  |
| --- | --- |
|  Company | Comment |
| Google | We do not see the necessity for the last bullet. The technical aspect is also unclear. Suggest removing it for now.In addition, we think the beam prediction with UEI can be added. |
| FL | I didn’t add UEI is because that is related to specification design other than the application of the study outcome to a certain scenarios.Whether 6GR will support UEI or not can be decided up to MIMO, but of course, with previous proposed conclusion, MIMO design can take into consider of predicted results.  |
| Sharp | Support |
| Vodafone | We propose to study beam management for NES. Specifically for spatial domain adaptation, by activating/deactivating antenna ports it will impact the shape of the beams that are transmitted by the base station, and beam selection optimized for network energy saving may benefit from the AI/ML framework |
| Fainity | Agree with this conclusion. In 6G, AI/ML based beam management/beam prediction should be applied for more corresponding use cases.  |
| Lenovo | Seems some of the cases only supported by a single company. It is better to agree on the case with majority support and further study the case with less support so far.At least the inter-cell beam prediction/M-TRP beam prediction and the inter-frequency beam prediction needs to be studied as they are based on different conditions than what we have in Rel-18/19. |
| CATT, CICTCI | For the last bullet, can we clarify how AI/ML is used for beam management under this assumptions (hybrid BF and distributed MIMO)? Intuitively, the first one is the same as R19 AI/ML BM, and the second one is the same as ‘Inter-cell beam prediction/M-TRP beam prediction’, the first bullet? |
| CMCC | Open to study these extensions for beam management in 6G except Tx-Rx pair prediction. We have studied it in Rel-18 AI BM study with fruitful evaluations, but finally we only specified Tx beam prediction with Rx beam is left to UE implementation. We think reconsidering it in 6G is not needed. |

### CSI enhancement

|  |  |
| --- | --- |
| New sub-use cases | Proposed companies  |
| spatial-frequency-temporal CSI compression. | NVIDIA \* |
| for network-side CSI prediction with SRS. | NVIDIA \* |
| Joint CSI prediction and compression | Panasonic \*, NEC\* |
| SRS + CSI compression | LGE\* |

Some use cases are proposed. However, I feel that all of them can be covered by general conclusion 2.2-1. I don’t see the point to re-study it again, any different view?

#### Question 2.2.2-1:

What is additional use case that hasn’t been studied in 5GA for CSI prediction and CSI compression with separate source and channel coding with 2-sided model?

|  |  |
| --- | --- |
| Company | Comment |
| FL  | Please share your view.  |
| Google | Based on what we studied in 5G, AI/ML is feasible for CSI prediction. We propose to consider AI/ML based CSI dwelling time prediction, which is based on the capability of CSI prediction. |
| MTK | Since CSI prediction and CSI compression are listed under “New use cases” in 2.3.1 and 2.3.3, we wish to clarify the reason for question 2.2.2-1. Is 2.3.1 and 2.3.3 not meant to include use cases with separate source and channel coding with 2-sided model? |
| Lenovo | For the first and the third one, we think they may correspond to case 2/3 in 5GA study. Not sure the combination of SRS for the second and the fourth one have a solid study in 5GA. |
| NVIDIA | Only UE-side CSI prediction is studied in 5GA. We propose to consider network-side CSI prediction in 6G, based on SRS (e.g., with SRS overhead reduction) |
|  |  |
|  |  |

### Positioning

|  |  |
| --- | --- |
| New sub-use cases | Proposed companies  |
| joint sensing and positioning, channel charting, and speed/doppler estimation. | NVIDIA \* |
| Based on AI/ML-based mobility/positioning or non-AI/ML-based positioning, NW may predict/determine location of UE and map it into sensing map. | Panasonic \*  |
| Positioning and sensing  | Qualcomm \* |

Some use cases are proposed without any evaluation result. If some particular use case as positioning extension, companies are encouraged to provide use case description, evaluation assumptions and results, as well as the impact on LCM and other spec impact.

##  New use cases

### CSI prediction and CSI-RS overhead reduction

#### Use case definition

|  |  |  |
| --- | --- | --- |
| Sub-use case | Model location | Views |
| (a) Spatial and/or frequency domain (b) Cross-frequency 1,2,4,5(c) Cross-beam CSI prediction for FR3 1,2,3(d) Spatial/freq/time 6,7(e) RS pattern design 1 Samsung 2 NTU\*3 NVIDIA, 4 LGE5 Apple\*6 Honor\*7 MediaTek8. Huawei/HiSi \* | (a)UE-sided model(b) NW-sided model 1,21 Qualcomm2 {CEWiT, IITM, Tejas Network, IITK}(c) Two-sided model 33 Huawei/HiSi\*; Joint RS pattern and channel estimation | (17) Nokia, Spreadtrum/UNISOC, Ericsson, Google, CATT/CICTCI, vivo, xiaomi, ZTE/Sanechips, Samsung, BJTU, Fujitsu, Lenovo, OPPO, LGE, NVIDIA, Qualcomm, DoCoMo(17) Huawei/HiSi \*, TCL\*, CT\*, {Tejas Network Limited, CEWiT, IIT Madras, IISC Bangalore, IIT Kanpur}\*, Panasonic\*，NTU\*, Apple\*, NEC\*, Honor\*, MediaTek \*, ETRI\*, CMCC\*, Sony\*,SKT\*,AT&T\*, {Indian Institute of Tech (M), IIT Kanpur}\*, Rakuten\*  |

\* without simulation results

**34** contributions proposed to study CSI-RS overhead reduction, wherein **17** of them provided preliminary simulation results. Most of companies assume CSI-RS overhead reduction is a UE-sided model. **Two** contributions (Qualcomm, {CEWiT, IITM, Tejas Network, IITK }) mentioned NW-sided model can be considered. **One** contribution (Huawei/HiSi) mentioned 2-sided model for joint CSI-RS pattern and channel estimation.

**All companies** support spatial and/or frequency domain CSI-RS overhead reduction. With AI at UE-sided model, there is minor/no SGCS/NMSE loss of predicted CSI compared with high CSI-RS overhead, and SGCS/NMSE gain can be observed comparing with non-AI based channel estimation for CSI calculation. In addition, **2** companies (Honor and MediaTek) mentioned spatial/frequency and time domain prediction.

**4** companies (Samsung, NTU, LGE, Apple) proposed to support cross- frequency CSI prediction. One company provide some preliminary results, that shows decent results in terms of SCGS for wideband CSI.

**3** companies (Samsung, NTU, NVIDIA) proposed to support cross-beam CSI prediction for FR3 (analog beam and digital precoding). One company provided some preliminary results, that shows decent results in terms of SCGS for CSI prediction cross-beams.

**1** contribution (Huawei/HiSi) mentioned RS pattern design or RS pattern design and channel estimation with 2-sided model. However, **one** contribution (Qualcomm) mentioned CSI-RS pattern/schemes allow lower complexity are preferred:

#### Main KPI

The following KPI were proposed/used for the evaluation:

* SGCS/NMSE
* Spectrum efficiency
* Throughput
* Model complexity

#### Proposal 3.3.1-1:

For 6GR AI/ML, support the study on CSI prediction and CSI-RS pattern design at least with UE-sided model, at least including the following with potential down selection:

* sparse CSI-RS design with less overhead in spatial and/or frequency domain,
* cross-frequency range CSI prediction,
* cross-beam domain CSI prediction for FR3, if applicable

Time domain CSI prediction can be additionally considered in the study.

|  |  |
| --- | --- |
| Company | Comment |
| Google | We think the time-domain overhead reduction can also be included. This should be a low-hanging fruit with regard to the feasibility of CSI prediction proved in 5G. |
| FL | @google, I haven’t see much results from companies to show the results with larger periodicity than the max values supported by NR, as the measurement input, if this is what you mean.With current formulation, nothing is precluded. I think we will study and design those parameters later in future study. If your intention is time domain prediction in the future, that can be covered by the last bullets.  |
| MTK | We wish to add “cross-antenna ports and/or antenna panels” and “use of multiple RS types for CSI-RS overhead reduction” as sub-use cases for CSI prediction. |
| Fainity | Support. |
| Lenovo | Generally, we are fine with this proposal. For first sub-bullet, the less CSI-RS overhead would not be represented in spatial domain, rather than in time-frequency resource, e.g., OFDM symbol and/or RE. Suggest to revise: **For 6GR AI/ML, support the study on CSI prediction and CSI-RS pattern design at least with UE-sided model, at least including the following with potential down selection:*** **sparse CSI-RS design to support spatial and/or frequency domain CSI prediction ~~with less overhead in spatial and/or frequency domain~~,**
* **cross-frequency range CSI prediction,**
* **cross-beam domain CSI prediction for FR3, if applicable**

**Time domain CSI prediction can be additionally considered in the study.** |
| CATT, CICTCI | Support. |
| SK Telecom | Support the proposal. We are interested in CSI prediction and CSI-RS overhead reduction with AI/ML. Regarding the second sub-bullet, it would be better to remove ‘range’. One question to FL would be: is there any reason to prioritize spatial/frequency domain over time domain for sparse CSI-RS design?  |
| CMCC | Support. But not sure why only FR3 is considered for cross-beam domain CSI prediction.  |
| NVIDIA | We support study on CSI prediction and CSI-RS pattern design, covering spatial, frequency, and time domain with same priority. Network-sided model can be additionally considered in the study. |

#### Conclusion 3.3.1-2:

For CSI prediction and CSI-RS pattern design at least with UE-sided model, study on

* Definition of each sub-use case
* AI receiver specific evaluation assumption, methodology and KPIs
* Whether/what is the specification impact on LCM (data collection, performance monitoring, inference)

|  |  |
| --- | --- |
| Company | Comment |
| FL | Conclusion is for out study in future meeting.  |
| Google | Support |
| Fainity | Support |
| Lenovo | Fine with this proposal. |
| CATT, CICTCI | Support. But this should be agreement rather than conclusion. |
| SK Telecom | Support |
| CMCC | Not sure why AI specific receiver is needed for AI CSI prediction. UE can use traditional receiver for CSI-RS measurement and use the measurement result as model input to predict CSI. |

#### Proposal 3.3.1-3: (low priority)

For CSI prediction and CSI-RS pattern design at least with UE-sided model, at least the following KPIs can be considered:

* SGCS/NMSE
* Spectrum efficiency
* Throughput
* Overhead
* Inference complexity

|  |  |
| --- | --- |
| Company | Comment |
| Google | Support. Probably we can re-organize it a bit by merging SE and Tput in one bullet.  |
| Lenovo | Inference latency will affect the CSI reporting timeline, which should be also considered. **For CSI prediction and CSI-RS pattern design at least with UE-sided model, at least the following KPIs can be considered:*** **SGCS/NMSE**
* **Spectrum efficiency**
* **Throughput**
* **Overhead**
* **Inference complexity**
* **Inference latency**
 |
| CATT, CICTCI | Support. |
| SK Telecom | OK with the proposal. |
| CMCC | Support. |
|  |  |

### DMRS design with AI receiver

#### Use cases definition

|  |  |  |
| --- | --- | --- |
| Sub-use case | Model location | Views |
| DMRS design or AI receiver(a) AI for channel estimation[interpretation?](b) AI for channel estimation & interpretation & equalization 1, 2(c) Data aided channel estimation 3,7(d) AI Receiver with multiple functions 1, 4, 5, 61 NVIDIA, 2 Boost\*3 Qualcomm4 MediaTek5 Futurewei 6 Lenovo7 Panasonic | Low overhead DMRS in general | One-sided model(Receiver side) | (17) Nokia, Futurewei, Kyocera, ZTE/Sanechips, DeepSig Spreadtrum/UNISOC, Ericsson, NVIDIA, OPPO, CATT/CICTCI, vivo, xiaomi, Fujitsu, InterDigital, Apple, Qualcomm, Ofinno(17) Huawei/HiSi \*, TCL\*, CT\*, {Tejas Network Limited, CEWiT, IIT Madras, IISC Bangalore, IIT Kanpur}\*, Lenovo \*, Panasonic\*, NTU\*, LGE\*, Boost\*, NEC\*, Honor\*, ETRI\*, CMCC\*, Sony\*, SKT\*, Sharp\*, {CEWiT, Tejas Network}\* |
| Sparse orthogonal DMRS | One-sided model(Receiver side) | (14) Nokia, Futurewei, Kyocera, Spreadtrum/UNISOC, Ericsson, CATT/CICTCI, vivo, xiaomi, ZTE/Sanechips, Qualcomm, NVIDIA, Apple, Fujitsu, Ofinno(5) Huawei/HiSi \*, CT\*, NTU\*, LGE\*, CMCC\* |
| Non-Orthogonal DMRS and Superimposed with data | One-sided model(Receiver side) | (4) Xiaomi, ZTE/Sanechips, OPPO, Lenovo, Qualcomm(9) Huawei/HiSi \*, CT\*, NVIDIA\*, NTU\*, LGE\*, Fujitsu\*, NEC\*, Honor\*, CMCC\*  |
| DMRS-Less(a) with special modulation design 1,2,3, 5(b) with special data pattern 4 | One-sided model 1,2,3,4, 5OrTwo-sided model 1,2,3, 51 NVIDA2 MediaTek3 Lenovo4 Interdigital5 DeepSig | (6) NVIDIA, Lenovo, InterDigital, Qualcomm, MediaTek, DeepSig(1) Huawei/HiSi \* |
| Joint RS pattern and channel estimation | Two-sided model | (1) Huawei/HiSi \* |

\* without simulation results

**31** contributions proposed to study DMRS overhead reduction in general, wherein **16** of them provided preliminary simulation results. Most of companies assume DMRS overhead reduction is one-sided model (receiver side). Some contributions two-sided model for DMRS-less scheme with transmitter sided for bit to constellation mapping, with AI trained constellation. And one contribution (Huawei/HiSi) mentioned 2-sided model for joint CSI-RS pattern and channel estimation.

**18** contributions explicitly proposed sparse orthogonal DMRS, and **13** contributions provided preliminary simulation results. With AI receiver, BLER/throughput gain can be observed comparing with conventional receiver.

**13** companies proposed to study the sub-use case for non-orthogonal DMRS superimposed with data.

**4** company provide some preliminary results, wherein BLER/throughput gain can be observed comparing with conventional receiver.

**7** companies proposed to study DMRS-less scheme with AI/ML receiver, and **6** contributions provided preliminary simulation results with decent BLER/throughput performance. **4** companies (NVIDA, MediaTek, Lenovo, DeepSig) explicitly mentioned the use of special modulation design at the transmitter, which may or may not require transmitter-sided model (two-sided model). **1** company (InterDigital) proposed special data pattern to facilitate the AI receiver with receiver-sided model.

**1** contribution (Huawei/HiSi) mentioned RS pattern design or RS pattern design and channel estimation with 2-sided model.

**1** contribution (Qualcomm) mentioned DMRS pattern/schemes allow lower complexity are preferred.

#### Assumption of Al/ML receiver

Different AI/ML receiver assumptions were proposed/used in the evaluations:

* AI/ML receiver for channel estimation directly with conventional Rx
* AI/ML receiver for channel filter coefficient generation for legacy CE
* AI/ML receiver replacing multiple blocks including CE+EQ+ demodulation
* AI/ML receiver replacing multiple blocks with join-block processing, including CE+EQ+ demodulation
* AI/ML receiver replacing whole Rx chains

#### Main KPI

The following KPI were proposed/used for the evaluation:

* raw BER/BLER/ Tput at given SNR or given TBS
* Inference complexity
* Inference time

#### Proposal 3.3.2-1:

For 6GR AI/ML, support the study on DMRS design at least with AI receiver (i.e., UE-sided model or NW-sided model) for both uplink and downlink, at least including the following with potential down selection:

* Sparse orthogonal DMRS
* Non-Orthogonal DMRS and Superimposed with data
* DMRS-less

FFS on whether to support study on DMRS design with two-sided model (i.e., paired AI receiver and AI transmitter)

|  |  |
| --- | --- |
| Company | Comment |
| Google | For DMRS-less, shall we change it into “no DMRS”? DMRS-less may be similar to sparse orthogonal DMRS. |
| Ofinno | Support |
| MTK | We support study of AI receiver (replacement of one block or multiple blocks) only for uplink, as training and inference complexity/latency is high for implementation of an AI receiver at the UE. Hence, only NW-sided model needs to be studied, so suggest the following change: “For 6GR AI/ML, support the study on DMRS design at least with AI receiver (i.e., ~~UE-sided model or~~ NW-sided model) for ~~both~~ uplink ~~and downlink~~, at least including the following with potential down selection:…” |
| Sharp | Support. Can we directly say “For 6GR AI/ML, study DMRS design…”? |
| Fainity | Support |
| Lenovo | Fine with the proposal. As we probably will have SI on AI-based CSI-RS reduction which is primarily a one-sided use case, we suggest to support two-sided design for DMRS-overhear reduction as well.We note that it is better that 6G AI study items are selected to cover different flavors. |
| CATT, CICTCI | Support in general. One question: we think most companies have PDSCH/PUSCH channels in mind, should we make it clear? Or is it really intended to cover more, e.g. PDCCH/PUCCH?  |
| SK Telecom | Although we see no huge necessity on two-sided model, the proposal is fine for us.  |
| CMCC | Support. |
| NVIDIA | This is an important use case. We support the study on DM-RS overhead reduction with AI-receiver in 6GR. |

#### Conclusion 3.3.2-2:

For DMRS design with AI receiver, further study on

* Definition of each sub-use case
* Assumptions of AI receiver
* AI receiver specific evaluation assumption, methodology and KPIs
* Whether/what is the specification impact on LCM (data collection, performance monitoring, inference)

|  |  |
| --- | --- |
| Company | Comment |
| FL | How to obtain noise-free channel for labelling? May related to assumptions of AI receiver |
| Google | We think we can add another study point: CQI calculation based on DMRS design with AI receiver. The new DMRS pattern and AI receiver would have some impact on the CQI accuracy. |
| Ofinno | For further consideration on various aspects, the following change seems better as:Conclusion 3.3.2-2:For DMRS design with AI receiver, further study at least on* Definition of each sub-use case
* Assumptions of AI receiver
* AI receiver specific evaluation assumption, methodology and KPIs

Whether/what is the specification impact on LCM (data collection, performance monitoring, inference) |
| Sharp | Fine with Ofinno’s updated version |
| Lenovo | As the guideline of 6GR AI is that the non-AI solutions would not be affected. The DMRS is critical for guaranteeing data transmission performance. It is unreasonable that the DMRS transmission of non-AI receiver is restricted by the DMRS for AI receiver. For example, the DMRS for AI-receiver is designed too uniquely so that the DMRS for non-AI receiver cannot be transmitted multiplexed with it. This goes against our original intention of improving system performance.Therefore, the coexistence with DMRS for non-AI receiver should be considered. For example, how to support multiplexing transmission of UE with AI capability and UE without AI capability in downlink. **For DMRS design with AI receiver, further study on*** **Definition of each sub-use case**
* **Assumptions of AI receiver**
* **AI receiver specific evaluation assumption, methodology and KPIs**
* **Whether/what is the specification impact on LCM (data collection, performance monitoring, inference)**
* **Coexistence with DMRS for non-AI receiver.**
 |
| CATT, CICTCI | Support FL’s proposal. But this should be agreement rather than conclusion. |
| SK Telecom | Fine with Ofinno’s updated version |
| CMCC | Generally OK, but if it is UE side model, the applicable functionality report should also be included in the LCM aspects. |

#### Proposal 3.3.2-3: (low priority)

For DMRS overhead reduction with AI receiver, at least the following KPIs can be considered:

* raw BER/BLER/ Tput at given SNR or given TBS
* Overhead
* Inference complexity
* Inference latency

|  |  |
| --- | --- |
| Company | Comment |
| Google | Probably we can add channel MSE as a KPI? |
| Lenovo | Fine with this proposal. |
| CATT, CICTCI | Support. |
|  |  |
|  |  |
|  |  |

### CSI compression

#### Use case definition

|  |  |  |
| --- | --- | --- |
| (sub)-use cases | Model location | Supported companies |
| CSI compression(a) Joint CE/with low RS density +CSI compression 2, 4, 6,7, 8(b) CSI with SRS 1,2,5,9(c) Low UE complexity 1,3,9(d) Joint time prediction 4,10(e) Eigenvector vs explicit channel 1,2(f) for HBF 11 vivo2 ZTE 3 Samsung4 BJTU5 LGE\*6 NVIDIA \*7 Panasonic \*8 NEC\*9 Qualcomm 10 BUPT\* based on 5GA separate coding only | Joint source/channel coding (JSCC) | Two-sided model | (9) vivo, ZTE, Samsung, BJTU, Lenovo, OPPO, Fujitsu, BUPT, Pengcheng(7) Spreadtrum/UNISOC\*, CATT/CICTCI\*, TCL\*, CT\*, CMCC\* Qualcomm?\*, NVIDIA\* |
| Joint source-channel coding and modulation (JSCM) | Two-sided model | (7) vivo, ZTE, Samsung, BJTU, ~~Lenovo~~, OPPO, Fujitsu, BUPT(6) CATT/CICTCI\*, Sony\*?, Qualcomm?\*, Lenovo,{Indian Institute of Tech (M), IIT Kanpur}\* , NVIDIA\* |
| Codebook based CSI feedback with downloadable basis/basis | NW-sided model | (2) Samsung, ZTE/Sanechips(1) Qualcomm \*？ |
| Linear compression matrix  | NW-sided model | (1) Samsung, |

\* without simulation results

**16** contributions proposed to study joint source/channel coding (JSCC) and 13 contributions proposed to study joint source/channel coding and modulation (JSCM) with two-sided model. 9 and 8 contributions provided preliminary simulation results, which showed better SGCS/NMSE than 5GA study with separated source and channel coding (SSCC) with same overhead for UCI transmission and same/similar complexity for most of or all the SNR range.

**3** contributions (Samsung, ZTE/Sanechips, Qualcomm) proposed codebook-based CSI feedback with downloadable (DLable) basis/codebook, and CSI reconstruction with NW-sided model. 2 contributions (Samsung, ZTE/Sanechips) provided preliminary simulation results, which showed better SGCS/NMSE, and/or higher UPT than eType II codebook.

**1** company (Samsung) proposed to study CSI compression with linear compression matrix at UE side and CSI reconstruction with NW-sided model. The simulation results showed better SGCS and SE than eTypeII codebook with same overhead for UCI transmission for all SNR range, and slightly lower performance than JSCM with 2-sided model, wherein, the same complexity as the NW-part model for decoder but much lower complexity at UE side than UE-part model or for eTypeII.

#### Other considerations

**5** contributions proposed to consider joint channel estimation with low RS density and CSI compression, **4** contributions proposed to support SRS assisted CSI feedback, 2 companies proposed to support CSI compression and time domain prediction, 2 companies support to study on both eigenvector and explicit channel, and 1 company mentioned CSI compression for hybrid beam forming. Besides, **3** companies mentioned low UE complexity for CSI compression.

#### Proposal 3.3.3-1:

For 6GR AI/ML, support the study on AI based CSI compression (in addition to the study in 5GA), at least including the following with potential down selection:

* for two-sided model,
	+ Joint source/channel coding (JSCC)
	+ Joint source-channel coding and modulation (JSCM)
* for NW-sided model
	+ Codebook based CSI feedback with downloadable basis/codebook
	+ Linear compression matrix
* in the study, at least the following can be considered with potential down selection:
	+ both precoder matrix and channel matrix
	+ joint channel reconstruction of CSI with SRS at NW side
	+ joint channel estimation and CSI compression at UE side
	+ time domain prediction
	+ with sparse CSI-RS
	+ hybrid beamforming, if applicable
	+ low UE complexity

Note: 5GA CSI compression (separated source/channel coding, SSCC) with 2-sided model can be considered as one of benchmark for evaluation.

|  |  |
| --- | --- |
| Company | Comment |
| Google | We failed to see the necessity for the study. We cannot study so many use cases in one release. According to the experience in 5G, such two-sided model based use case is hard to be deployed, and it requires quite a lot of time for study. |
| FL | @ google, there are two subuse case for NW-sided model. And I think it is hard to do down selection in this meeting. This direction got large support. In addition, this direction allows further study with potential down selection, either within first 3 meetings or in the future.  |
| Vodafone | We would like to extend the study of CSI compression to consider the work done in Rel-18 for NES spatial/power domain adaptation, specifically for CSI sub-configuration reports for different antenna port patterns, as it can facilitate the adoption of such NES techniques. |
| Lenovo | We are generally fine with the proposal. However, on ‘low UE complexity’, seems it is a metric for evaluate benefit of a scheme and it is not of same type as other bullets. We prefer to remove it. |
| CATT, CICTCI | OK to study this use case. However, two-sided model use case is experiencing a baby-step forward and just start normative in R20 5G-A. We suggest to put more focus on most interested sub-use cases JSCC/JSCM with limited variants, not to be very spreading, thus:* in the study, at least the following can be considered with potential down selection:
	+ both precoder matrix and channel matrix
	+ joint channel reconstruction of CSI with SRS at NW side
	+ ~~joint channel estimation and CSI compression at UE side~~
	+ ~~time domain prediction~~
	+ ~~with sparse CSI-RS~~
	+ ~~hybrid beamforming, if applicable~~
	+ ~~low UE complexity~~
 |
| SK Telecom | We are quite sceptical about the necessity on two-sided model. Fine with the study on CSI compression for one-sided model. |
| CMCC | OK to further study CSI compression in 6G, but we should focus on the essential part, there are many controversial consideration points put here, it may be hard to coverage finally. We propose to delete the third bullet.And for “linear compression matrix”, it has been studied in 5G-A and also discussed in the Rel-20 CSI compression simultaneously. We can wait for more progress on Rel-20 5G-A CSI compression. So, we suggest to modify as below: Proposal 3.3.3-1:For 6GR AI/ML, support the study on AI based CSI compression (in addition to the study in 5GA), at least including the following with potential down selection:* for two-sided model,
	+ Joint source/channel coding (JSCC)
	+ Joint source-channel coding and modulation (JSCM)
* for NW-sided model
	+ Codebook based CSI feedback with downloadable basis/codebook
	+ ~~Linear compression matrix~~
* ~~in the study, at least the following can be considered with potential down selection:~~
	+ ~~both precoder matrix and channel matrix~~
	+ ~~joint channel reconstruction of CSI with SRS at NW side~~
	+ ~~joint channel estimation and CSI compression at UE side~~
	+ ~~time domain prediction~~
	+ ~~with sparse CSI-RS~~
	+ ~~hybrid beamforming, if applicable~~
	+ ~~low UE complexity~~

Note: 5GA CSI compression (separated source/channel coding, SSCC) with 2-sided model can be considered as one of benchmark for evaluation.  |

#### Conclusion 3.3.3-2:

For AI-based CSI compression, further study on

* Definition of each sub-use case
* For the evaluation assumption, methodology and KPIs, take 5GA study as the starting point and further study on necessary change
* For specification impact on LCM (data collection, performance monitoring, inference)
	+ for NW-sided model, study on whether/what is the specification impact on LCM for each corresponding sub-use case
	+ for two-sided model, take 5GA study outcome as the starting point, and study on necessary change for each corresponding sub-use case

|  |  |
| --- | --- |
| Company | Comment |
| FL | LCM may be quite clear for 2-sided model, but whether LCM is needed for NW-sided model can be further clarified. |
| Google | We failed to see the necessity for the study. We cannot study so many use cases in one release. According to the experience in 5G, such two-sided model based use case is hard to be deployed, and it requires quite a lot of time for study. |
| Lenovo | Agree. |
| CATT, CICTCI | Support. But this should be agreement rather than conclusion. |
| CMCC | Support. But if for two-sided model, the model pairing and inter-vendor collaboration should also be included in the LCM aspects. |
|  |  |

### (de-)Modulation

#### Use case definition

|  |  |  |
| --- | --- | --- |
| (sub)-use cases | Model location | Supported companies |
| (a) Constellation design with legacy receiver 1, 2, 3,5,6(b) Constellation design with AI demodulation 1,2, 5,6(c) Constellation design with end-to-end AI receiver 4, 51 ZTE/Sanechips2 vivo3 xiaomi4 Mediatek5 OPPO6 Lenovo | offline 1, 2, 3,5,6orreceiver-sided model1,2,5 ortwo-sided model4,5,6 | (4)Vivo, xiaomi, ZTE/Sanechips, Lenovo \*OPPO, MediaTek (without RS) with receiver side model(8){Tejas Network Limited, CEWiT, IIT Madras, IISC Bangalore, IIT Kanpur}\*,~~Lenovo \*~~, OPPO \*, Fujitsu\*, Spreadtrum/UNISOC \*, NEC\*, Honor\*?, Rakuten\* |

\*without simulation results

AI/ML for modulation/demodulation are widely proposed by **12** contributions. **4** contributions (Vivo, xiaomi, ZTE/Sanechips, MediaTek) provided some evaluation results, wherein **3** companies used non-AI receiver with constellation design with AI shaping, **2** companies also submit results with AI receiver (one-sided model), **1** company showed performance with trained constellation without DMRS.

#### Conclusion 3.3.4-2:

For modulation constellation design, AI/ML can be used as a design tool, where AI/ML based receiver can be an implementation choice.

|  |  |
| --- | --- |
| Company | Comment |
| FL | Constellation design with the help of AI/ML can be 3GPP engineering. AI receiver may be implementation choice. Unless LCM is needed, no need to define this as one 6GR AI use case. Please indicate if you have any additional view.  |
| Google | OK |
| MTK | We believe constellation design is not restricted to 3GPP engineering, as the NW could re-train the constellation based on a change in scenario and/or monitor the performance of the uplink AI transceiver and e.g., choose to fall back to non-AI transceiver. Thus, LCM is needed, and this should be classified as a 6GR AI use case. |
| Lenovo | We believe there will be spec impact especially for two-sided model. Also, if probability shaping is adopted as a valid use case, there could be some spec impact.We suggest having a proposal on study of AI-based modulation similar to the previous sections.**Proposal**: For 6GR AI/ML, support the study on modulation design, at least including the following with potential down selection:* For legacy receiver
* For AI-demodulator
* AI-based modulator/demodulator

Conclusion:For AI-based modulation, further study on* Definition of each sub-use case
* For the evaluation assumption, methodology and KPIs, take 5GA study as the starting point and further study on necessary change
* For specification impact on LCM (data collection, performance monitoring, inference)
 |
| CATT, CICTCI | OK for the case when ‘fixed constellation map is derived based on AI/ML’.  |
| NVIDIA | In our contribution, we also propose constellation learning with simulation results:*Study AI/ML for pilotless communication with constellation learning, including (1) constellation-only learning and (2) end-to-end learning of transmitter constellations and receiver algorithms*These two sub-use cases correspond to (a) Constellation design with legacy receiver and (c) Constellation design with end-to-end AI receiver in the FL summary table.Would appreciate FL to update your summary to include our proposal. |
|  |  |

### AI for PA non-linearity handling

#### Use case definition

|  |  |  |
| --- | --- | --- |
| (sub)-use cases | Model location | Supported companies |
| AI based digital post-distortion (DPoD) | Receiver-sided model | (3) Ericsson, vivo, Samsung(3) Kyocera \*, CATT/CICTCI\*, Huawei/Hisi |
| AI based-DPD | Transmiter-sided model | (1)Vivo(1)Huawei/HiSi \*, |

\* without simulation results

**6** companies proposed to study on AI/ML for PA non-linearity handling, where all of the companies proposed AI based digital post-distortion (DPoD) and 2 companies proposed AI based-DPD. **3** companies provided preliminary simulation results and show the gain in BLER/throughput gain.

#### Conclusion 3.3.5-1:

For AI/ML for PA non-linearity handling, study on the following

* Definition of each sub-use case
* Whether/what is the specification impact especially on LCM for AI/ML (data collection, performance monitoring, inference)
* Evaluation assumption, methodology and KPIs, if applicable

|  |  |
| --- | --- |
| Company | Comment |
| FL | Some clarification is needed to have better understanding on spec impact on, especially whether AI LCM is needed. Then we can further conclude whether this can be treated as RAN 1 led use case.  |
| Google | In our view, this should be studied by RAN4 instead of RAN1.  |
| FL  | The intentions is to let’s check whether something RAN 1 needs to do, before agreeing the study.  |
| Vodafone | Support to study, but it is not clear if this enhancement is to be done at the UE or the base station or both. If it is to be done at the base station, studying the impacts from not having all UEs in coverage of the base supporting this feature is necessary. |
| Lenovo | Better to study whether this case is led by RAN1 and RAN4. |
| CATT, CICTCI | OK. This should be agreement rather than conclusion.Also, ‘metric’ seems missing from the last bullet:* Evaluation assumption, methodology, metric and KPIs, if applicable

One last question is that, why ‘if applicable’ is added? Is there anything in this bullet not applicable in any case? |

### Others use cases with evaluation results

|  |  |  |  |
| --- | --- | --- | --- |
| Index  | Use cases | Model Location | Supported companies |
| 1) | Joint modulation and precoding  | 2-sided model | (2)ZTE/Sanechips, OPPO, (1)NEC\* |
| 2） | AI for waveform | Transmitter-sided  | (1)Vivo, (1)Boost\* |
| 2-sided model | (2)Vivo, Samsung |
| 3） | SRS overhead reduction | NW-sided model | (1) vivo, (6) Spreadtrum/UNISOC \*, LGE\*, NEC\*, Sony\*, SKT\*, AT&T\* |
| 4） | JSCCM for HARQ | 2-sided model[NW-sided model?] | (1) Qualcomm(3){Indian Institute of Tech (M), IIT Kanpur}\*, Honor\*？Sony\*？, |
| 5） | AI based UL precoding  | 2-sided model | (1)Vivo, (3)ZTE/Sanechips \*, LGE\*, Fujistu\* |
| 6） | Power control/Path loss production  | NW-sided model? | (1)Nokia, (2)Google \*, Sharp\* |
| 7） | AI/ML-based interference prediction | UE-sided model | (1)Vivo, (2)NVIDIA \*, Boost\* |
| 8） | AI for DCI (a)prior information aided DCI decoding(b)DCI information lossless compression | (a)UE-sided model(b)2-sided model | (1)CMCC(1)Rakuten\* |
| 9） | Token Communication | ? | (1) Huawei/Hisi |
| 10） | AI-based PRACH receiver | NW-sided model | (1) Ofinno |
| 11） | LLM-Based Prediction of Measurement Events  | ? | (1)BJTU |

#### Questions 3.3.6:

1) For proponent, please update some clarification, especially on the assumptions on the model location in Table 1

2) Please provide your support/concern into the following table 1. (if any of your view in the Tdoc missed, please update both Table 1 and previous Table)

3) Any additional comment, please fill in table 2.

**Table 1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index  | Use cases | Model Location | Supported companies | Concerns?  |
| 1) | Joint modulation and precoding  | 2-sided model | (2)ZTE/Sanechips, OPPO, (1)NEC\* |  |
| 2） | AI for waveform | Transmitter-sided  | (1)Vivo, (1)Boost\* |  |
| 2-sided model | (2)Vivo, Samsung |  |
| 3） | SRS overhead reduction | NW-sided model | (1) vivo, (6) Spreadtrum/UNISOC \*, LGE\*, NEC\*, Sony\*, SKT\*, AT&T\* | [NVIDIA] We support study SRS overhead reduction |
| 4） | JSCCM for HARQ | 2-sided model[NW-sided model?] | (1)Qualcomm(3){Indian Institute of Tech (M), IIT Kanpur}\*, Honor\*？Sony\*？, |  |
| 5） | AI based UL precoding  | 2-sided model | (1)Vivo, (3)ZTE/Sanechips \*, LGE\*, Fujistu\* |  |
| 6） | Power control/Path loss production  | NW-sided model? | (1)Nokia, (2)Google \*, Sharp\* | [Sharp]: for OLPC, we understand UE-sided model to obtain the pathloss/parameters in calculation of uplink power is needed. |
| 7） | AI/ML-based interference prediction | UE-sided model | (1)Vivo, (2)NVIDIA \*, Boost\* |  |
| 8） | AI for DCI (a)prior information aided DCI decoding(b)DCI information lossless compression | (a)UE-sided model(b)2-sided model | (1)CMCC(1)Rakuten\* |  |
| 9） | Token Communication | ? | (1)Huawei/Hisi |  |
| 10） | AI-based PRACH receiver | NW-sided model | (1) Ofinno |  |
| 11） | LLM-Based Prediction of Measurement Events  | ? | (1)BJTU |  |

**Table 2 for additional comments, if any**

|  |  |
| --- | --- |
| Company | Comment |
| CMCC | 1. For AI/ML-based DCI enhancement

(a)prior information aided DCI decoding at UE side: The AI/ML-based DCI prediction model could be used to provide the decoder with more prior information and improve the decoding performance. Simulation results show the AI/ML DCI decoder can achieve >5 dB improvement at BLER@1% and ~1.5 dB at BLER@0.1% compared to the baseline1. For AI/ML-based DCI enhancement

(b)DCI information lossless compression: A same DCI prediction model is used in NW and UE, which can be achieved by model transfer. Simulation results using field data show significant DCI overhead reduction benefits: 88.7% of cases achieve 87.5% overhead reduction by compressing the original 48-bit payload with 24-bit CRC to a 3-bit Error Pattern Index with 6-bit CRC. The aggregate overhead reduction is 77.6%. |
|  |  |
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|  |  |
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### Other proposed use cases without simulation results

|  |  |  |  |
| --- | --- | --- | --- |
| Index | (sub)-use cases | Model location | Proposed by companies |
|  | AI for link adaptation /MCS selection | NW-sided model  | NVIDIA \*Lekha \*Sharp\* |
|  | AI for NES | ? | CATT/CICTCI\*, LGE\*, ETRI \*, Vodafone\* {CEWiT, Tejas Network}\* |
|  | AI based ISAC | ? | Spreadtrum/UNISOC \*, Panasonic \*. Boost\*, Deepsig\*, {CEWiT, Tejas Network}\* |
|  | AI/ML-enabled RAN Digital Twin | ? | Huawei/Hisi \* |
|  | Anomaly detection and fault prediction | ?  | NVIDIA \* |
|  | AI based traffic prediction AI based DRX、DRX | One-sided? | Vivo\*, ZTE/Sanechips\*，Honor\*, AT&T\*, {CEWiT, Tejas Network}\* |
|  | AI/ML based channel coding | Receiver-sided model, implementation based2-sided model?  | {Tejas Network Limited, CEWiT, IIT Madras, IISC Bangalore, IIT Kanpur}\*, Boost \* |
|  | Scrambler/ descramblerorinterleaver, de-interleaver | auto-decoder or a joint two-sided model, | {Tejas Network Limited, CEWiT, IIT Madras, IISC Bangalore, IIT Kanpur}\* |
|  | AI-powered adaptive frame structure | NW-sided model?2-sided model?  | Lekha \* |
|  | AI based HARQ | ? | Boost\*, NEC\* |
|  | Spectrum Sensing | ? | Deepsig\* |

#### Comments from FL:

Please provide evaluation results to tigger the discussion on the above use cases. No discussion in this meeting. If anything missed, please let me know offline.

## Contact information

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