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1 Introduction

MIMO technology is fundamental to NR networks. Rel-17 WID 'Further enhancements on MIMO for NR' [1] extends specification supports in enhancements on multi-beam operations, multi-TRP, SRS, CSI measurement and reporting. While Rel-17 FeMIMO is in progress, companies start to share their views on MIMO in Rel-18 [3]-[19].

Based on those inputs and our own understanding, this paper provides classification of potential MIMO enhancement features in Rel-18, namely, enhancements on UL MIMO, beam management, multi-TRP/panel, CSI measurement and report, and artificial intelligence/machine learning (AI/ML)-enabled MIMO. In Section 2, technologies in each category of enhancement features are discussed in each subsection, respectively. And Section 3 summaries our considerations on MIMO enhancements in Rel-18.

2 Discussion

2.1 UL MIMO enhancements

New applications like XR and video surveillance motivate studies towards UL-centric or UL-heavy scenarios. Comparing with DL MIMO, there is still gaps to fill in UL, in terms of coverage, capacity, etc. In Rel-17, SRS capacity, coverage and flexibility is improved, but it is more intended for channel acquisition other than data transmission.

The following table summarizes companies' views on potential UL MIMO enhancements in Rel-18.

Table 1 Companies' views on UL MIMO enhancements in Rel-18

Company	Tdoc	Input
China Telecom	RP-210528	Capacity enhancement • Higher order modulation and Higher order MIMO. • DMRS enhancement. • Flexible spectrum allocation, e.g. dynamic FDD, more UL carriers than DL carriers, flexible association of DL and UL carriers.
ZTE, Sanechips	RP-210616	• UL spatial multiplexing/layer mapping – More MIMO antennas/layers e.g. 8 layers – Layer to codeword mapping (support 2 MCS or modulation orders for 2-4 layers) – Frequency selective precoding • Uplink beam management – Enhance the case where beam correspondence cannot be utilized e.g. more UL carriers than DL carrier – UL simultaneous multi-panel transmission
Huawei, HiSilicon	RP-210661	• UL high-resolution precoding: UL precoding enhancement on the sub-band precoding, high-resolution codebooks and more antennas (4T, 8T). • DMRS enhancements: Number of DMRS ports extension along with DMRS interference reduction for more parallel UL. • Enhanced power control by multi-TRP: UL Power control by jointly considering multiple TRPs in case of multi-TRP scenario
CATT	RP-210670	• Study UL frequency-selective precoding to accommodate wider system bandwidth in FR1/FR2. • Study higher-order UL MIMO to 8 layers to bridge the gap between DL and UL spectral efficiency, in FR1/FR2. • Study multi-panel joint transmission for spectral efficiency, coverage and blockage mitigation in FR2.

Ericsson	R1-2103668	• Proposal 1 Specify faster than RRC switching of UL waveform and study, if beneficial specify, introduction of multi-layer PUSCH for DFT-S-OFDM. • Proposal 2 Specify DMRS capacity enhancements for Type 1 DMRS to at least double the number of orthogonal DMRS ports in one OFDM symbol

Technical features attracting the most attention are enabling higher order MIMO (e.g., up to 8 layers) and sub-band precoding in UL. Both features are targeting at a higher UL data rate to meet stringent requirements for UL-heavy applications. On the other hand, they both bring extra complexities in gNB and UE implementation, as well as the increased payload size especially in L1/L2 control signaling and possibly in reporting content. It may also need to distinguish FR1 and FR2 for UL MIMO enhancement in Rel-18, for example, in FR2 it is quite rare that 8 layers of transmissions can be supported considering LOS-dominant mmwave propagation condition, and application of narrow beam would level the frequency selectivity too.

To sum up, the following table lists features with interested companies and simple analysis of pros and cons.

Table 2 Potential UL MIMO enhancement features in Rel-18

features	Interested companies	Pros	Cons
UL Higher order MIMO	China Telecom, ZTE, Sanechips, Huawei, HiSilicon, CATT, Ericsson (for DFT-s-OFDM)	• Higher UL capacity	• Increased gNB and UE complexity • Increased UE power consumption
UL Sub-band precoding	China Telecom, ZTE, Sanechips, Huawei, HiSilicon, CATT	• Higher UL capacity • Robustness against frequency selectivity	• Increased gNB and UE complexity • Increased DCI payload size
Increased number of UL DMRS ports	China Telecom, Huawei, HiSilicon, Ericsson	• Higher MU UL capacity • Scheduling flexibility	• Increased gNB and UE complexity • Increased UL interference
Higher resolution UL codebooks	Huawei, HiSilicon	• Higher UL capacity	• Increased gNB and UE complexity • Increased DCI payload size

Based on above discussions, we have the following proposal for UL MIMO enhancements.

Proposal 1: In Rel-18, specify features to increase UL capacity by supporting up to 8 layers UL transmission and UL sub-band precoding in FR1.

2.2 Beam management enhancements

Enhancements on multi-beam operations in Rel-17 include the introduction of common beam for data/control transmission/reception for DL/UL and unified TCI framework to support higher L1/L2-centric intra- and inter-cell mobility and/or a larger number of configured TCI states. Meanwhile, uplink beam selection for UEs equipped with multiple panels is considered for UL coverage loss mitigation due to MPE.

Along with growing deployments of FR2 networks, companies express their views on potential enhancements for multi-beam operations, as summarized in the following table.

Table 3 Companies' views on beam management enhancements in Rel-18

Company	Tdoc	Input
Samsung	RP-210293	• Area #3: incomplete support of multi-beam and multi-TRP/panel especially in FR2 – Rel-17 unified TCI framework can be extended to support more efficient intra-and inter-cell beam management including beam tracking (predictive), refinement, as well as positioning-assisted and UE-initiated beam management – Multi-TRP/multi-panel support in Rel-17 is limited to only synchronous inter-TRP/panel and up to 2-panel reception. It can be extended to support asynchronous scenario and more than 2 panels in Rel-18.
vivo	RP-210324	• Observation: Degraded mobility performance and high UE power consumption could be challenge for FR2 deployment or UDN. • Proposal: Potential solutions for degraded mobility performance and high UE power consumption should be studied for FR2 deployment or UDN.
China Telecom	RP-210528	• Ensure higher mobility performance in current handover procedures, such as: – Ensure high reliability and 0ms interruption during HO procedure;

		– Enhance robustness of NG-based handover… • Reduce data interruption for mobility procedures in MRDC scenario, such as: – Reduce data interruption for inter-MN handover without SN change procedure; – Ensure 0ms interruption for PScell change procedure… • Optimize data forwarding procedure to enhance data continuity and reduce BS load. • Reduce UE power consumption or network signaling during mobility procedure. • Other aspects related to mobility enhancement, such as fast failure detection and recovery.
China Unicom	RP-210532	• FR2 mobility issues – Service continuity in mobility scenarios – Frequently handover in mobility scenarios
ZTE, Sanechips	RP-210616	• Uplink beam management – Enhance the case where beam correspondence cannot be utilized e.g. more UL carriers than DL carrier – UL simultaneous multi-panel transmission
ZTE, Sanechips	RP-210620	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) in a Rel-18 WI. • Study and evaluate the feasibility and potential system level gain on predictable mobility for beam management based on the identified scenario(s). • Evaluate and, if needed, specify beam-management-related enhancements for predictable mobility, involving beam measurement, beam report and beam indication.
CATT	RP-210670	• Study UL frequency-selective precoding to accommodate wider system bandwidth in FR1/FR2. • Study higher-order UL MIMO to 8 layers to bridge the gap between DL and UL spectral efficiency, in FR1/FR2. • Study multi-panel joint transmission for spectral efficiency, coverage and blockage mitigation in FR2.
Lenovo	RP-210673	• to study beam/CSI enhancements for use-cases & deployment scenarios where the inherent characteristics (of these scenarios) can be leveraged to reduce the need for frequent beam/CSI measurements, reporting & indication/update – UE's movement and/or location characteristics, for example deterministic/predicted/periodic/circular range of movement – Multiple UEs follow similar movement and/or path • to study methods for the identified scenarios to facilitate low complexity, low overhead beam-management and CSI framework for achieving non-redundant and less frequent beam/CSI measurements/reporting
Ericsson	R1-2103668	• Proposal 9 Investigate, and if necessary, specify enhancement to L1/L2-centric inter-cell mobility to increase the areas over which the functionality is appliable. • Proposal 10 Investigate and if necessary, specify enhancements to L1/L2-centric mobility that increases the flexibility and reduces the need for RRC pre-configuration of measurement targets.

It can be seen that proposals above focus mainly on two technical features, STxMP (simultaneous transmission across multiple panels) and improved efficiency of beam management.

STxMP could be closely related to standard efforts on uplink beam selection for UE with multiple panels in Rel-17 and its counterpart in DL, i.e., simultaneous multi-TRP transmission with multi-panel reception, which is being discussed in Rel-17 too. It is believed that STxMP can be used to boost UL data rate and to provide robustness against blockage particularly in FR2. On the other hand, it is also argued that challenges on the UE implementations to simultaneously transmitting with multiple panels, as well as increased UE power consumption, may undermine the potential benefits of STxMP.

Beam management efficiency and L1/L2 intra- and inter-cell mobility efficiency has been constantly improved since its introduction in NR. However, the overhead and latency is still not satisfactory, especially for UE moving at a higher speed. It is mainly due to the RS and signaling overhead to train the beams from a large beam set and RRC involved (re)configurations. In particular, positioning-assisted beam management is proposed, as well as predictive beam management if considering a predictive/fixed trajectory of UE movement. It can be expected that based on positioning information and trajectory information, gNB would be able to transmit less frequently the reconfiguration/indication signaling, to configure a much smaller set of reference signals for beam management, and UE would be able to do less measurements and reporting too. However, this method may fail to provide the promised gain in scenarios other than those limited cases with LOS and quasi-static channel conditions. Meanwhile, it also raises questions on how to timely collect the positioning and/or trajectory information.

For ease of read, the following table provide a summary of features with interested companies and simple analysis of pros and cons.

Table 4 Potential beam management enhancement features in Rel-18

features	Interested companies	Pros	Cons
STxMP (simultaneous transmission across multiple panels)	ZTE, Sanechips, CATT,	• Higher UL capacity • Robustness against blockage	• Increased UE complexity • Increased UE power consumption
Improved efficiency of beam management	Samsung, ZTE, Sanechips, Lenovo	• Faster beam selection and tracking • Less BM RS measurement and report • Less control signalling • Adaptive configurations	• Suitable scenarios may be limited • Prediction accuracy • Extra support on the collection of position and/or trajectory information
Enhancements on L1/L2-centric mobility	Vivo, China Telecom China Unicom, ZTE, Sanechips, Ericsson	• Reduced latency	• Increased UE complexity • Increased gNB complexity
Enhancement when beam correspondence cannot be utilized	ZTE, Sanechips	• Special case with more UL CCs than DL CCs	• Not sure about gain over current UL beam sweeping method

Based on above discussions, we have the following proposal for beam management enhancements.

Proposal 2: In Rel-18, specify enhancements for simultaneous transmission across multiple UE panels, and identify and specify features to enhance beam management to support more efficient L1/L2 intra- and inter-cell mobility for moving UE.

2.3 Multi-TRP/panel enhancements

Multi-TRP/panel enhancements in Rel-17 deal with reliability and robustness for PDCCH/PUSCH/PUCCH, inter-cell multi-TRP operations, beam management related enhancements for simultaneous multi-TRP transmission with multi-panel reception, and enhanced support in HST-SFN scenarios.

The following table summarizes companies' views on potential enhancements for multi-TRP/panel.

Table 5 Companies' views on Multi-TRP/panel enhancements in Rel-18

Company	Tdoc	Input
Samsung	RP-210293	• Area #1: distributed MIMO in low band – Low band (<1GHz) helps to reach wider geographical areas in large cities and suburban. Due to the large wave length in low band, utilizing a large number of antennas may not be feasible in practice. – In the current NR spec, the support of distributed MIMO is lacking especially in terms of the geographically distributed antenna panels and having different number of antenna elements for different panels • Area #3: incomplete support of multi-beam and multi-TRP/panel especially in FR2 – Rel-17 unified TCI framework can be extended to support more efficient intra-and inter-cell beam management including beam tracking (predictive), refinement, as well as positioning-assisted and UE-initiated beam management – Multi-TRP/multi-panel support in Rel-17 is limited to only synchronous inter-TRP/panel and up to 2-panel reception. It can be extended to support asynchronous scenario and more than 2 panels in Rel-18.
Huawei, HiSilicon	RP-210661	• UL high-resolution precoding: UL precoding enhancement on the sub-band precoding, high-resolution codebooks and more antennas (4T, 8T). • DMRS enhancements: Number of DMRS ports extension along with DMRS interference reduction for more parallel UL. • Enhanced power control by multi-TRP: UL Power control by jointly considering multiple TRPs in case of multi-TRP scenario
China Telecom	RP-210528	• MIMO – Enhancement for CSI measurement and reporting – multi-TRP/panel enhancement
Ericsson	R1-2103668	• Proposal 5 Specify mixed mode single-DCI and multi-DCI multi-TRP to support high reliability with improved spectral efficiency for intra-UE multiplexing. • Proposal 6 Specify Multi-TRP CSI enhancements for multi-TRP URLLC schemes.

		• Proposal 8 Specify support for a wide bandwidth scheduled PDSCH without a QCL to TRS to significantly simplify multi-TRP operation with dynamic point selection.

It can be observed for multi-TRP/panel enhancements there exist diverse interests in different frequency ranges. In FR1, especially for low bands below 1GHz, geographically distributed antenna panels are equipped to support massive MIMO. In this case, whether additional enhancement is needed greatly depends on whether current multi-panel codebook can work with the considerations of physical separation of those gNB panels.

In FR2, it is still required to improve the efficiency, as discussed in beam management session. And the enhancements are closely related to beam management enhancements too. For example, if STxMP can be enabled, specification efforts would be needed to support simultaneous transmission to multiple TRPs in FR2. And if predictive beam management can be supported, MTRP operations based on predictive beams would be a natural choice to extend the robustness and reliability.

To summarize, the following table provide simple discussions on each feature.

Table 6 Potential Multi-TRP/panel enhancement features in Rel-18

features	Interested companies	Pros	Cons
Support geographically distributed antenna panels	Samsung	• support massive MIMO in low band	• Current multi-panel codebook may work
Improved efficiency of MTRP	Samsung, Ericsson	• Faster beam selection and tracking • Less BM RS measurement and report • Less control signalling • Adaptive configurations	• Suitable scenarios may be limited • Prediction accuracy • Extra support on the collection of position and/or trajectory information
Asynchronous inter-TRP/panel operations	Samsung	• relaxed requirement of MTRP operation	• Maybe not typical deployment • Increased UE complexity
Support more than 2-panel reception	Samsung	• Higher DL capacity and robustness	• Increased UE complexity • Increased UE power consumption
UL MTRP Power control enhancement	Huawei, HiSilicon	• Less UL interference	• Two sets of power control parameters for PUSCH can already be simultaneously activated for MTRP in Rel-17
No TRS for MTRP DPS	Ericsson	• Less reconfiguration signalling for DPS	• May degrade PDSCH demodulation performance

Based on above discussions, we have the following proposal for Multi-TRP/panel enhancements.

Proposal 3: In Rel-18, evaluate and, if needed, specify multi-panel codebook enhancements for support geographically distributed antenna panels in FR1, and specify features to facilitate more efficient MTRP operation in FR2 along with the design of Rel-18 enhancements for beam management.

2.4 CSI enhancements

Enhancements on CSI measurement and reporting in Rel-17 mainly include better support of CSI reporting for DL multi-TRP/panel NCJT transmissions and Type II port selection codebook enhancement to explore FR1 FDD partial reciprocity. To better support channel acquisition especially in high mobility scenarios, companies shared their views on potential enhancements for CSI measurement and reporting in Rel-18, as summarized in the table below.

Table 7 Companies' views on CSI enhancements in Rel-18

Company	Tdoc	Input
Samsung	RP-210293	• Area #2: high resolution and overhead reduction of CSI – DFT-based codebook in NR can be limited in providing more precise CSI feedback. Different approaches need to be considered, e.g., explicit feedback of eigenvectors and progressively-refined CSI reporting, for further enhancing MU-MIMO performance. – For high-speed UEs, accurate time-domain channel tracking requires frequent CSI update. Doppler-domain CSI compression can facilitate time-domain overhead reduction.
China Telecom	RP-210528	• MIMO – Enhancement for CSI measurement and reporting

		– multi-TRP/panel enhancement
Fraunhofer IIS, Fraunhofer HHI	RP-210533	Observation 1: A performance loss of up to 30% is observed for a moving UE at 30 km/h. Observation 2: In UE mobility scenarios, the following is observed: - Doppler spread of the channel can be very large, - Large performance loss is obtained when channel variations are fast and CSI measurement and update rate is too small, - Very high CSI (CQI and/or PMI) update rate is required to handle fast channel variations even for UEs with low-mobility, - Increased use of DL resources due to frequent CQI/PMI measurements, - Increased use of UL resources due to high CQI/PMI feedback rate (increased CSI feedback overhead), and - Increased UE battery consumption. Observation 3: The current R16/upcoming R17 CSI (CQI/PMI) report depends on the fast fading channel variations. A high CSI (CQI and/or PMI) update rate is required in UE-mobility scenarios, where the channel variations are fast and the channel coherence time is small. Observation 4: To drastically reduce the CSI feedback rate in UE-moving scenarios, the CSI report should contain Doppler spectrum-related information associated with the multipath propagation channel and UE motion. Observation 5: When the CSI report contains a Doppler spectrum-related information, the gNB can perform precoding in the time/Doppler-domain to compensate for the fast-fading variations of the channel, and - Less DL resources are required for CQI/PMI measurements, - Less UL resources are required for CSI reporting, - UE complexity and UE battery consumption is reduced, and - Better performance is expected in channels with fast fading. Proposal 1: Specify CSI enhancements for UE mobility.
Lenovo	RP-210673	• to study beam/CSI enhancements for use-cases & deployment scenarios where the inherent characteristics (of these scenarios) can be leveraged to reduce the need for frequent beam/CSI measurements, reporting & indication/update – UE's movement and/or location characteristics, for example deterministic/predicted/periodic/circular range of movement – Multiple UEs follow similar movement and/or path • to study methods for the identified scenarios to facilitate low complexity, low overhead beam-management and CSI framework for achieving non-redundant and less frequent beam/CSI measurements/reporting
Ericsson	R1-2103668	• Proposal 3 Study, and if beneficial, specify post-decoding CSI feedback for PDSCH. • Proposal 4 Specify early CSI reporting in Msg3 triggered by the already existing CSI request bit in the RAR grant, both for contention-based and non-contention-based random access. • Proposal 6 Specify Multi-TRP CSI enhancements for multi-TRP URLLC schemes. • Proposal 7 Specify flexible URLLC CSI triggering even when a 'High Latency' CSI is being processed.

It can be observed that the major concern with current CSI framework is overhead due to frequent measurements and reporting, especially considering UE movement in a high mobility scenario. To address this concern, companies propose to utilize Doppler domain information to compress CSI or to reduce the report occurrences because it is shown that channel variation in Doppler domain is slower than that in time domain. Furthermore, it is suggested that UE movement and location information can be used to avoid frequent CSI measurement and reporting. However, performance of channel estimation with Doppler domain processing may degrade in complicated NLOS scenarios, as well as the performance of any method trying to couple location and exact CSI. And it would certainly introduce higher complexities to estimate both in time domain and Doppler domain.

For ease of read, the following table provide a summary of features with interested companies and simple analysis of pros and cons.

Table 8 Potential CSI enhancement features in Rel-18

features	Interested companies	Pros	Cons
Improved efficiency of CSI measurement and report	Samsung, Fraunhofer IIS, Fraunhofer HHI, Lenovo, Ericsson	• Less frequent measurement and report in high-mobility scenario • Less signalling	• Suitable scenarios may be limited • Increased UE complexity

		• Faster feedback	• Extra support on the collection of position and/or trajectory information
Higher resolution with non DFT codebook	Samsung	• Precise channel information	• increased UE complexity • increased payload of CSI report
Post-decoding CSI feedback for PDSCH	Ericsson	• Faster and more accurate OLLA	• DMRS based CQI may not be stable

Based on above discussions, we have the following proposal for CSI enhancements.

Proposal 4: In Rel-18, identify and specify features to facilitate more efficient CSI management and reporting for fast moving UE.

2.5 Introduction of AI/ML in MIMO

RAN intelligence is now being studied in RAN3 SI 'Study on enhancement for data collection for NR and ENDC', which focuses on AI/ML functionality and corresponding types of inputs/outputs [2]. Some examples of identified use cases are energy saving, load balancing, mobility management, coverage optimization, etc. A strong interest is also observed in bringing AI/ML into physical layer. More specifically, MIMO technology embracing the power of AI/ML is believed to have better performance and companies' proposals on introduction of AI/ML in MIMO are summarized in the following table.

Table 9 Companies' views on AI/ML-enabled MIMO in Rel-18

Company	Tdoc	Input
vivo	RP-210321	• AI/ML based technology is data driven, with its livelihood lying in evolution based on data from practical engineering problems; – 3GPP provides the best platform for such data driven evolution; • Rel 18 is an important release that may put the basis for future two or more releases; • Study of potential areas for AI/ML application on air interface should be started in Rel 18; – AI/ML+RS: DMRS channel estimation – AI/ML+RS: CSI-RS overhead reduction – AI/ML+CSI: CSI feedback – AI/ML+Positioning – AI/ML+Mobility : Fast intra cell beam selection – AI/ML+Mobility : Fast inter cell beam selection – AI/ML+Mobility : Channel prediction
ZTE, Sanechips	RP-210614	Proposal: • Follow-up normative work should be setup in Rel-18 considering the popular AI use cases identified in RAN3 focusing higher layer impacts. • Study on AI applications in physical layer can be considered to start the AI standardization work on PHY for 5G Advanced. Potential enhancements for AI applications in PHY aspects • Potential enhancements for Beam Management – Beam tracking for predictable mobility – Enhancements on beam reporting, beam activation and beam indication – Beam selection based on varying traffic type and UE distribution • Enhancements for AI on CSI feedback/prediction – CSI/interference prediction in time/frequency domain – Parameterized/compressed CSI feedback – Reduction on RS overhead and measurement – Adaptive antenna/beam group selection – Downloadable codebook • Potential enhancements for AI on channel prediction for demodulation – RS overhead reduction by sharing DMRS across frequency/time domain or by using SRS for demodulation – Required signalling to assist or align the channel prediction between gNB and UE • Potential enhancements for AI on MCS selection – Feed back channel/interference information to assist outer loop link adaptation for MCS selection

		– UL MCS selection by UE • Potential enhancements for AI on resource allocation – Multi-slot resource allocation Proposal: Consider the above potential enhancements for standardization on AI in PHY aspects.
InterDigital	RP-210672	Possible PHY Layer Enhancements for NR • MIMO CSI feedback – CSI feedback compression – CSI prediction • RS overhead reduction – Adaptive RS density based on UE AI processing capability • Mobility/Beam management optimizations – Optimized beam measurements – Predictive beam/mobility management – Enhanced beam failure recovery • Positioning enhancements – Improved accuracy in NLOS – Robustness in presence of synchronization errors Study on evaluation of AI-based PHY enhancements • Identify use case and deployment scenarios. • Study performance evaluation methodology for AI based solutions. – Study assumptions on the AI models, algorithms, training aspects and data sets. • Study standardization impacts for selected use cases for which AI methods are shown to be beneficial. • Study characterization and signaling of UE capabilities w.r.t AI processing
CATT	RP-210719	Convergence between 5G RAN and AI There has been growing interests in convergence between 5G RAN and AI. A RAN3-led SI is on-going in this area, where some key use cases have been highlighted, i.e., energy saving, mobility management, traffic steering, and load balance. It is foreseen that normative work is possible based on progress of these studies. For the other possible use cases, such as QoE management, network slice management, etc., we believe more studies can be carried out to better understand the possible benefit as well as impact to RAN. Besides, there are also good potential for AI in physical layer aspects. One example is channel modelling and CSI feedback in MIMO system. These may also be studied separately than the higher layer aspects as the expertise required is quite different. To summarize, convergence between 5G RAN and AI is a promising technical area, which pave the way for 5G evolution and an even more intelligent next generation network. The study and work scope in Rel-18 can therefore be discussed and decided on a case by case basis.
OPPO	RP-210256	To have a Rel-18 study item: • To have a common understanding of AI/ML algorithm frame work without touching algorithm itself: – For example which ML/AI category or architecture is applied for which use cases – The potential impact on hardware and software e.g. computing power, storage capability etc. • To take principle introduced in FS_NR_ENDC_data_collect for network optimization into account; • To focus on link level use cases including: – Technical justification, feasibility and potential performance enhancement compared to benchmark of 5G network – To conclude which ones are valuable to be specified • To investigate potential standard impact case by case including but not limited to: – Output and input of ML/AI algorithm – Information exchanged over Uu and/or network interface Note: It is assumed both network node and UE can be ML/AI model training or inference host
Lenovo, Motorola Mobility	RP-210447	For Rel-18, the potential study and working area regarding intelligence in RAN includes • Continue to study to use AI technology to improve 5G network performance for more use cases, e.g. for channel estimation, MIMO, and IAB topology management, if benefits are identified; • To study RAN evolution to support any kind of AI services besides those for network optimization; • To study RAN evolution to support distributed intelligence, which may include intelligent task segmentation, data sharing, computing offloading and learning model sharing among devices and RAN nodes for a certain AI task.

It can be observed that companies consider Rel-18 could be the right time to start the study of AI/ML-enabled MIMO, including potential use cases, performance gain and possible spec impacts. Particularly, it is believed that beam management and CSI could benefit from the application of AI/ML at least in terms of overhead and latency reduction.

Accurate prediction or inference empowered by AI/ML can be used to save resources consumed by frequent measurements and reports. For example, to enhance beam management efficiency, it is expected that gNB and UE could only exchange a subset of beam measurement results and infer the best beam choice of a larger set. Similarly, for CSI acquisition, it is expected that gNB could obtain the channel status of all antenna ports by measurement results of a small subset of ports.

On the other hand, there is always a question mark on the generalization issue of AI/ML models, which may only be able to deliver performance gain in limited and well-chosen scenarios. And it is not yet clear what additional data is required to enable AI/ML, regardless of detailed AI/ML algorithms. Therefore a study is exactly what needed to better support specifications enabling AI/ML in MIMO in further releases.

Discussions above are summarized in the next table, we have the following proposal to study AI/ML-enabled MIMO in Rel-18.

Table 10 Potential use cases of AI/ML-enabled MIMO

features	Interested companies	Pros	Cons
AI/ML-enabled CSI	Vivo, ZTE, Sanechips, InterDigital, CATT	• Lower overhead (RS, report, configurations, L1/L2 signalling, etc.)	• Suitable scenarios may be limited • Extra support on the collection of data
AI/ML-enabled Beam management	Vivo, ZTE, Sanechips, InterDigital	• Lower overhead (RS, report, configurations, L1/L2 signalling, etc.) • Lower latency	• Suitable scenarios may be limited • Extra support on the collection of data
AI/ML-enabled RS	Vivo, ZTE, Sanechips, InterDigital	• Lower RS overhead	• Suitable scenarios may be limited • Extra support on the collection of data
AI/ML-enabled L1/L2 mobility	Vivo, ZTE, Sanechips, InterDigital, CATT	• More accurate handover • Lower overhead and latency	• Suitable scenarios may be limited • Extra support on the collection of data

Proposal 5: In Rel-18, study the use cases and performance gain of AI/ML-enabled MIMO.

3 Conclusion

In this contribution, we provided our views on CSI enhancement for multi-TRP transmission, and we proposed that:

Proposal 1: In Rel-18, specify features to increase UL capacity by supporting up to 8 layers UL transmission and UL sub-band precoding in FR1.

Proposal 2: In Rel-18, specify enhancements for simultaneous transmission across multiple UE panels, and identify and specify features to enhance beam management to support more efficient L1/L2 intra- and inter-cell mobility for moving UE.

Proposal 3: In Rel-18, evaluate and, if needed, specify multi-panel codebook enhancements for support geographically distributed antenna panels in FR1, and specify features to facilitate more efficient MTRP operation in FR2 along with the design of Rel-18 enhancements for beam management.

Proposal 4: In Rel-18, identify and specify features to facilitate more efficient CSI management and reporting for fast moving UE.

Proposal 5: In Rel-18, study the use cases and performance gain of AI/ML-enabled MIMO.

4 References

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