3GPP TSG RAN Meeting #91e
Electronic Meeting, March 16-21, 2021

RP-210614

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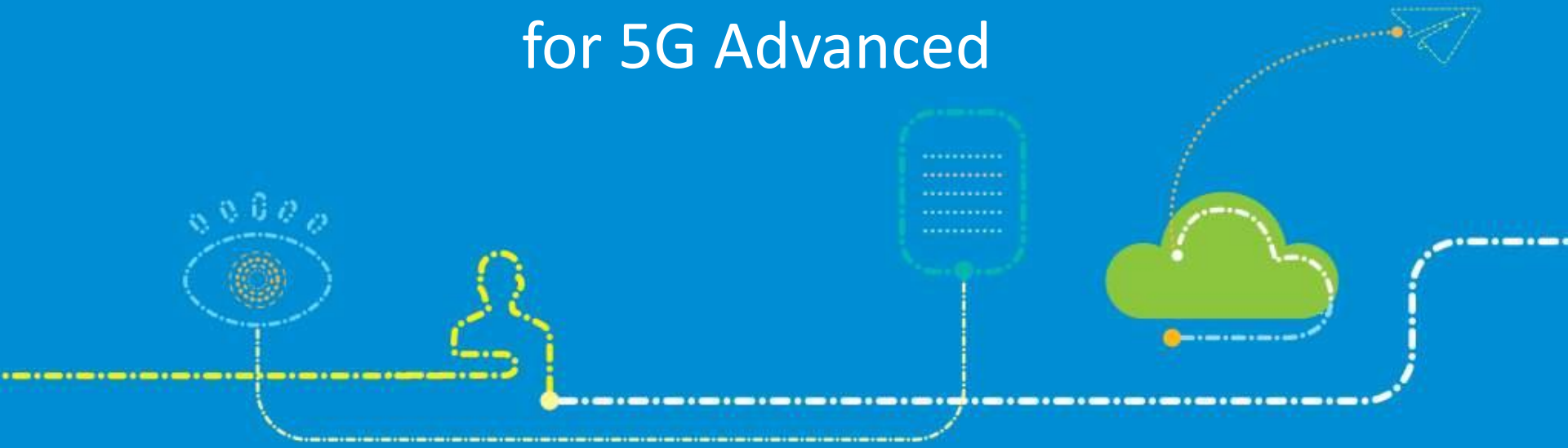
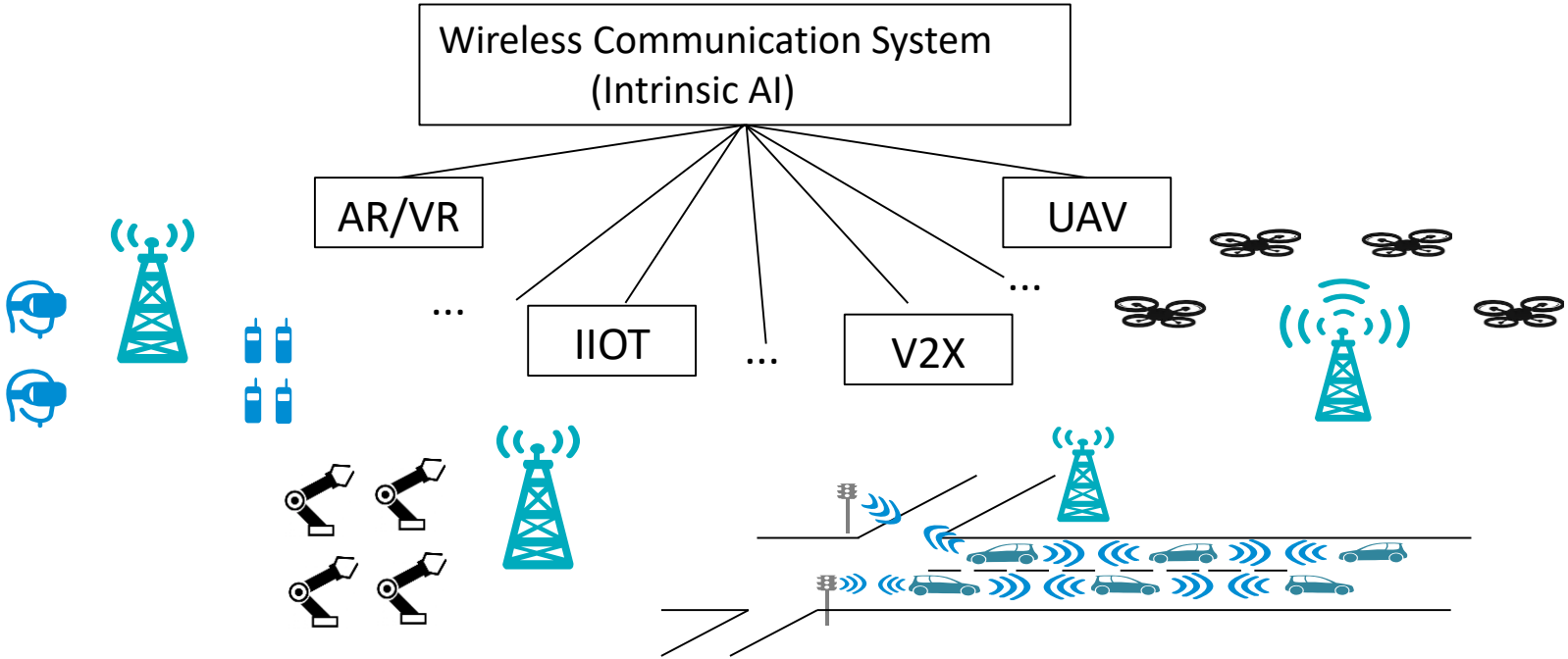
Source: ZTE, Sanechips
Agenda: 9.13

Support of Artificial Intelligence Applications for 5G Advanced



Intrinsic AI

AI is expected to be the core functionality with standard support in 5G advanced networks



- Support AI everywhere - covering massive variety of use cases and all communication layers
  - AI for 5G advanced (Designing AI to enhance communication systems)
  - 5G advanced for AI (Designing communication systems for better support of AI)

AI applications in physical layer and higher layers

New SID: Study on further enhancements for data collection (RP-201304) has been approved in RAN#88e. The main objective is:

– Study high level principles for RAN intelligence enabled by AI, the functional framework (e.g. the AI functionality and the input/output of the component for AI enabled optimization) and identify the benefits of AI enabled NG-RAN through possible use cases e.g. energy saving, load balancing, mobility management, coverage optimization, etc.

In addition, strong interests have been observed in AI applications on physical layer or air interface. We see the need of standardization for AI applications in both higher layer and physical layer aspects.

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.*

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Potential Benefits of AI standardization in PHY aspects

- AI algorithms are used in the current networks
  - However, limited applications in PHY due to complexity and lack of coordination between gNB and UE
- Enhancements (e.g. by providing assisted information) can be beneficial to achieve faster/more accurate learning.
- gNB and UE can collaborate on training and execution to reduce complexity.
- Machine learning used in physical layer has been drawn a lot of interest in recent research.
- The potential benefits are, e.g. :
  - Acquiring more accurate channel information with less CSI feedback overhead
  - RS overhead can be reduced for CSI acquisition/beam management or demodulation
  - Reduce control signalling overhead
  - More accuracy for positioning
- These potential benefits translate to better system performance e.g. in terms of throughput and reliability

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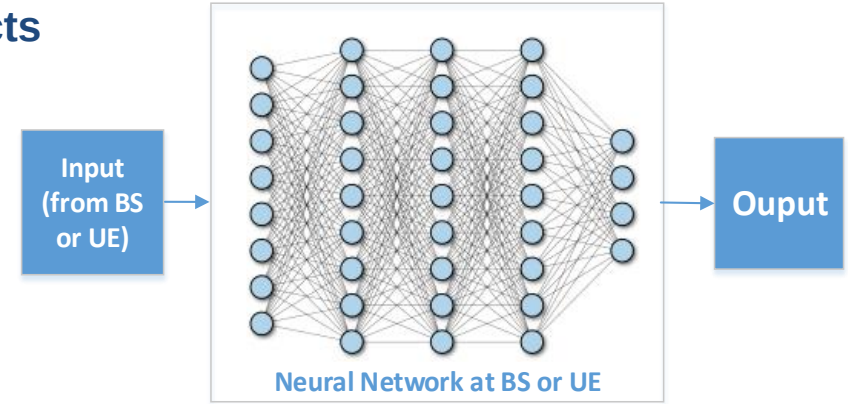
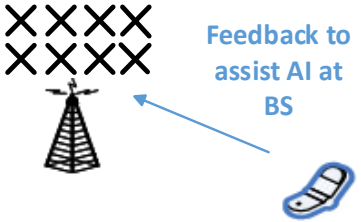
AI based 5G-Advanced Networks

Identify potential AI applications in PHY aspects

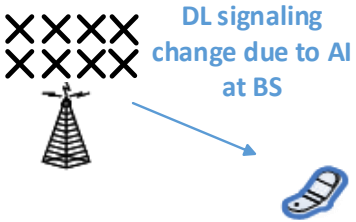
- Beam management/predictable mobility
- CSI acquisition/Link adaptation
- Positioning
- Reference Signals
- Resource allocation…



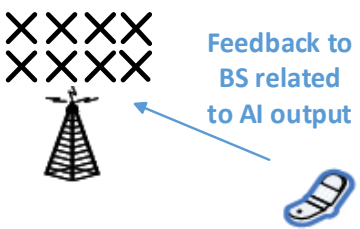
Potential standardization impacts:



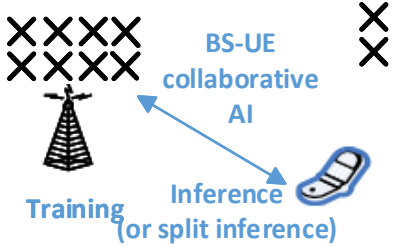
Feedback from UE helps AI training for better prediction at gNB



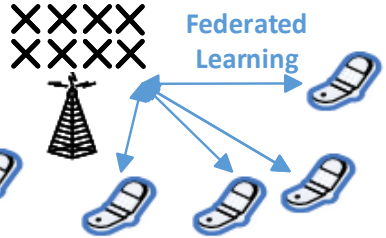
AI outcome from gNB is signaled to UE for better operation (signaling for prediction)



Feedback from UE based on output of AI prediction at UE



UE performs inference based on training result from gNB and local input. Or split inference is performed at UE & gNB.



Distributed/Federated Learning among multiple UEs

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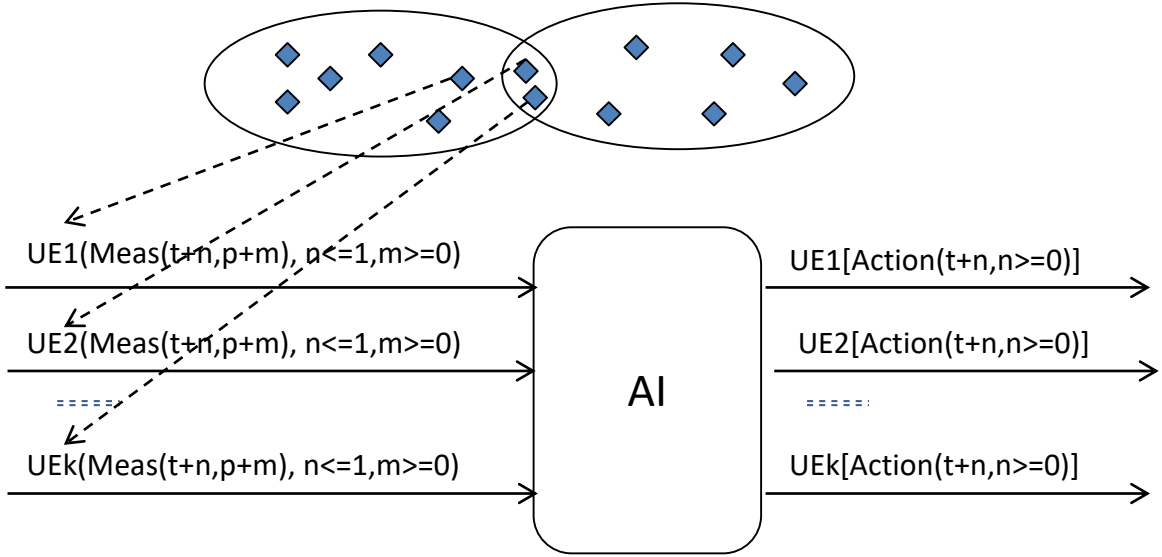
AI for Mobility and Beam Management



- AI model: Action for now(t0) or prediction for future(t1,t2...) for one UE is deduced based on measurement/event from related UEs jointly by taking their history(t-1,t-2...) and position stamp (p+m) into account. e.g. scheduling/beam tracking at gNB
- UE may predict future event/measurement (t1) by running AI algorithm based on measurements in the past (t-1,t-2). Predicted result is fed back to gNB e.g. mobility/beam prediction at UE

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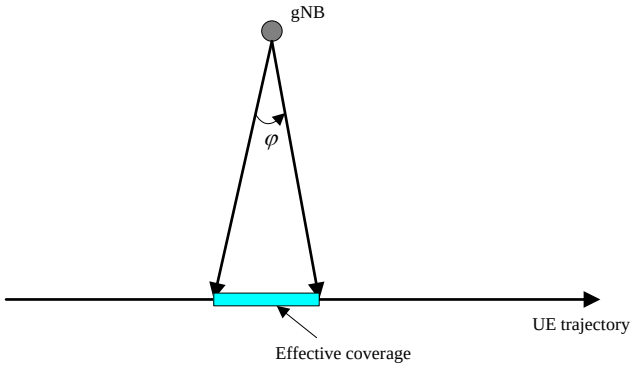
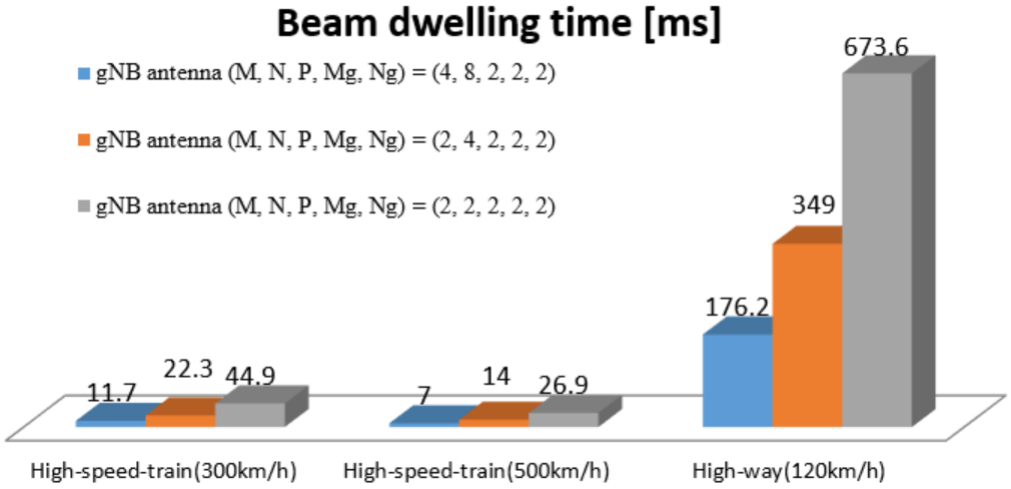
Predictable Mobility for Beam Management



Effective coverage depending on beam-width, distance and speed



- Beam dwelling time depends on multiple factors including UE speed, distance between gNB and UE and beam-width of the beams.
- It can be observed that the beam dwelling time can be as small as 7ms. With the current beam management procedure including beam reporting, beam group activation and beam indication, it is hard to meet this beam update requirement. To make sure narrow beams can be used for better coverage and performance in high speed scenarios, it is beneficial to use AI on beam prediction together with trajectory prediction for mobility.
- Potential standardization impacts include enhancements on beam reporting, beam activation and beam indication.

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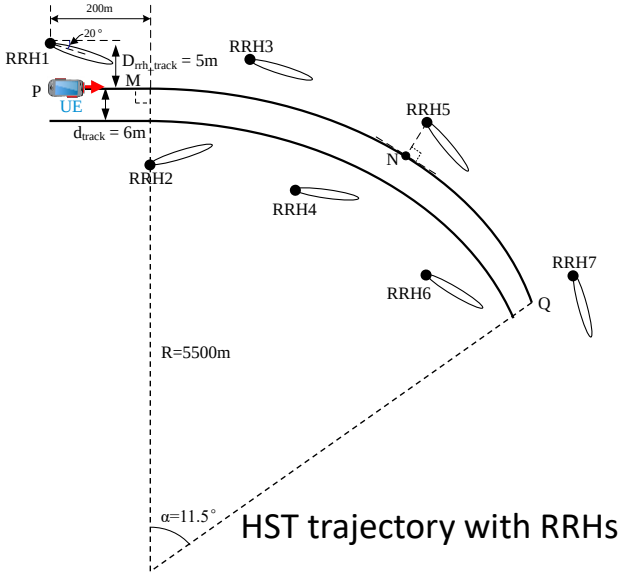
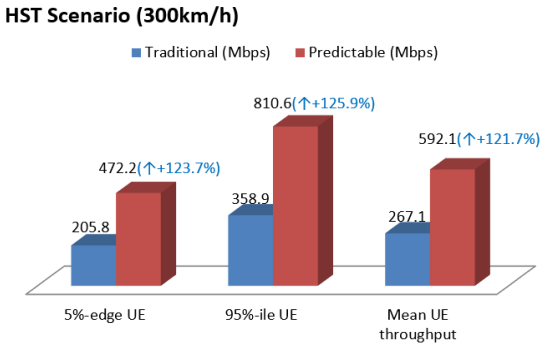
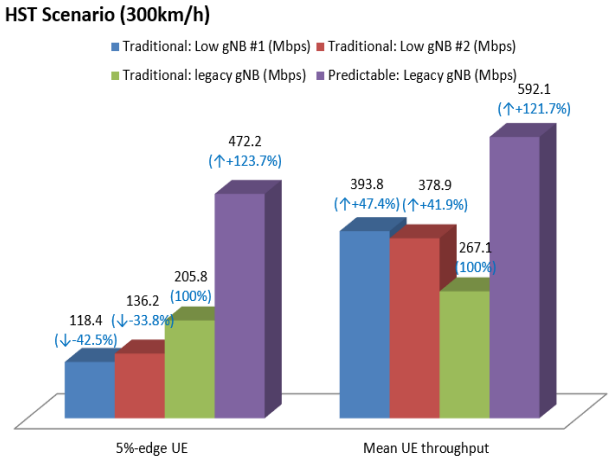
Predictable Mobility for Beam Management



HST trajectory with RRHs





- When mobility is predictable, beam management can be also predictable.
- With predictable beam management based approach, it can be observed that significant performance gain is obtained due to RS overhead reduction and/or narrow beams.
- Details can be found in RP-210620.

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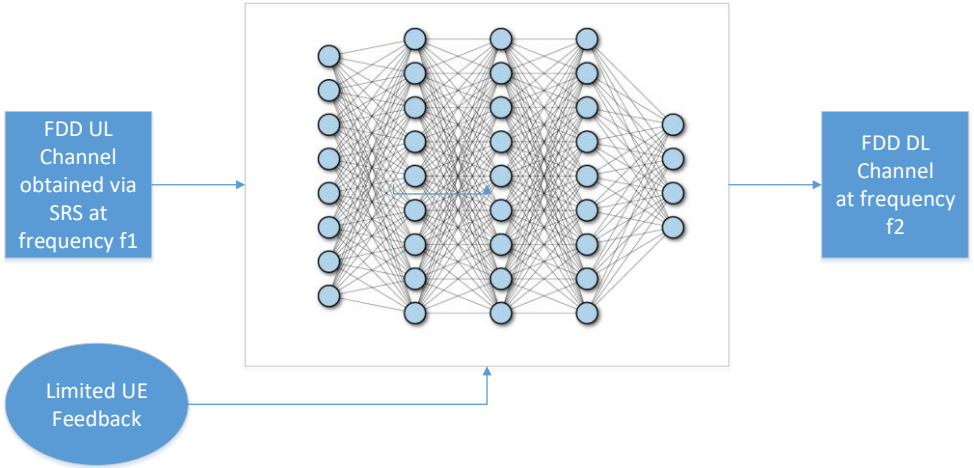
CSI prediction in frequency domain for CSI acquisition

ML neural network
E.g. CNN (convolutional neural network)



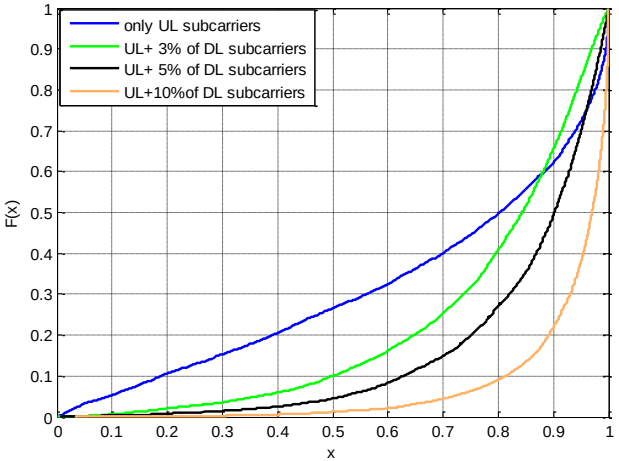


Fig 1. CDF curves of correlation between estimated and real DL channel response

- FDD channel reciprocity with limited CSI feedback
  - FDD channels also have reciprocity in the sense of UL and DL essential paths which are often sparse
  - By machine learning, FDD DL channel can be obtained via channel reciprocity with limited feedback
- Potential enhancement: Parameterized CSI feedback for limited subcarriers

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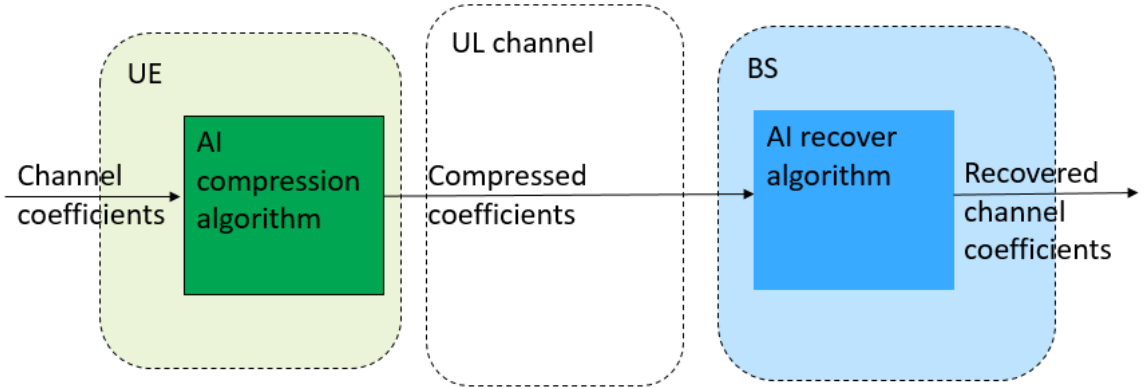
CSI compression feedback based on AI: general procedure

- AI algorithm can compress the channel coefficient vectors in both spatial and frequency domain to a new coefficient vector with smaller size, to optimize the system performance v.s. overhead.
  - More accurate CSI feedback can enable better MU operation for massive MIMO
- For a trained AI algorithm in UE or BS side
  - At UE: Input is the original channel coefficients measured from P CSI-RS ports in M RBs, and output is a new coefficient vector with smaller size. The size of the new coefficient vector depends on compression ratio, which is the ratio between the overhead to report the original channel matrix and the overhead to report the compressed coefficients.
  - At BS: Input is the compressed coefficient vector received from UE, and output is the recovered channel coefficients for all the M RBs.



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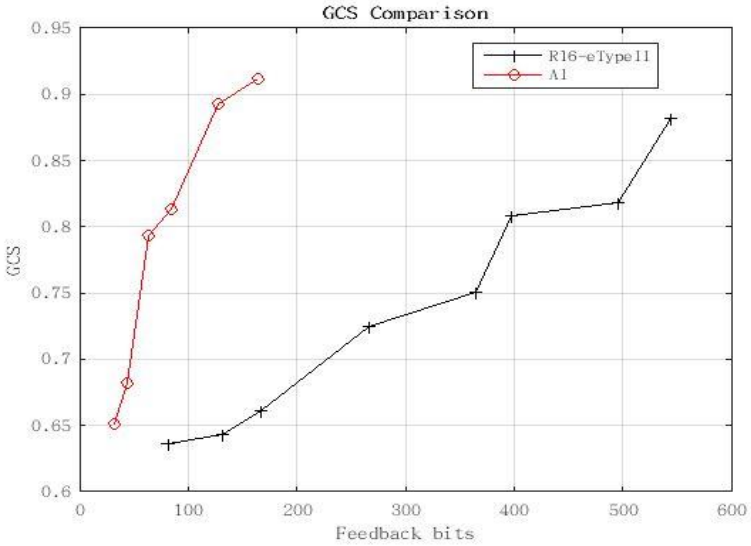
CSI compression feedback based on AI: evaluation results

- Evaluations are conducted to show the benefit of AI based approach to compress and feed back CSI.
- BS has 32 antennas. UE has one receive antenna. The bandwidth has 125 RBs.
- Baseline is the Rel-16 eType II codebook to compress channel matrix in spatial and frequency domain.
- X axis is the number of feedback bits. Y axis is Generalized Cosine Similarity (GCS) between two channel vectors $\mathbf{v}_1$ and $\mathbf{v}_2$ defined as $\mathrm{GCS}(\mathbf{v}_1, \mathbf{v}_2) = \frac{|\mathbf{v}_1 \mathbf{v}_2^{\mathrm{H}}|}{\|\mathbf{v}_1\|_2 \cdot \|\mathbf{v}_2\|_2}$.
- It can be observed for a given performance level, AI based approach shows significant overhead saving compared with Rel-16 eType II. Similarly, for same number of feedback bits, large performance gain can be achieved. These reveal the GREAT potential of AI based approach.



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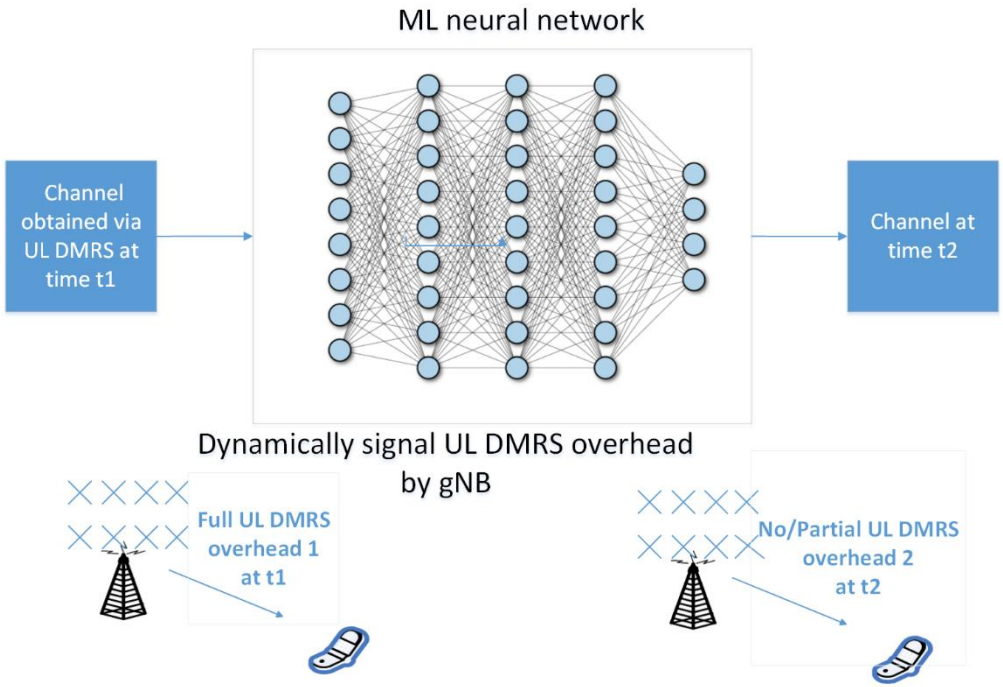
CSI prediction in time domain for demodulation



- Potential enhancement: Support more flexible DMRS indication, RS overhead reduction

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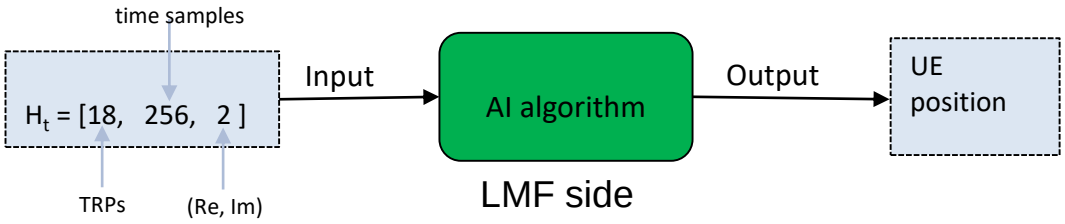
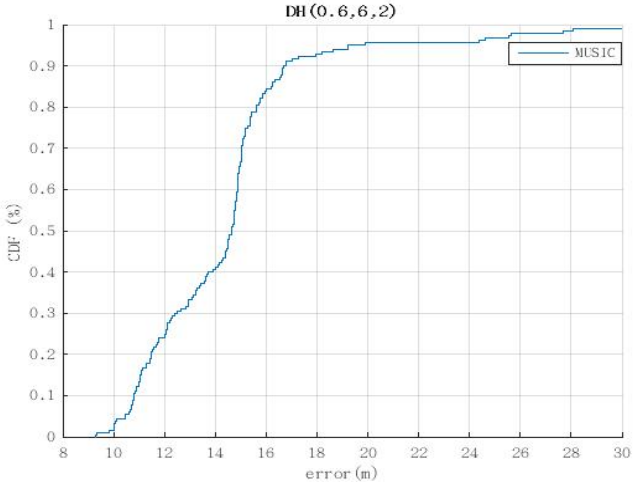
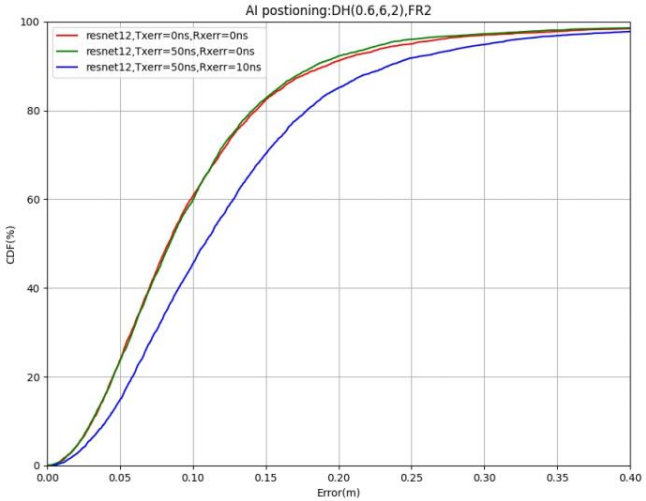
Positioning based on AI

- AI can significantly improve positioning accuracy in scenario with low LoS probability





vs.



- 15m positioning errors by traditional positioning solution in DH scenario with very high NLOS probability
- 0.2m positioning errors by AI positioning in DH scenarios with very high NLOS probability and/or with 50ns synchronization errors

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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

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Potential enhancements for AI applications in PHY aspects

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

Potential enhancements for AI on positioning for more accuracy

- Consider both UE-assisted and UE based positioning method

Proposal: *Consider the above potential enhancements for standardization on AI in PHY aspects.*

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Thanks

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