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Agenda: 9.11

# Applications of Artificial Intelligence in MIMO Networks



# Introduction

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

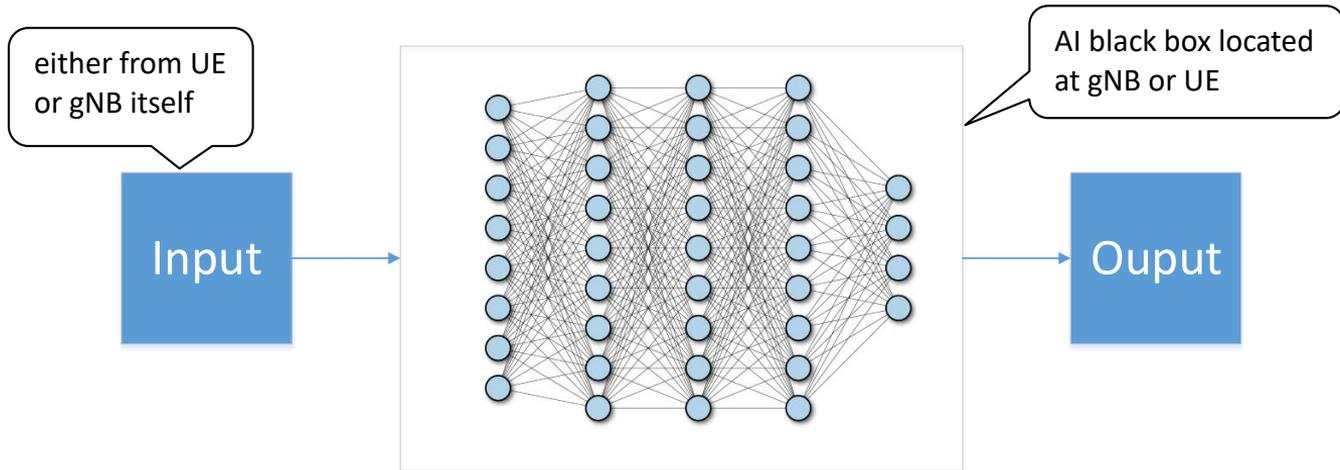
It was discussed whether "beam management" is explicitly listed as one of the possible use cases. However, it was removed due to the possible need of RAN1 involvement. Nevertheless, companies have shown their strong interest in AI applications on physical layer. We see the need of studying standardization impact of AI applications in both higher layer and physical layer aspects.

In this contribution, we discuss the potential AI applications in MIMO networks.

# Potential Benefits

- 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 for MIMO has been drawn a lot of interest in recent research.
- The potential benefits are:
  - 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
- These potential benefits translate to better system performance e.g. in terms of throughput and reliability

# Generic model of AI and its standardization impacts



Potential standardization impacts:



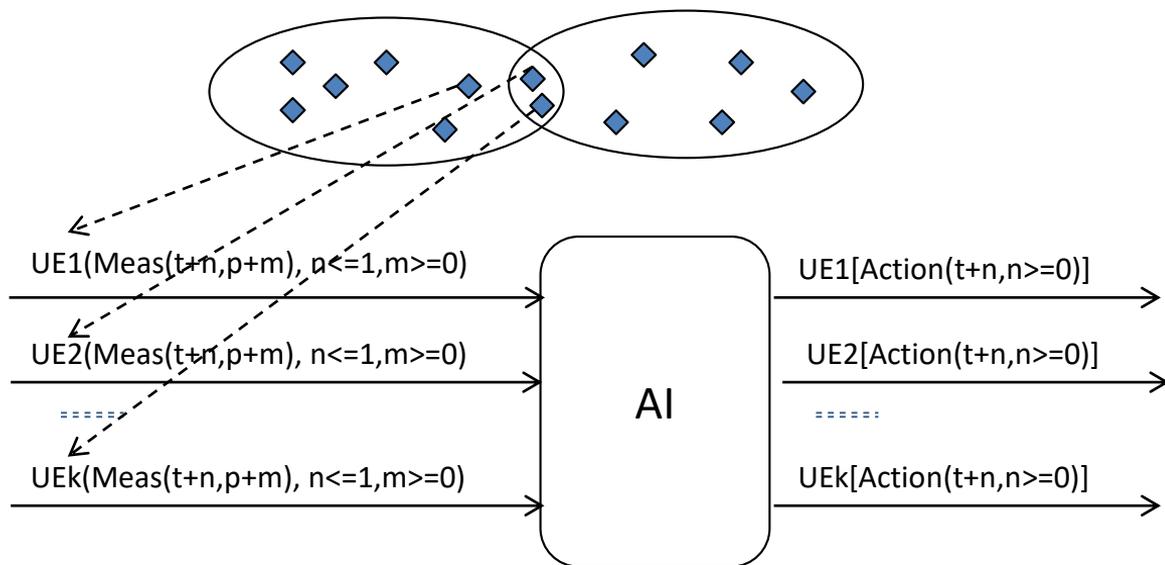
Feedback from UE helps AI training for better prediction at gNB

AI outcome from gNB is signaled to UE for better operation

Feedback from UE based on output of AI prediction at UE

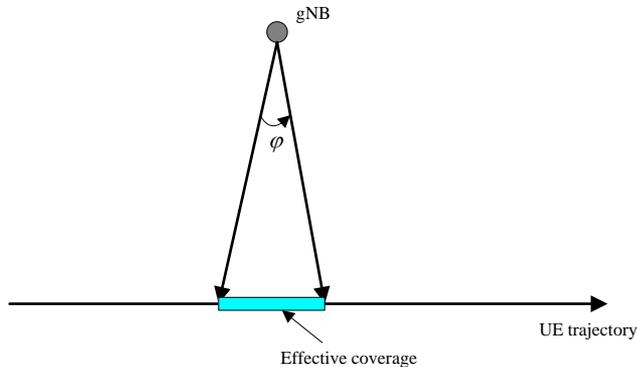
UE execute based on training result from gNB and local input

# AI for Mobility and Beam Management



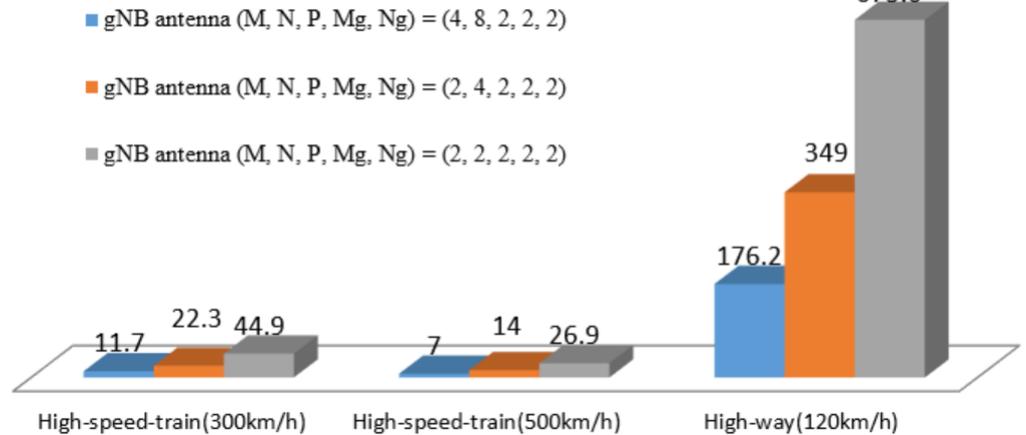
- AI model: Action for now( $t_0$ ) or prediction for future( $t_1, t_2 \dots$ ) for one UE is deduced based on measurement/event from related UEs jointly by taking their history( $t-1, t-2 \dots$ ) and position stamp ( $p+m$ ) into account. e.g. scheduling/beam tracking at gNB
- UE may predict future event/measurement ( $t_1$ ) 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

# AI for Beam Management



Effective coverage depending on beam-width, distance and speed

### Beam dwelling time [ms]



- 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.

# CSI prediction in frequency domain for CSI acquisition

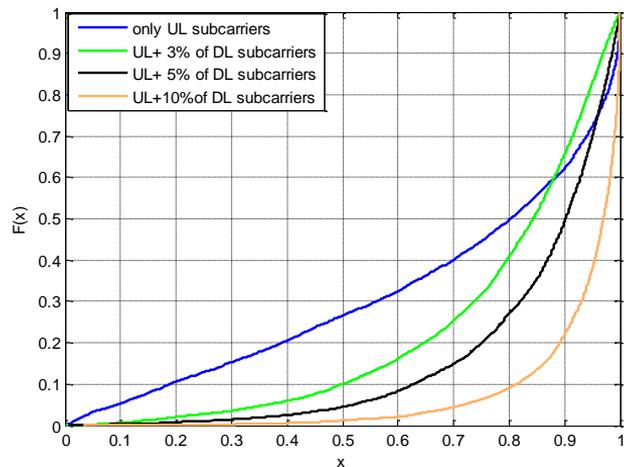
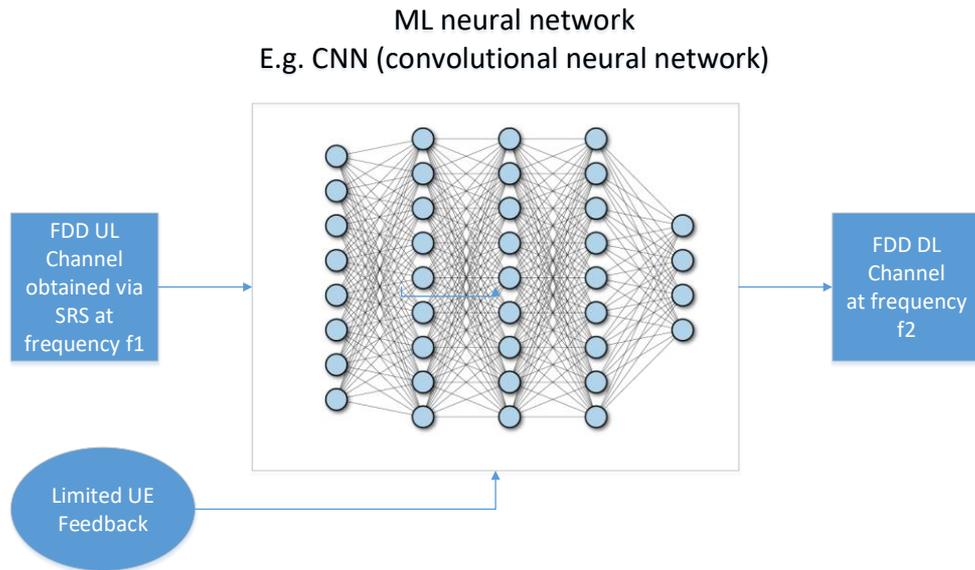
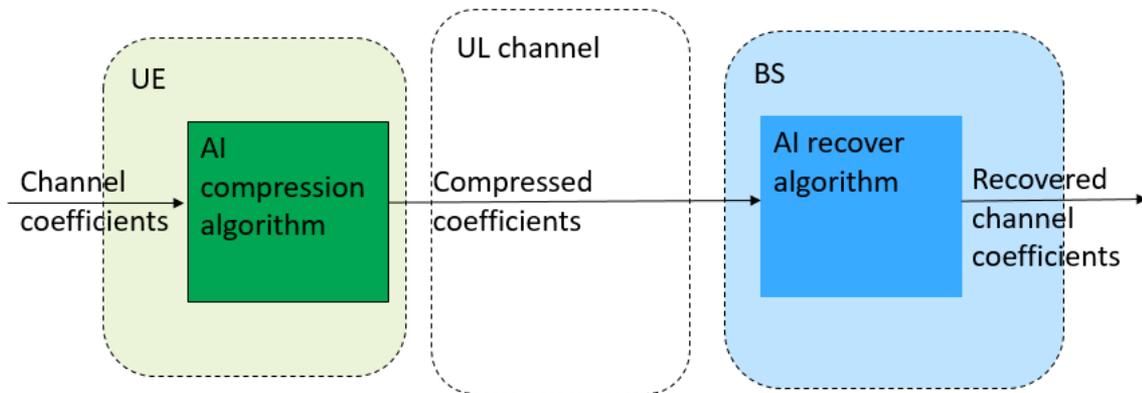


Fig 1. CDF curves of correlation between estimated and real DL channel response

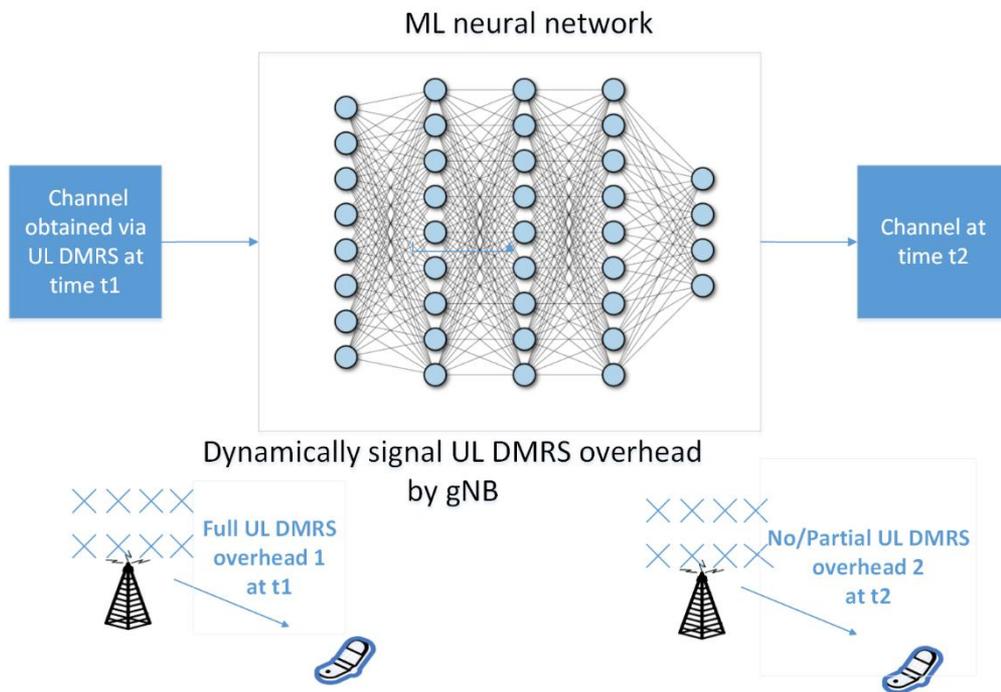
- FDD channel reciprocity with limited CSI feedback
  - FDD channels also have reciprocity in the sense of UL and DL essential paths which are often sparse
  - By machine learning, FDD DL channel can be obtained via channel reciprocity with limited feedback
- Potential enhancement: Parameterized CSI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

# 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.



# CSI prediction in time domain for demodulation



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

# 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 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

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

# Thanks



Tomorrow never waits

