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Study on AI/ML based air interface enhancement in Rel-18

3GPP TSG RAN Meeting #91e RP-210321

Electronic Meeting, 16th– 26th March, 2021

Agenda Item: 9.13

Document for: Discussion & Decision

General thinking of AI/ML application on air interface

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Limitations of current design in air interface

Independent optimization for modules dependent on each other

- E.g., Independent optimization for DL channel acquisition and DL precoding;

Linear sub-optimal algorithms and solutions for non-linear problems

- E.g., Linear channel estimation for non-linear parameter estimation problems

Performance degradation with practical impairments or restrictions

- E.g., EVM degradation and increased unwanted emission when approaching saturated output power due to PA non-linearity;

Non future-proof design without enough flexibility to conduct scenario specific optimization/evolution

- E.g., Performance degradation with type I/II codebook for irregular antenna array in space limited scenarios;
- E.g., Complicated (if not impossible) retuning of system parameters to adjust for evolving traffic/environment

AI/ML is a powerful tool to address challenges for air interface designs

Joint design of several modules could be easily done using AI

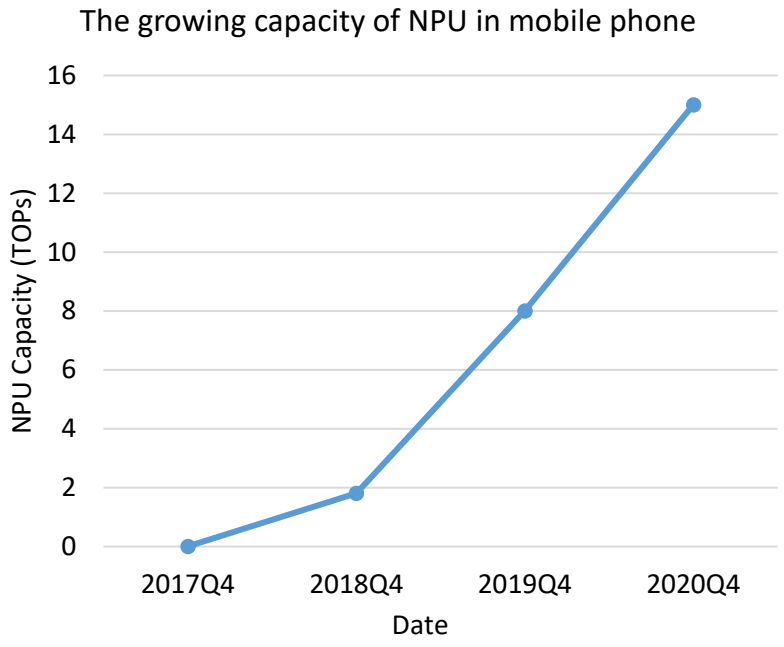
AI solutions could obtain near-optimal solutions for non-linear problems

Modeling of practical impairments becomes possible with AI

PHY layer design based on neural network provides the possibility to continuously evolve for various scenarios

General thinking of AI/ML application on air interface

- AI/ML based air interface is feasible using chipset in current mobile phone :
  - The capacity of one typical NPU used in current mobile phone is 15T operations (OPs) per second. From 2017Q1, the capacity of typical NPU in mobile phone is growing very fast year by year.
  - The complexities of typical AI networks are listed in the below table and it is seen that the complexity of AI/ML based air interface is already affordable now.



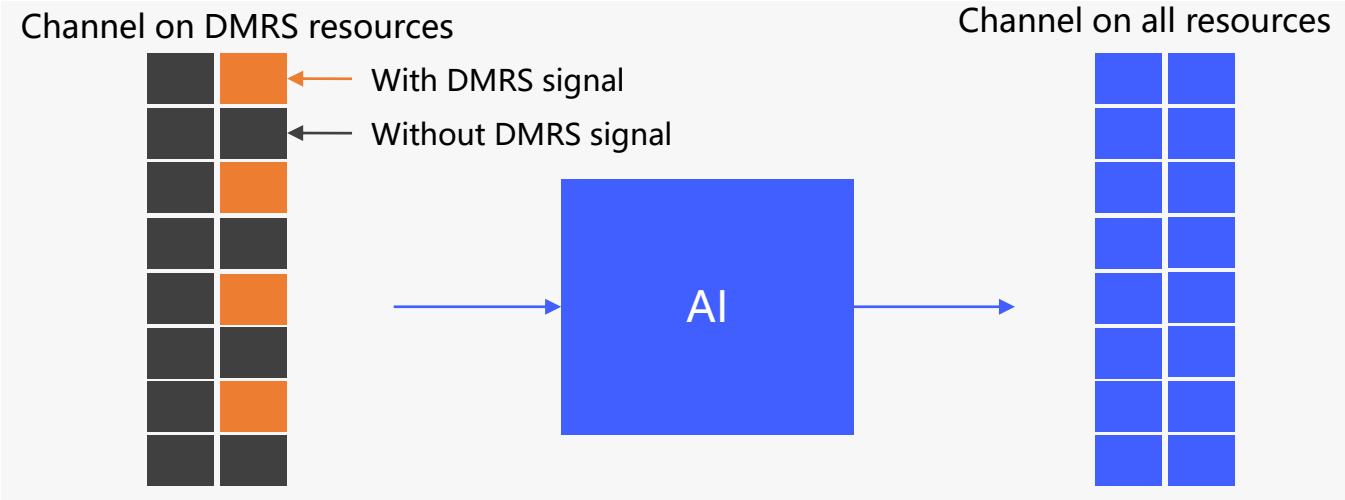
	Complexity (OPs)	Ratio of capacity of the typical chipset in 1 second
Inception V2	4.1G	2.7e-4
Inception V3	12G	8.0e-4
CaffeNet	724M	4.8e-5
GoogleNet	2G	1.3e-4
MobileNet	1.15G	7.7e-5
AI network for DMRS in the slides	222M	1.5e-5 (1.5e-2 in 1ms)
AI network for CSI feedback in the slides	8.9M	5.9e-7 (5.9e-4 in 1ms)
AI network for beam management in the slides	544K	3.7e-8 (3.7e-5 in 1ms)
AI for channel prediction in the slides	7.3M	4.9e-7 (4.9e-4 in 1ms)

General thinking of AI/ML application on air interface

- 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

- The near-optimal AI/ML network largely reduces the MSE, without assistance of TRS.



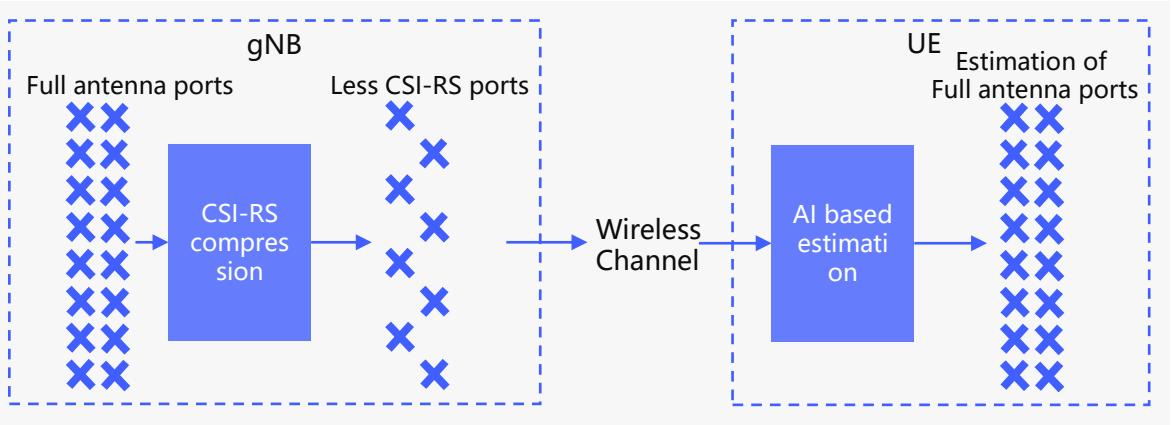
Method	MSE
AI network 1： no TRS	8.5e-4
AI network 2： using TRS	8.4e-4
no AI： using TRS	7.3e-3

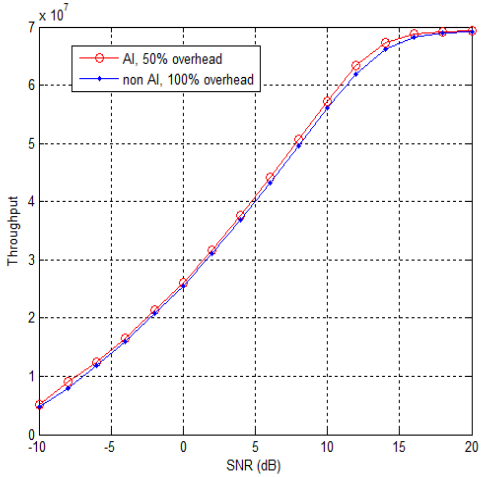
- Potential specification impact includes at least
  - Framework and procedures on exchange of neural network related information between network and UE that facilitate learning on radio environment;
  - QCL relationship and TRS transmission and reception that facilitate the new receivers;
  - DMRS patterns optimized for the new receivers;

Parameters： LLS, SNR 10dB, UE speed 3km/h, TDL-C 300ns, 3.5G Hz, 1 gNB antenna, 1 UE antenna, 50 RBs. DMRS takes 6 subcarriers in 1 RB and 2 symbol in 1 slot.

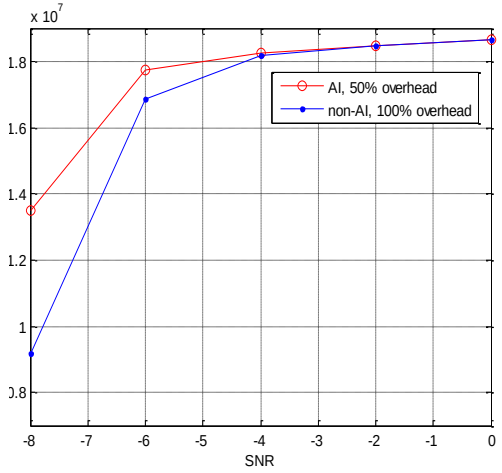
AI/ML+RS: CSI-RS overhead reduction

- Using 50% CSI-RS overhead, AI based CSI-RS compression could achieve better throughput than traditional algorithm with 100% CSI-RS overhead.





32 gNB antennas



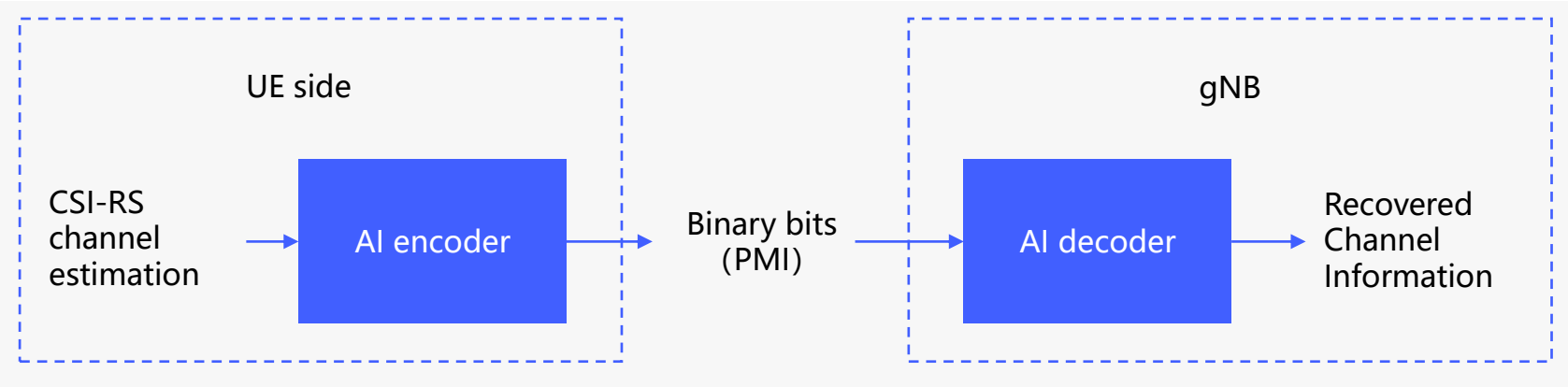
128 gNB antennas

- Potential specification impact includes at least:
  - Framework and procedures on exchange of neural network related information between network and UE that facilitate learning on radio environment;
  - Exchange of neural network that is used for the UE to generate full port CSI;
  - CSI-RS transmission and reception with compressed ports;

Parameters: LLS, UE speed 3km/h, CDL-C 300ns, carrier frequency 3.5G Hz, 32/128 gNB antennas, 32/128 CSI-RS ports, 4 UE antennas, 52 RBs..

AI/ML+CSI: CSI feedback

- AI network is not limited to certain restrictions of current codebook design.
- For low overhead case, 30% Tput gain is achieved using AI, compared to NR specified solutions.



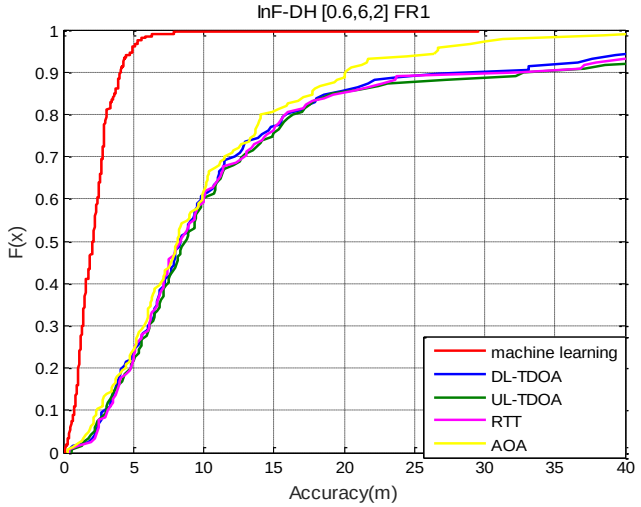
Method	Spectrum efficiency (bit/s/Hz)
NR specified solution	6.41
AI	8.28

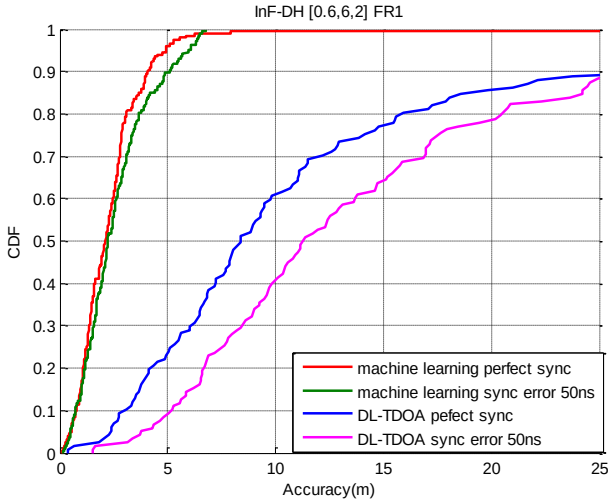
- Potential specification includes at least:
  - Framework and procedures on exchange of neural network related information between network and UE that facilitate learning on radio environment;
  - Exchange of neural network for aligned CSI computation between UE and gNB;
  - New CSI measurement and computation procedures;

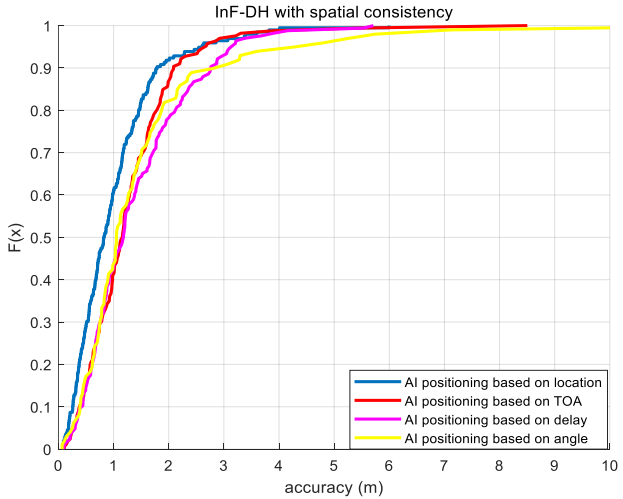
Parameters: SLS, UMi 38.901, 7 cells, 3 sectors for each cell, UE speed 3km/h, carrier frequency 3.5 GHz, 32 gNB antenna ([Mg Ng M N P] = [1 1 2 8 2]), 4 UE antenna ([Mg Ng M N P] = [1 1 2 2 2]), 52 RBs. The overhead of PMI is 58 bits.

AI/ML+Positioning

- Compared to Rel-16/Rel-17 solutions, AI/ML based solutions could increase the accuracy dramatically at least from the following aspects
  - To combat NLOS in DH scenarios
  - To combat synchronization error between different TRPs
  - To combat Tx-Rx timing error between different TRPs and Ues





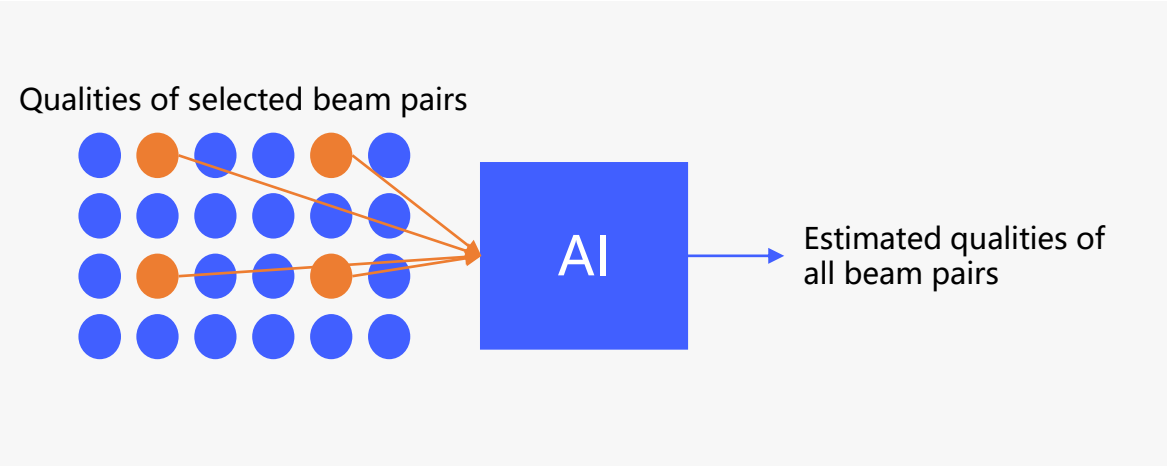


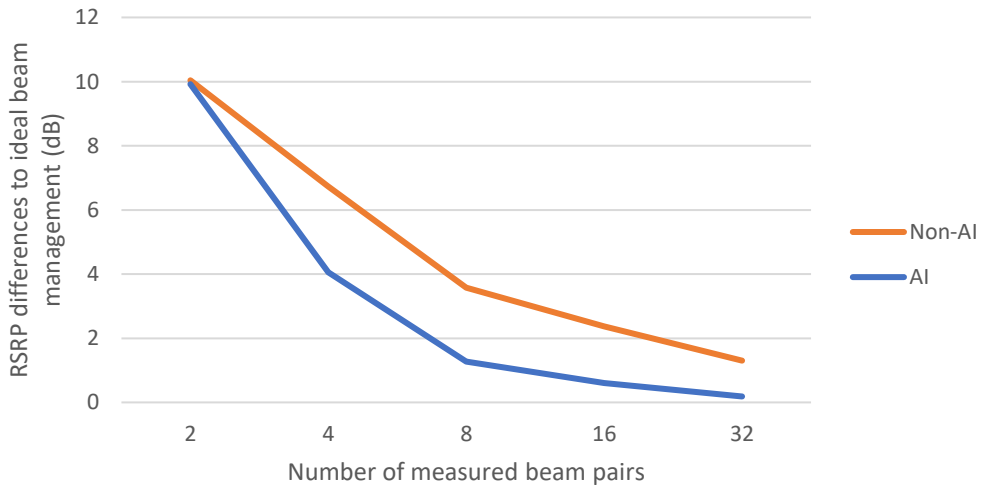
- Potential specification impact includes at least:
  - Framework and procedures on exchange of neural network related information between network and UE that facilitate learning and inference;
  - New measurement and reporting procedures with aligned neural network between gNB and UEs;

Parameters: Deployment and channel model is based on current Rel-17 Positioning item discussion. InF-DH is focused..

AI/ML+Mobility: Fast intra-cell beam selection

- Measure small number of beam pairs, and use AI to estimate qualities of all beam pairs. It could used for both intra-cell beam management and inter-cell beam management.
- Compared to the measurement of 32 beam pairs in non-AI method, AI only needs to measure 8 beam pairs hence reducing measurement time by 75%, expediting overall beam management process.



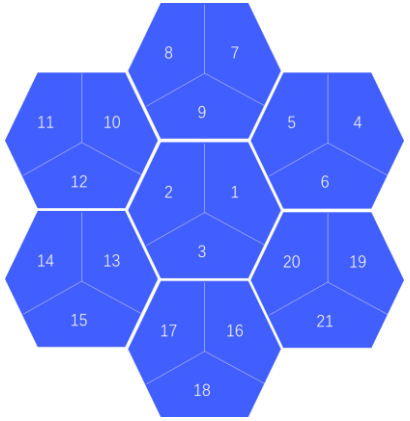


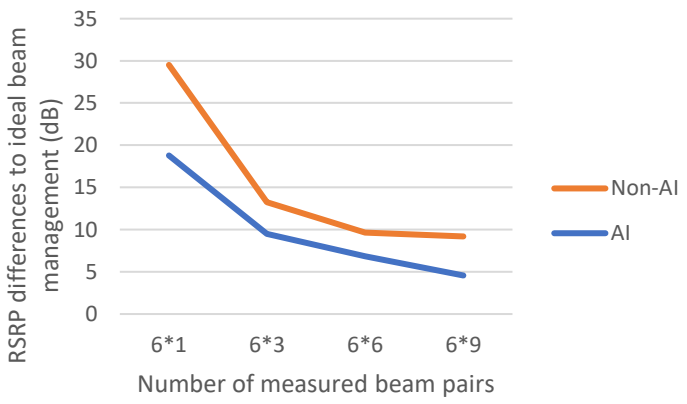
- Potential specification impact includes:
  - Framework and procedures on exchange of neural network related information between network and UE that facilitate learning and inference;
  - Exchange of neural network for aligned beam measurement between UE and gNB;
  - Support of beam measurement reports with more than 4 beams;

Parameters: SLS, UMi 38.901, 7 cells, 3 sectors for each cell, UE speed 3km/h, carrier frequency 30GHz, subcarrier spacing 120KHz, 64 gNB antenna ([Mg Ng M N P] = [1 1 4 8 2]), 16 UE antenna ([Mg Ng M N P] = [1 1 2 4 2]). L1-RSRP based beam selection method, 32 gNB beams and 16 UE beams, and then total 256 beam pairs.

AI/ML+Mobility: Fast inter-cell beam selection

- Similar mechanism could also be used to facilitate inter-cell measurement;
  - Compared to the measurement of 54 beam pairs in non-AI method, AI only needs to measure 18 beam pairs hence reducing measurement time by 67%, expediting overall beam management process.
- Potential specification impact includes
  - Framework and procedures on exchange of neural network related information between network and UE that facilitate learning;
  - Exchange of neural network information for aligned L1/L3 measurement for inter-cell mobility procedure;
  - L1/L3 inter-cell mobility procedures optimized with the AI/ML enhancement;

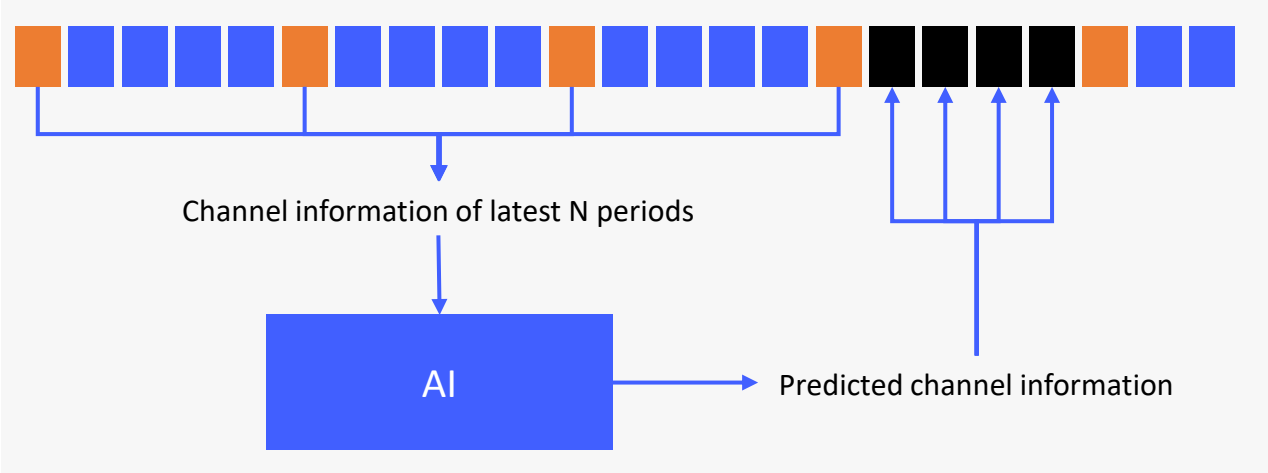




Parameters: SLS, UMi 38.901, 7 cells, 3 sectors for each cell, UE speed 3km/h, carrier frequency 30GHz, subcarrier spacing 120KHz, 64 gNB antenna ([Mg Ng M N P] = [1 1 4 8 2]), 16 UE antenna ([Mg Ng M N P] = [1 1 2 4 2]). L1-RSRP based beam selection method. For each cell, 32 gNB beams and 16 UE beams, and then total 256 beam pairs. UE measures beams from 6 neighboring cells and then total 256*6=1536 beam pairs.

AI/ML+Mobility: Channel prediction

- Using the outdated channel information from previous RS detection, AI could predict the future channel information very well.



Case	NMSE	
	Speed 3km/h	Speed 30km/h
No channel prediction	0.15	1.6
AI with information of 2 periods	2.5e-8	2.6e-7
AI with information of 4 periods	3.3e-9	4.2e-8
AI with information of 6 periods	7.9e-10	1.9e-8
AI with information of 8 periods	5.0e-10	5.6e-9
AI with information of 10 periods	3.3e-10	4.2e-9

- Potential specification impact:
  - Framework and procedures on exchange of neural network related information between network and UE that facilitate learning and inference;
  - Exchange of neural network information for CSI report that facilitates channel/beam prediction;
  - Related measurement and reporting procedures;

Parameters: LLS, UE speed 3km/h or 30km/h, CDL-C 300ns, carrier frequency 4G Hz, 32 gNB antennas, 2 UE antennas, 1 RB, maximum 1 layer, RS period 10 slots. No noise is considered.

Potential areas for AI/ML application in air interface

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- The following can be studied in Rel-18 for potential application of AI/ML in air interface:
  - Methodology and metrics for evaluation of AI/ML in air interface, including whether and how to construct data set for training/validation/test, whether and how to align DNN models etc.;
  - Framework, procedures and performance of applying AI/ML in the following areas, including related information needed for training and inference:
    - (Joint) optimization of one or more the following:
      - RS transmission and estimation, including DMRS/SRS/CSI-RS, etc.
      - CSI feedback, including application channel prediction
    - Mobility enhancement, including enhancement on intra-cell beam management and inter-cell mobility optimization;
    - Positioning enhancement
  - Potential specification impact of applying AI/ML in above areas, including related procedures;

THANK YOU