

Agenda Item: 4.3

Source: Samsung

Title: On the support of AI in PHY for 5G Advanced

Document for: Discussion and Decision

List

- ◇ Motivation & Challenges
- ◇ AI-PHY topics
- ◇ Directions for Rel-18

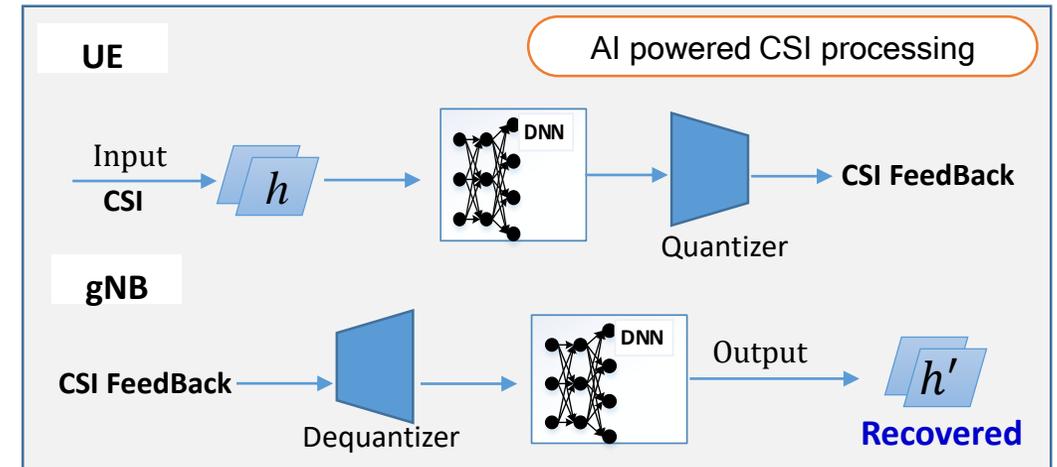
- ◇ AI might be suitable to solve issues for which conventional solutions have either model deficit or algorithm deficit

Existing wireless pain-points	Potential AI abilities
Hard to model / NP-hard problems	Data-driven to determine suitable model/solutions
Practically “non-implementable” optimal solutions	Finding near-optimal solutions via affordable training cost and processing complexity
Non-linearity of active RF components @ TX & RX	Modeling based on real hardware datasets

- ◇ New study area in PHY: exploring practical gain of data-driven approaches over model-based approaches
- ◇ Expectations on AI in PHY
 - ◆ To relax conventional design requirements
 - ◆ To reduce communication overhead
 - ◆ To optimize link performance
- ◇ Key challenges of applying AI in PHY
 - ◆ Problem of model generalization fitting for various wireless channel scenarios → concerning on offline training
 - ◆ Lack of theory, boundary analysis and explainable → lead to huge test efforts & no evaluation methodology in 3GPP
 - ◆ How to support training (offline, online, fast real-time) with acceptable training overhead
 - ◆ Availability of high computational power embedded in devices for supporting complex AI algorithms
- ◇ Some interesting topics in AI-PHY
 - ◆ CSI processing
 - ◆ Beam management
 - ◆ Non-linearity handling

- ◇ Accurate CSI is the one of fundamental to the success in wireless systems
 - ◆ Quantized CSI feedback with limited feedback overhead limits the spectral efficiency
 - ◆ CSI estimation is most power-consuming job in both gNB and UEs
- ◇ Possible AI powered CSI processing
 - ◆ **CSI prediction:** across time and frequency @ UE without actual pilot
 - ◆ **CSI estimation:** across band or DL/UL channel @ gNB
 - ◆ **CSI feedback:** CSI compression @ UE with AI encoder + CSI inference @gNB with AI decoder
 - Example in CSI feedback

UE		gNB	
CQI, PMI, RI			
Quantized CSI			
Methods	Compression Rate	Indoor	outdoor
CsiNet ^[1]	1/64	-5.84	-1.93
CRNet ^[2]		-6.49	-2.13



[1] C. Wen, W. Shih and S. Jin, "Deep Learning for Massive MIMO CSI Feedback," IEEE Wireless Communications Letters, vol. 7, no. 5, pp.748-751, Oct. 2018

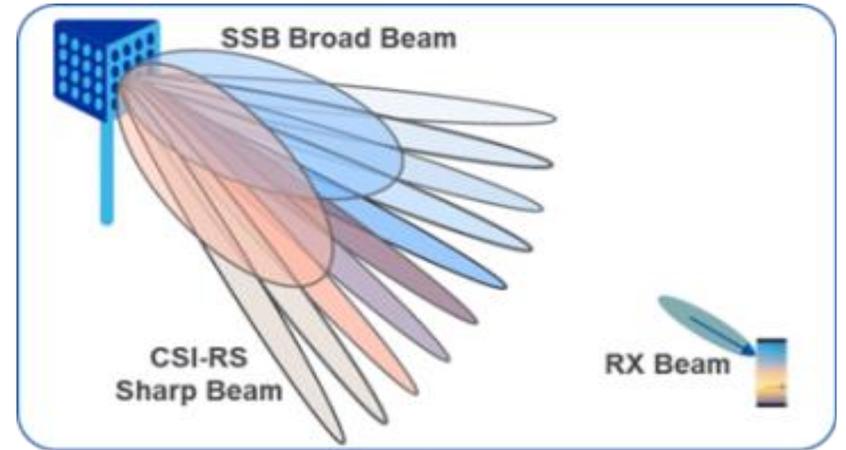
[2] Z. Lu, J. Wang, and J. Song, "Multi-resolution CSI feedback with deep learning in massive MIMO system," in Proc. IEEE Int. Commun. Conf. (ICC), Jun. 2020, pp. 1-6.

◇ For mmWave and high frequency band, using massive analog beam is unavoidable

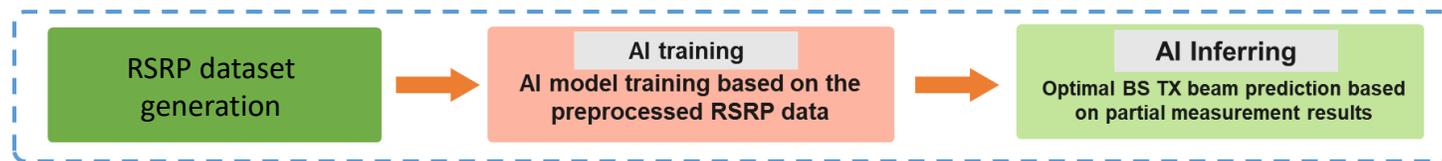
- ◆ Latency of beam alignment via exhaustive searching
- ◆ Heavy overhead of beam measurement and report

◇ Possible AI powered beam management

- ◆ **Beam alignment:** select best beam width and size
- ◆ **Beam measurement:** using partial beam set among full beam set
- ◆ **Beam prediction:** best beam selection from past (limited) beam reporting
 - Example of beam prediction



As-is: beam alignment, selection, and tracking via exhaustive searching



Algorithm	Accuracy for Choosing Top1~3 Beams	Ave. RSRP diff. between selected and best beam	Ratio of # of CSI-RS per cycle (under serving SSB coverage)
Conventional	83.3%	3.6 dB	100%
AI powered	85.6%	3.2 dB	25%

- AI power scheme can predict the “best” beam from the selected beam subset measurements

◇ High PAPR leads to low PA efficiency with large P_o or EVM degradation with non-linear distortion

- ◆ PA PO (max. 6.5dB MPR in RAN4 spec) reduces coverage
- ◆ Bad EVM may limit BLER of high order modulation

◇ **AI powered nonlinearity handling**

- ◆ Digital pre-distortion: improve linearity for better coverage
- ◆ Equalization at the receiver: improving link performance or improving energy efficiency
 - Example of AI-based equalization
 - Better EVM after non-linear EQ → improving BLER → better support high data rate such as 256 QAM
 - Real-time online training for modeling TX-RX non-linearity may required

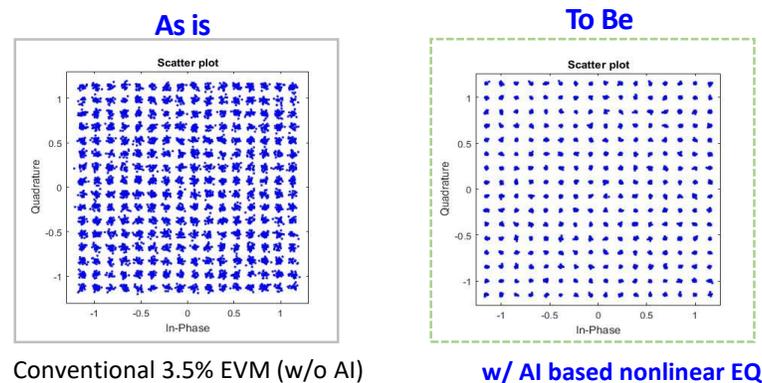


Illustration of non-linear EQ effect



Illustration of ideal gain (1Tx antenna and 1Rx antenna)

- ◇ AI in PHY is to address complex tasks for which there is no prior close-form solution or there is non-negligible defects of conventional solutions
 - ◇ Gain in practice is still unclear and should be carefully studied.

- ◇ A new study item is expected over Rel-18 duration to evaluate practical gain and feasibility of applying AI in 5G NR PHY. The objectives would include:
 - ◇ Study appropriate evaluation methodology (training based)
 - ◇ Identify the necessary specification support to facilitating AI in PHY, even though AI itself is black box and implementation specific
 - e.g., how to collect data-sources for online training, which may impact RS design, measurement, feedback/report etc.
 - e.g., new signaling/control procedure to leverage AI, incl. device capability indication, and AI model management (for offline trained models) etc.
 - ◇ Define requirements, KPIs, are metrics to evaluate AI based solutions