Dynamic Wireless Resource Management and Transceiver Adaptation for Efficient Spectrum Utilization and Coexistence

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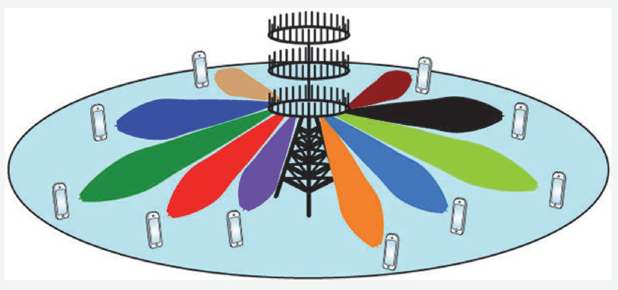
Massive MIMO and CSI Feedback in FDD



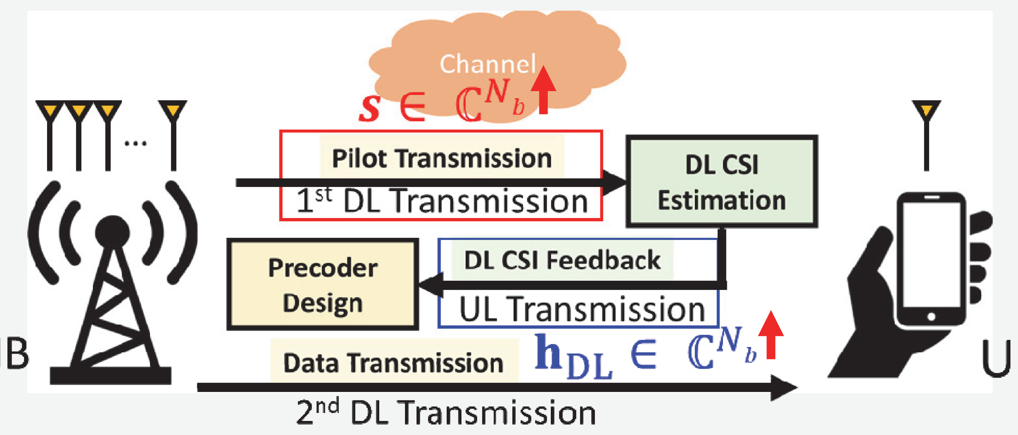
- High capacity
- Strong robustness
- Reduced latency
- Higher efficiency

Downlink signal and CSI in massive MIMO at k-th RB:

$$y_{\mathrm{DL}}^{(k)} = \mathbf{h}_{\mathrm{DL}}^{(k)H}\mathbf{w}_{\mathrm{DL}}^{(k)} s^{(k)} + n_{\mathrm{DL}}^{(k)} \quad (1)$$

$$\mathbf{H}_{\mathrm{DL}}^{\mathrm{SF}} = \left[\mathbf{h}_{\mathrm{DL}}^{(1)} \;\cdots\; \mathbf{h}_{\mathrm{DL}}^{(\kappa)}\right] \in \mathbb{C}^{N_b \times \kappa} \quad (2)$$

Excessive pilots and **UE feedback overhead** for DL CSI acquisition at gNB: Need feedback/recovery.



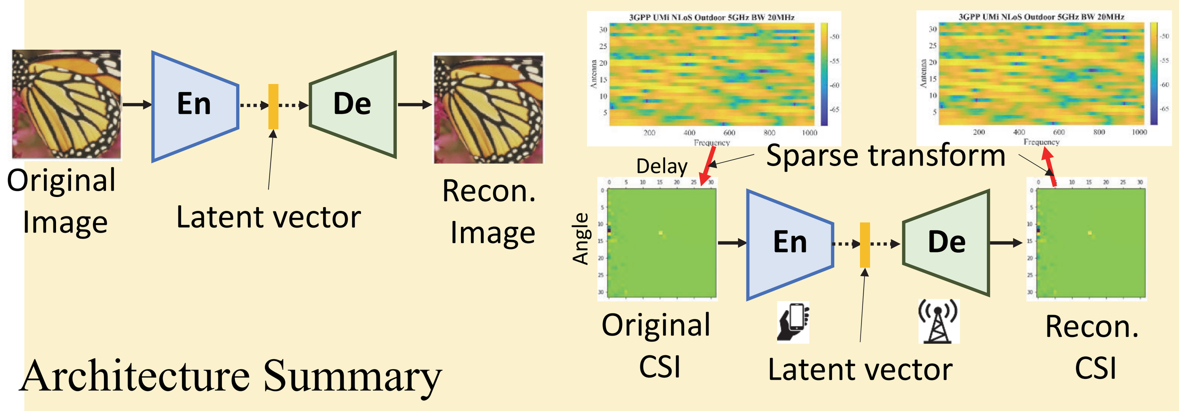
CSI Compression and DNN:

CSI Compression and Recovery by Exploiting Sparsity

Sparse transform: $\mathbf{H}^{\mathrm{AD}} = \mathbf{F}_A \mathbf{H}^{\mathrm{SF}} \mathbf{F}_D^H$ (3)

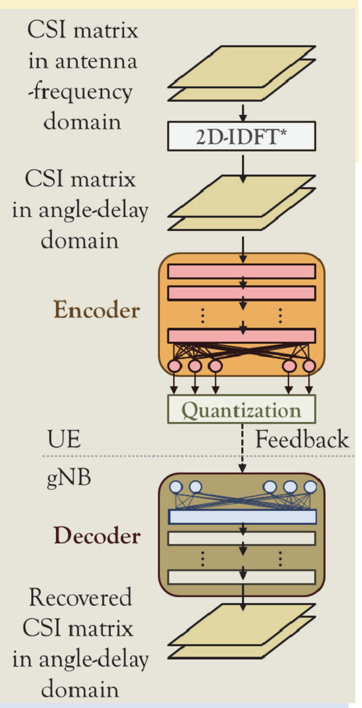
$$\mathbf{H} = \mathbf{H}^{\mathrm{AD}}\mathbf{T} = \mathbf{H}^{\mathrm{AD}} \begin{bmatrix} \mathbf{I}_{N_t \times N_t} \\ \mathbf{0} \end{bmatrix} \in \mathbb{C}^{N_b \times N_t} \quad (4)$$

AE-based CSI feedback: **CSI = Image?**



Architecture Summary
- Encoder (UE): **H** → Q(**q**)
- Decoder (gNB): $Q(\mathbf{q})$ → **H**

e.g., *CsiNet [Wen et al. 2018]*



Challenges:

[C1]: Outdoor CSI Recovery Accuracy
[C2]: Limited Pilot Resource
[C3]: High complexity & model size
[C4]: Cost of model retraining (mobility)
[C5]: Inflexible size & compression ratio

Our Contributions

[R1] **FDD-reciprocity Aided DNN Recovery: C1**

[R2] **FDD-reciprocity Aided Pilot Reduction: C2**

[R3] **Temporal Correlation Aided DNN Recovery : C1**

[R4] **Low-complexity, scalable encoder: C3, C5**

[R5] **Training-free & model-driven light models: C4**

Abbreviations:

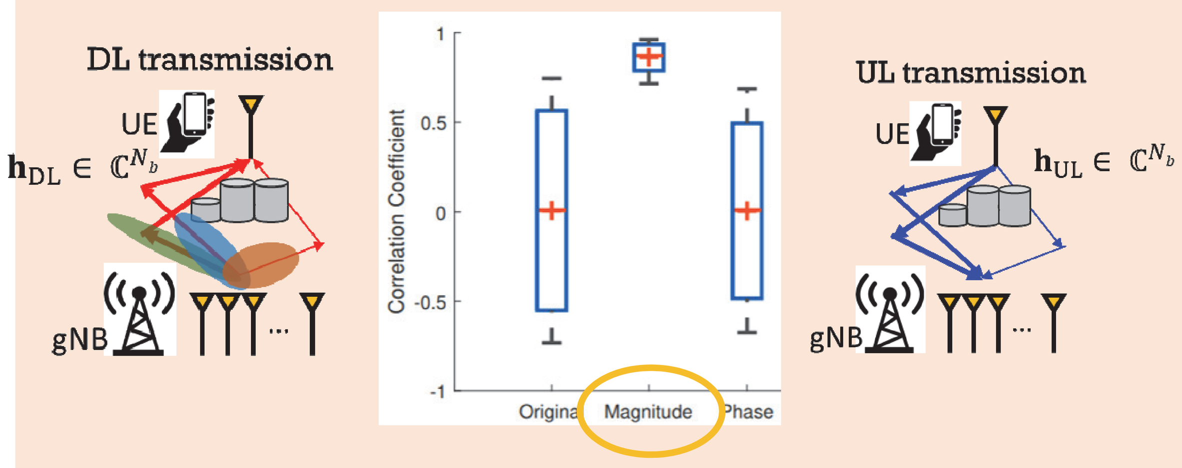
- MIMO: Massive Input Massive Output
- CSI: Channel State Information
- FDD: Frequency-Division Duplexing
- UE: User Equipment
- DL: Downlink
- UL: Uplink
- DNN: Deep Neural Network
- AE: Autoencoder

Leveraging FDD reciprocity (C1):

TDD: $\mathbf{h}_{UL} = \mathbf{h}_{DL}$ FDD: $\mathbf{h}_{UL}$ ✘= $\mathbf{h}_{DL}$

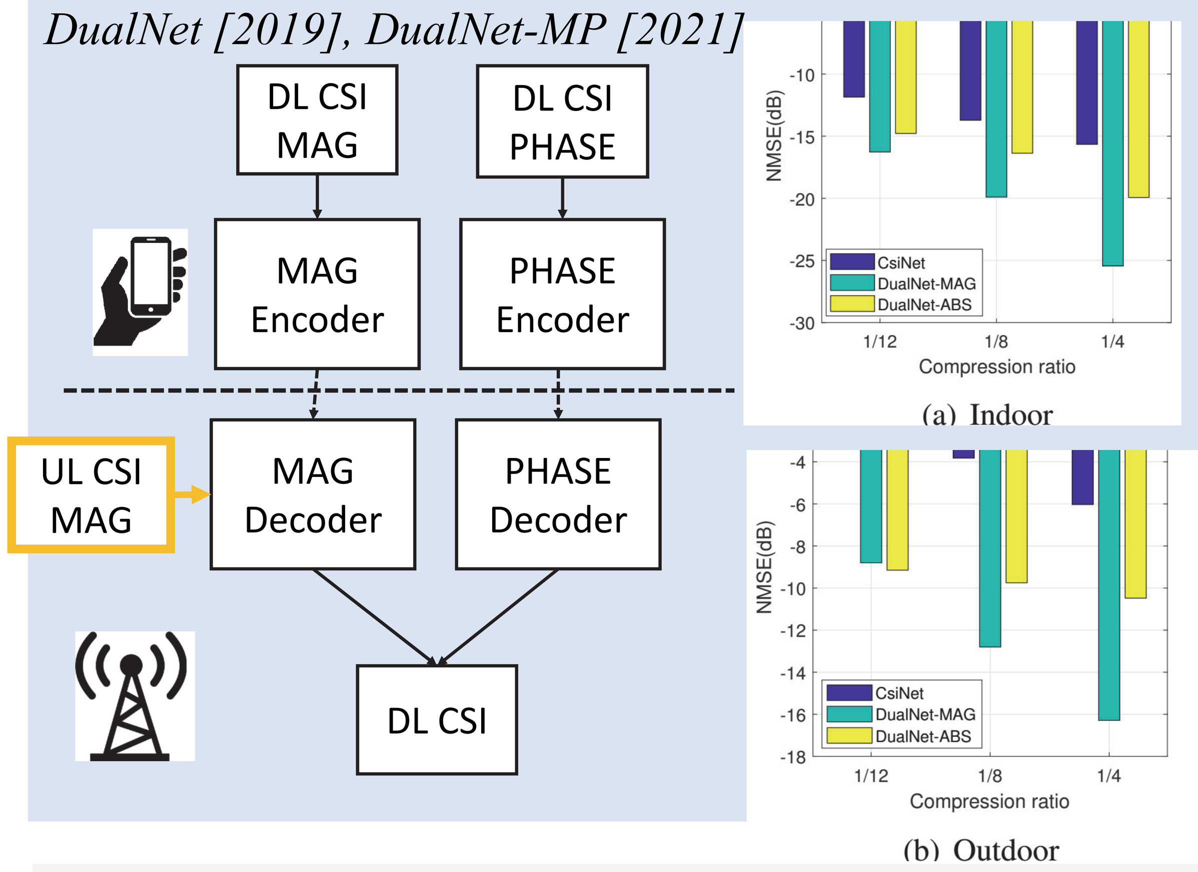
CSI reciprocity in FDD? Multipaths/scatters lead to angular and delay reciprocity between $\mathbf{h}_{UL}$ and $\mathbf{h}_{DL}$

Evidence of FDD "mag" reciprocity



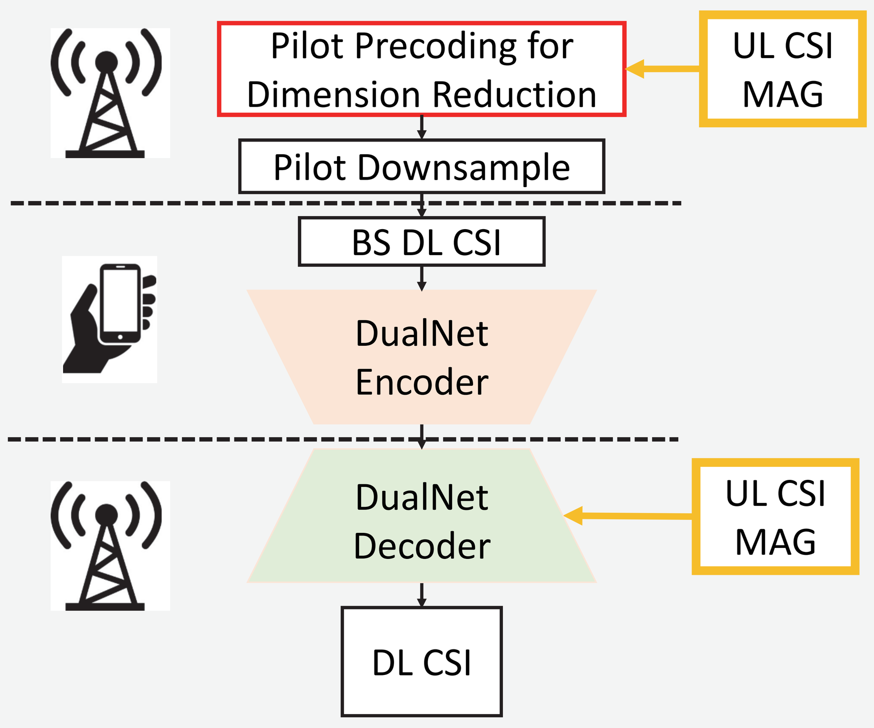
FDD-reciprocity Aided DNN Recovery (C1):

DualNet [2019], DualNet-MP [2021]



FDD-reciprocity Aided Pilot Reduction (C2):

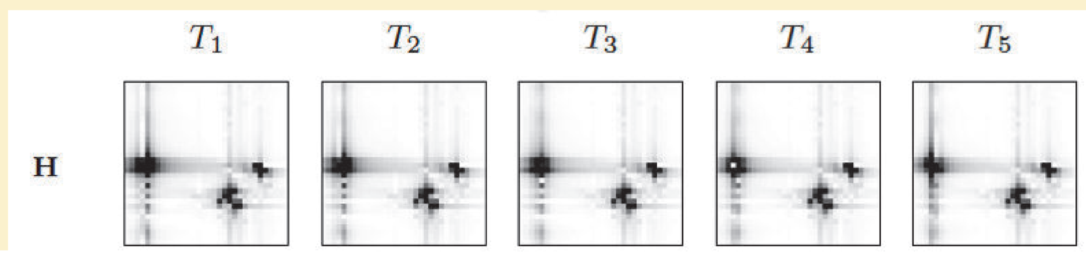
BSdaulNet [2023], FDD reciprocity aided pilot precoding:



Fading CSI under Mobility (C1):

Markovian model $H(\mathbf{H}_t|\mathbf{H}_{t-1},\ldots,\mathbf{H}_1) = H(\mathbf{H}_t|\mathbf{H}_{t-1})$

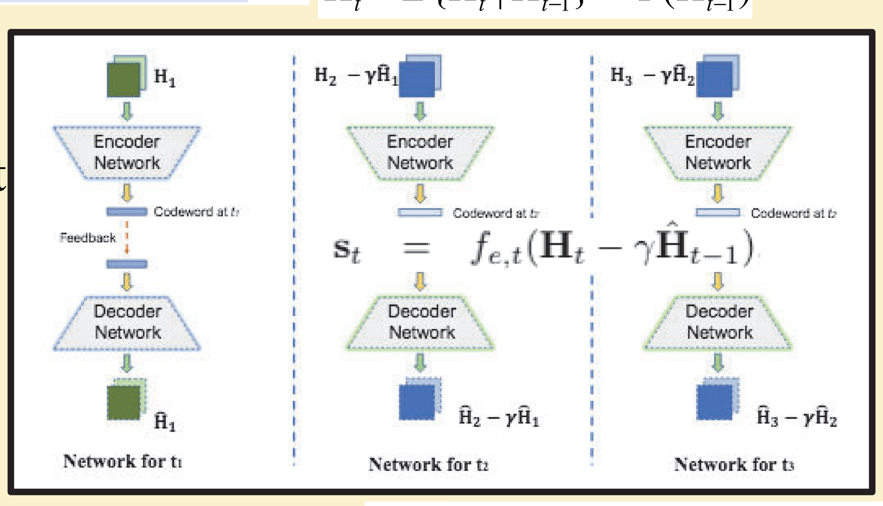
Encode Conditional CSI entropy $H(\mathbf{H}_t|\mathbf{H}_{t-1}) \le H(\mathbf{H}_t)$

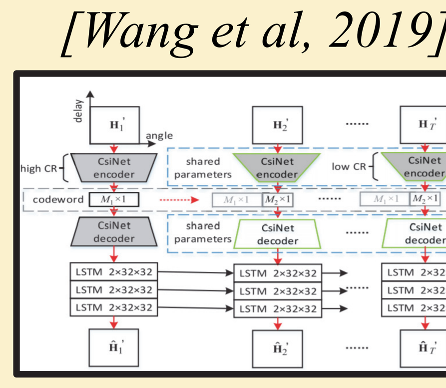


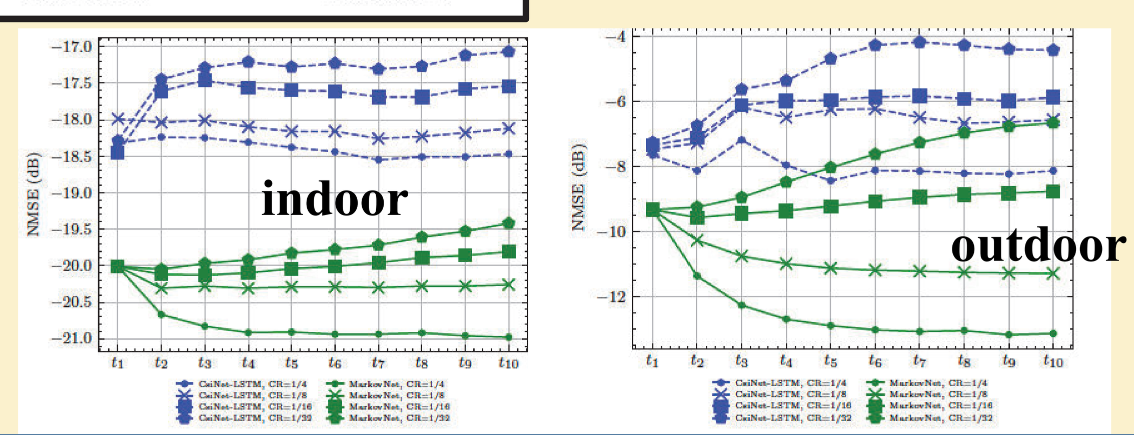
$\hat{\mathrm{H}}_t = E\{\mathrm{H}_t \mid \mathrm{H}_{t-1}\} = \Psi(\mathrm{H}_{t-1})$

CsiNet-LSTM [Wang et al, 2019]:

Markovnet [2021]:



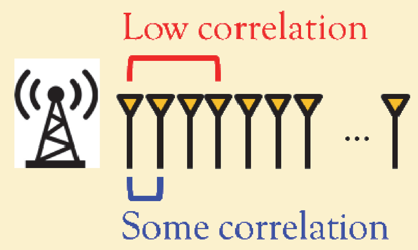




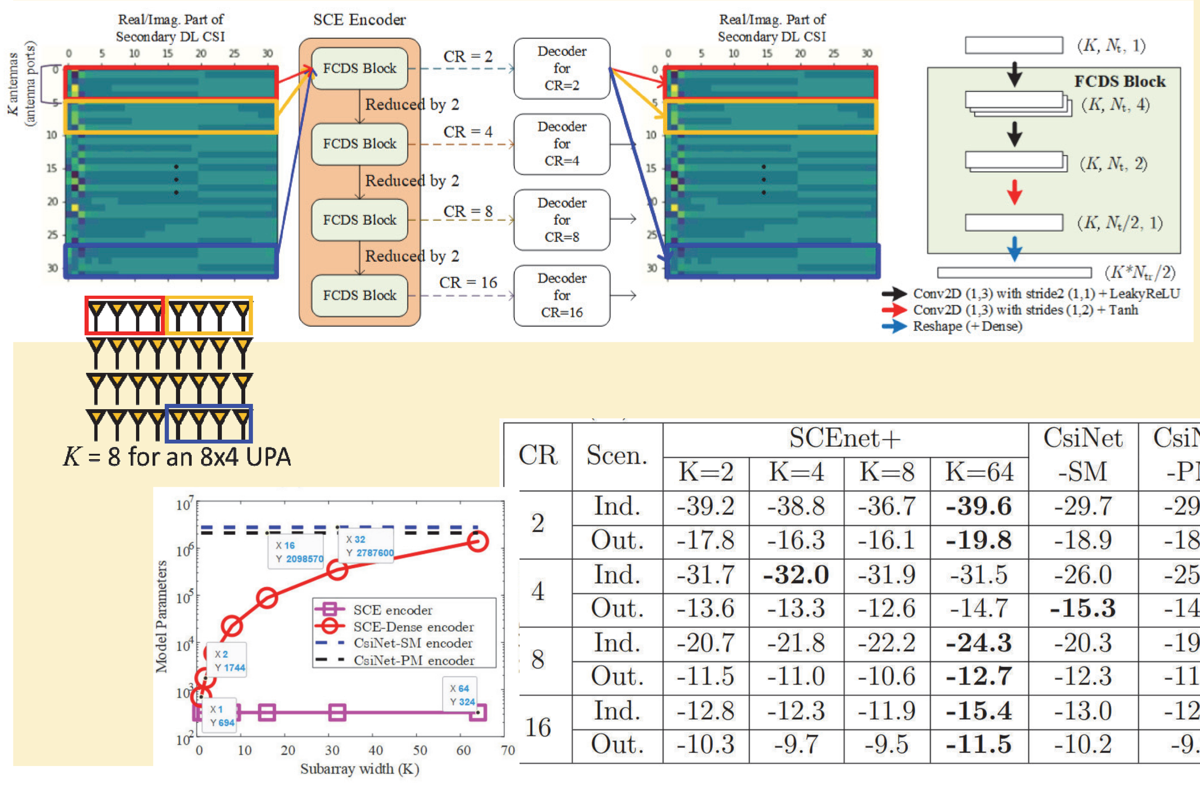
Low-complexity, scalable encoder (lightweight) (C3, C5):

Problems of existing CSI feedback

- Model size ∝ N_b^2
- Scalability: fixed input size & compression ratio



SCEnet [2023]: scalable, light-weight CSI feedback:



CR	Scen.	SCEnet+ K=2	SCEnet+ K=4	SCEnet+ K=8	SCEnet+ K=64	CsiNet -SM	CsiNet -PM
2	Ind.	-39.2	-38.8	-36.7	**-39.6**	-29.7	-29.8
	Out.	-17.8	-16.3	-16.1	**-19.8**	-18.9	-18.8
4	Ind.	-31.7	**-32.0**	-31.9	-31.5	-26.0	-25.9
	Out.	-13.6	-13.3	-12.6	-14.7	**-15.3**	-14.5
8	Ind.	-20.7	-21.8	-22.2	**-24.3**	-20.3	-19.1
	Out.	-11.5	-11.0	-10.6	**-12.7**	-12.3	-11.2
16	Ind.	-12.8	-12.3	-11.9	**-15.4**	-13.0	-12.0
	Out.	-10.3	-9.7	-9.5	**-11.5**	-10.2	-9.2

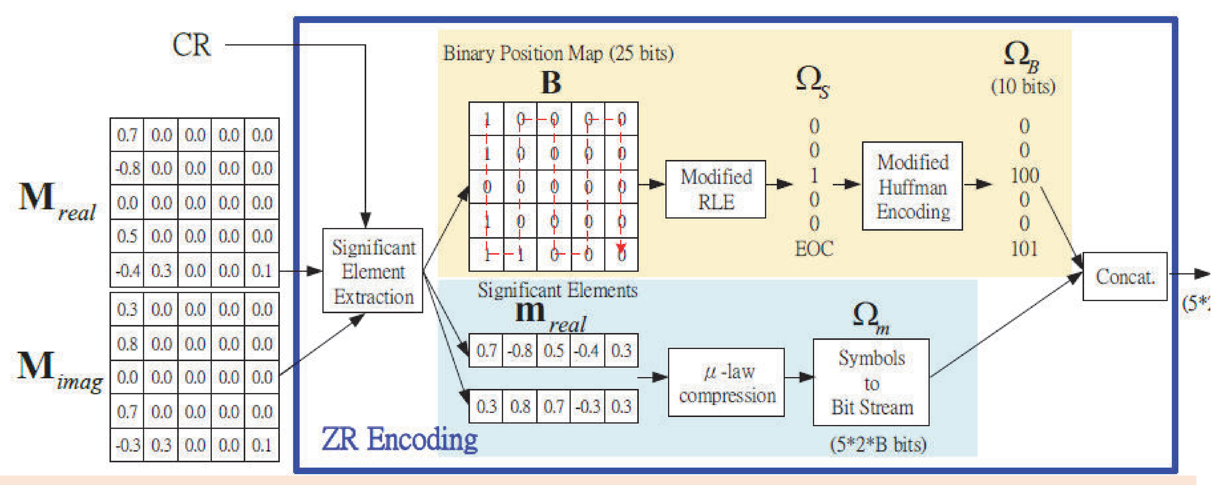
Training-free & model-driven light models (C4):

Additional problems of existing CSI feedback

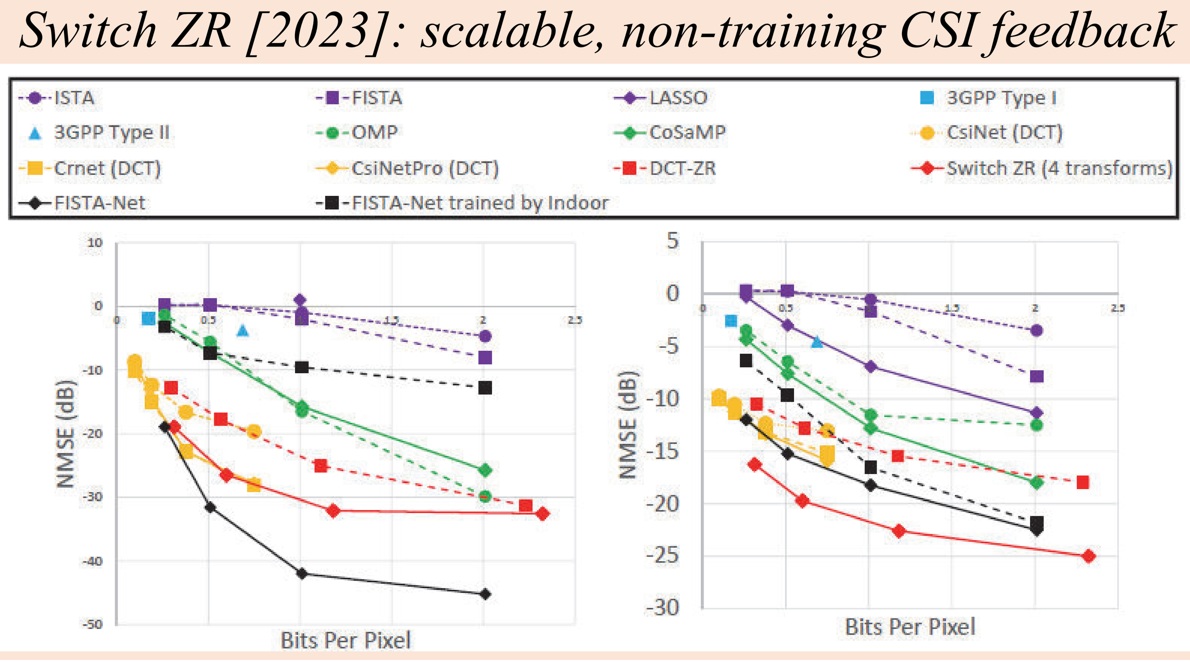
- Sensitive to CSI delay profile
- Cost of model retraining
- Overkill using large model

A low-complexity **training-free** generic encoding

- **depends on** its **delay sparsity** &
- **irrelevant** to its **delay profile**



Switch ZR [2023]: scalable, non-training CSI feedback



Publications:

[R1] Y. -C. Lin, Z. Liu, T. -S. Lee and Z. Ding, "Deep Learning Phase Compression for MIMO CSI Feedback by Exploiting FDD Channel Reciprocity," IEEE Wirel. Comm. Lett., 10(10): 2200-2204, Oct. 2021.

[R2] Y. -C. Lin, T. S. Lee and D. Zhi. "Exploiting Partial FDD Reciprocity for Beam Based Pilot Precoding and CSI Feedback in Deep Learning," under review, IEEE Trans. Wirel. Comm.

[R3] Z. Liu, M. del Rosario and Z. Ding, "A Markovian Model-Driven Deep Learning Framework for Massive MIMO CSI Feedback," IEEE Trans. Wirel. Commun., vol. 21, no. 2, pp. 1214-1228, Feb. 2022

[R4] Y. -C. Lin, T. S. Lee and Z. Ding, "An Efficient and Scalable Deep Learning Framework for Dynamic CSI Feedback under Variable Antenna Ports," under review, IEEE Trans. Wirel. Comm.

[R5] Y. -C. Lin, T. –S. Lee and Z. Ding, "Training-free Model-driven Low-complexity Models for Channel State Feedback in Massive MIMO FDD System," submitted to GLOBECOM 2023.

[R6] M. del Rosario and Z. Ding, "Learning-Based MIMO Channel Estimation Under Practical Pilot Sparsity and Feedback Compression," IEEE Trans. Wirel. Commun., vol. 22, no. 2, pp. 1161-1174, Feb. 2023.

[R7] Z. Liu, M. del Rosario, X. Liang, L. Zhang and Z. Ding, "Spherical Normalization for Learned Compressive Feedback in Massive MIMO CSI Acquisition," IEEE ICC Workshops, Dublin, Ireland, 2020, pp. 1-6

[R8] Y. -C. Lin, T. -S. Lee and Z. Ding, "Deep Learning for Partial MIMO CSI Feedback by Exploiting Channel Temporal Correlation," in Asilomar Conf., Pacific Grove, CA, USA, 2021, pp. 345-350.