

Smarter technology for all

3GPP TSG RAN Rel-18 workshop
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Study on AI/ML for Physical Layer Enhancement in Rel-18

Lenovo

Overview

Artificial Intelligence(AI)/Machine Learning(ML)

- Learn and perform certain tasks *via training neural networks* with vast amounts of data.
- Successfully applied in computer vision (CV) and nature language processing (NLP) areas.

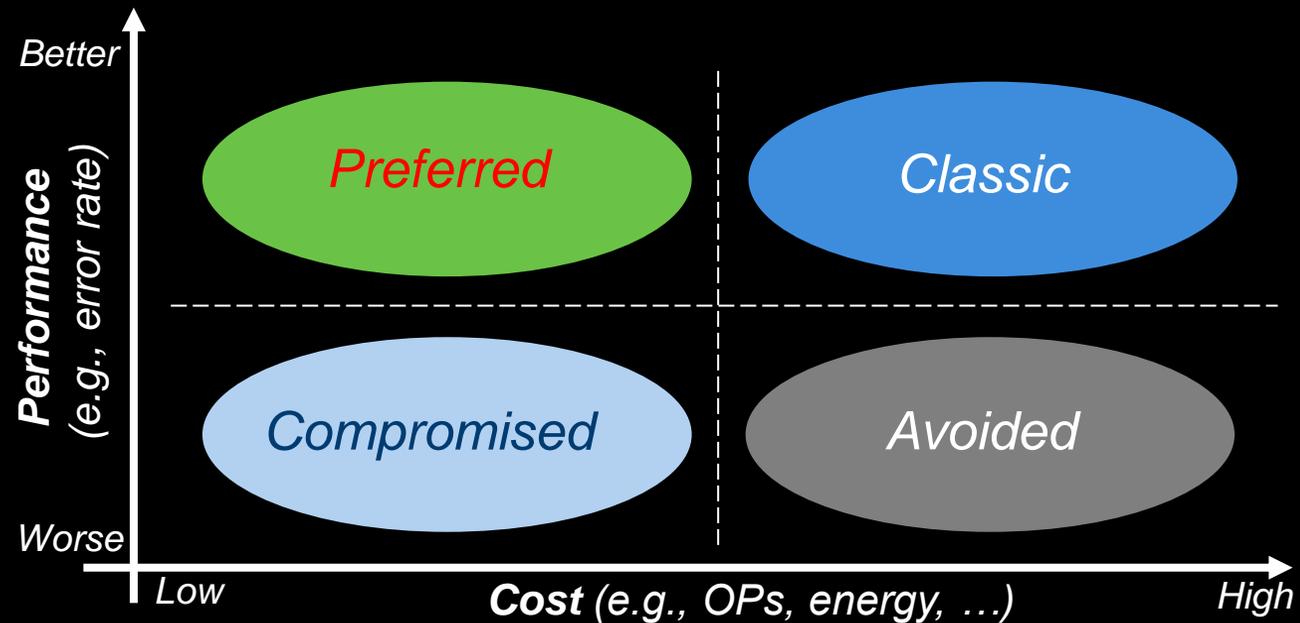
*The availability of **data** and **compute resources** play key roles for the AI/ML-based approaches to obtain good inference results.*

A typical physical layer in a wireless communication system

- Cascaded modules architecture for signal processing
- Develop algorithms based on the mathematic models

*The **model accuracy** and **algorithm complexity** play key roles for the signal processing to obtain good link performance.*

Preferred Solutions with AI/ML

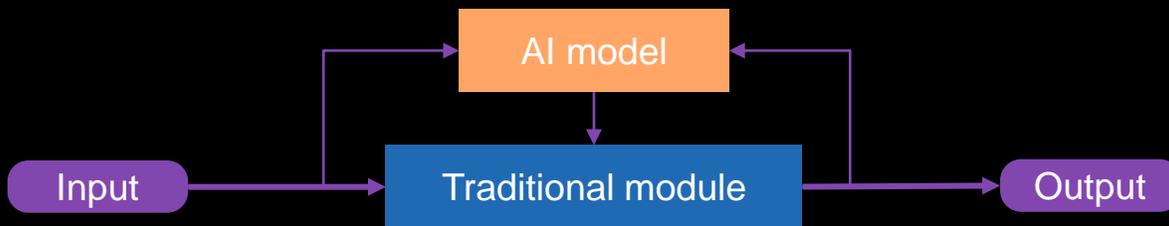


The solution with lower cost (e.g., overhead, complexity, energy) to obtain better expected performance (e.g., throughput, latency) is always preferred.

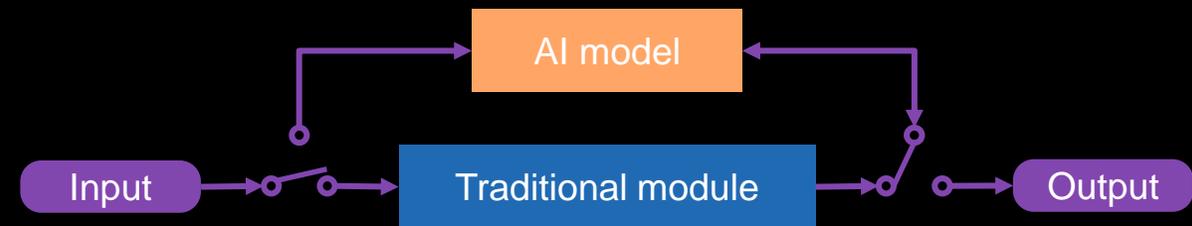
Motivation

To improve the link performance with AI/ML capability to assist or replace the traditional module, which has imprecise model and/or high solution cost.

- **Link performance**: throughput, block error rate, latency, ...
- **Imprecise model**: simplified or impractical assumptions, ...
- **Solution cost**: overhead, compute complexity, energy consumption, ...

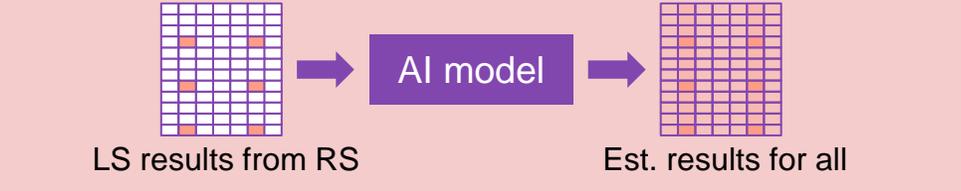
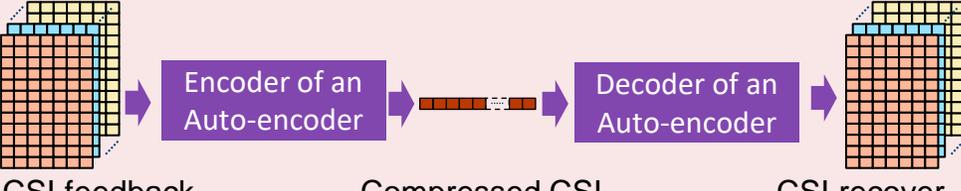
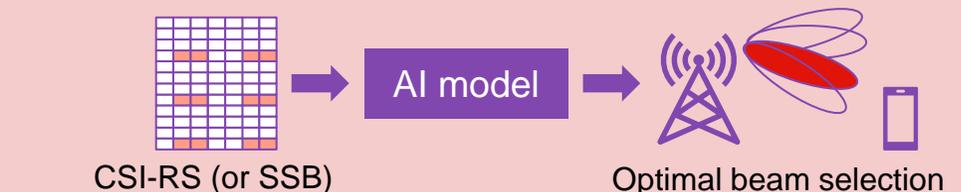
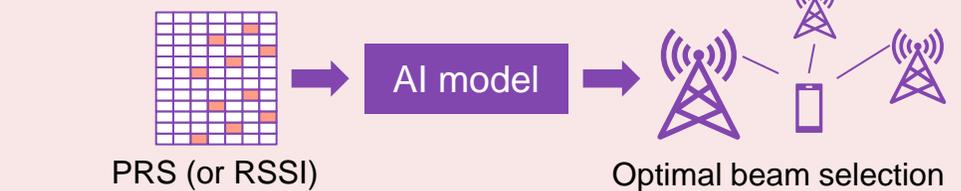


AI/ML-assisted scheme, which is used to refine the imprecise model, e.g., hardware impairment, to improve performance.



AI/ML-based scheme, which is used to replace the module with high complexity, e.g., CSI feedback with compress sensing.

Potential Improvements

Modules	Challenges to improve	Implementation example
Channel estimation	<ul style="list-style-type: none"> • Accuracy (i.e., quality) • Overhead of reference signals • Assumptions on the statistic models • Impairments (e.g., hardware) modeling 	 <p>LS results from RS → AI model → Est. results for all</p>
CSI feedback	<ul style="list-style-type: none"> • Flexible quantization • Overhead with many antennas • Effective compression and de-compression schemes 	 <p>CSI feedback → Encoder of an Auto-encoder → Compressed CSI → Decoder of an Auto-encoder → CSI recover</p>
Beamforming	<ul style="list-style-type: none"> • Optimal weights calculation • Overhead for beam acquisition, refining and switching 	 <p>CSI-RS (or SSB) → AI model → Optimal beam selection</p>
Positioning	<ul style="list-style-type: none"> • Accuracy and stability • NLOS propagation impact • Overhead of reference signals 	 <p>PRS (or RSSI) → AI model → Optimal beam selection</p>

Observations

If being well trained, the AI/ML-based method can be better than the traditional one.

- Learning **more accurate model** (e.g., correlation property, hardware impairment) via training.
- **Less RS overhead** needed to obtain the same performance.
- More **effective compression** via learning the sparse property in CSI.

The benefit is sensitive with the **dataset construction** for training.

- Considered factors for dataset generation, e.g., SNR, interference, mobility, delay spread.
- Whether the input signals are stationary or not has impact on the benefit.

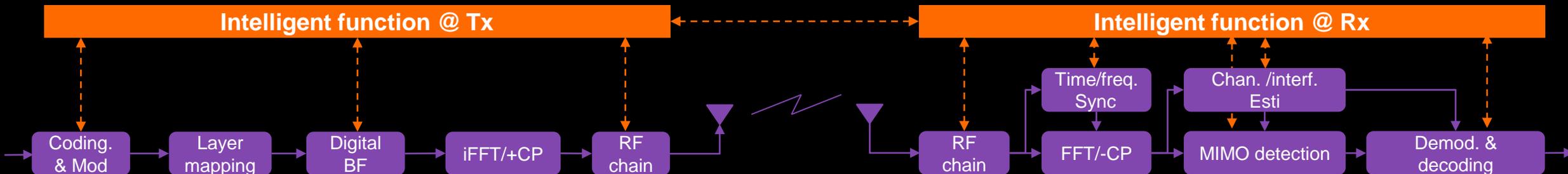
Different within CV/NLP, it is challenging for wireless physical layer to obtain the **ground-truth data** for supervise learning in practice.

- The reference signals can be used in physical layer as a kind of ground-truth.
- Note that it is impossible to obtain the ‘ideal’ channel information as the ground-truth.

Proposed Study Objectives

Study a general **framework** to involve AI/ML capability (i.e., intelligent function) within physical layer

- Study the potential improvements in each module within physical layer
 - Such as overhead reduction and estimation accuracy improvement.
- Define the intelligent function on physical layer and the interfaces to the modules
 - Including what data to be collected and generated for training and inference, respectively.



An illustration to introduce intelligent functions and interfaces with modules in physical layer.

Proposed Study Objectives (Cont.)

Study a common **evaluation methodology** on the AI/ML-based (or -assisted) approaches

- Construct the reasonable **dataset** for training, validation and test
 - Such as tuned results from defined channel models, field trial results, ...
- Study the **benchmarks** and **criteria for comparison**
 - Such as compute complexity, sensitivity with input data selection, ...

Study the potential **impacts on the specification enhancement.**

- Identify whether the proposal is an implementation issue or not.
 - Such as the local channel estimation improvement.
- Design the corresponding enhancement features, if needed.
 - Such as new signaling, interfaces, procedures or even new reference signals.

thanks.

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