Interference-Aware ML Receivers for Single-User MIMO LTE Systems

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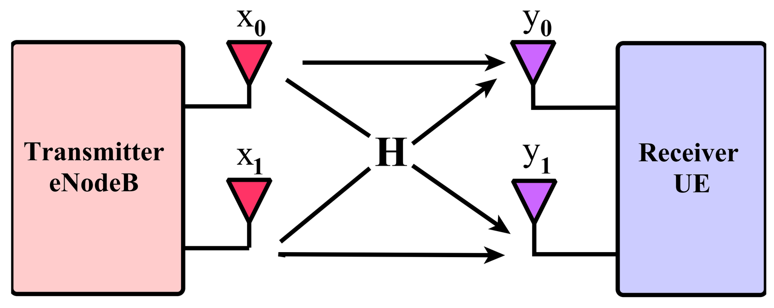
Motivation

Spatial Multiplexing
↪ increases throughput by multi-codeword transmission



Signal model of MIMO systems:

$$\mathbf{y} = \mathbf{HPx} + \mathbf{n}$$

Challenges in SU-MIMO:

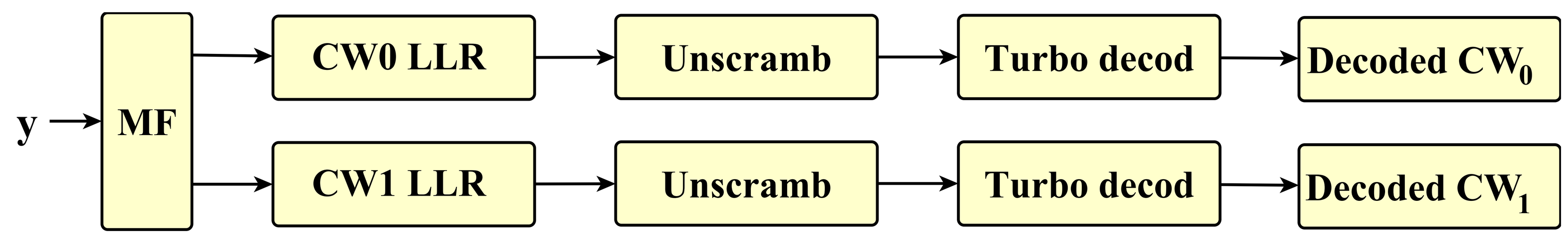
- resolve interference created by multiple streams
- compute Channel State Information in a fast and accurate way
- handle HARQ retransmissions for two codewords
- satisfy computational complexity requirements

Main Questions to Answer

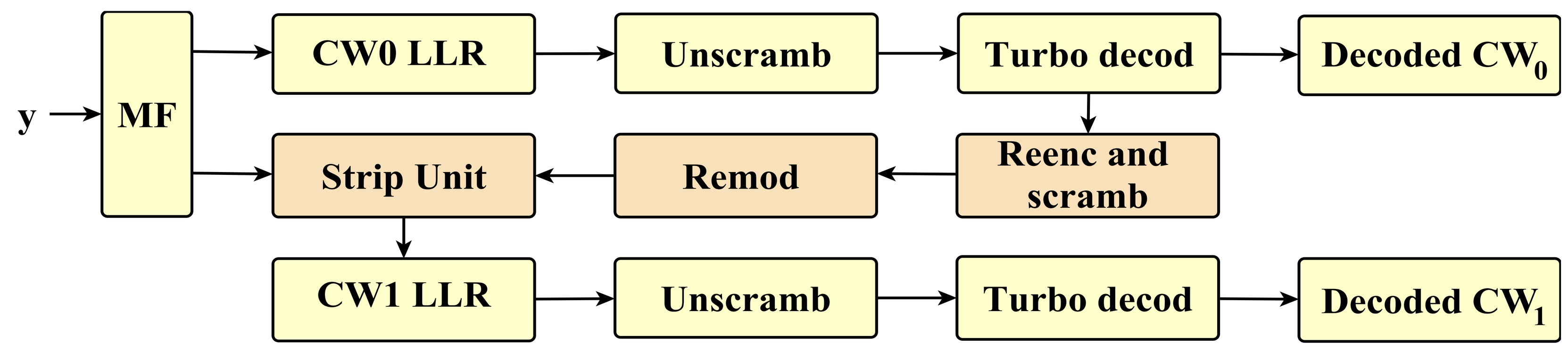
1. Are there low complexity receivers with near-optimal performance levels, that can be deployed in the real time systems?
2. How they can be integrated in practical systems, such as LTE?
3. How can they support essential protocols, such as Link Adaptation and HARQ?

Interference-Aware (IA) Architecture

Parallel Interference-Aware Receiver (PIA)



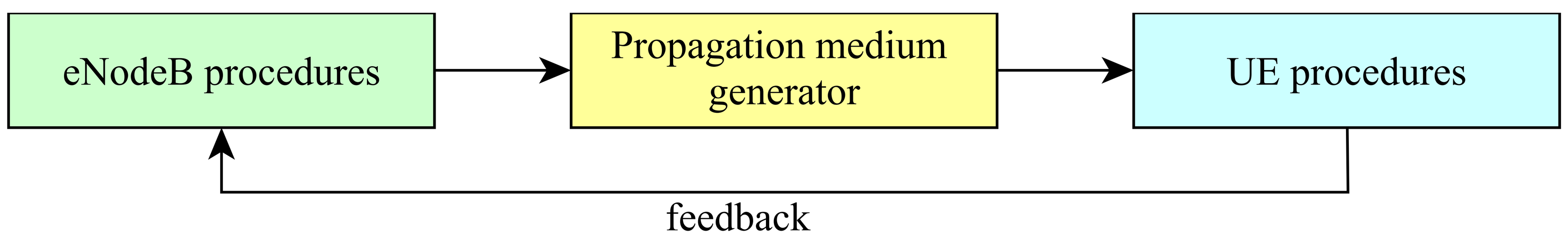
Successive Interference Canceling Receiver (SIC)



IA LLR metrics take into account interfering constellation and reduce complexity from dual to single stream [Ghaffar and Knopp, 2010].

3GPP-Complying Simulation Framework

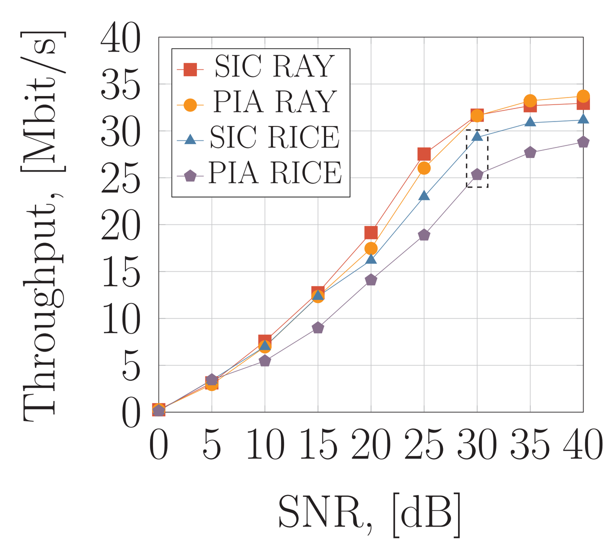
The downlink simulator is part of the OAI platform developed at Eurecom. Users can simulate, emulate, and run the LTE network in real time.

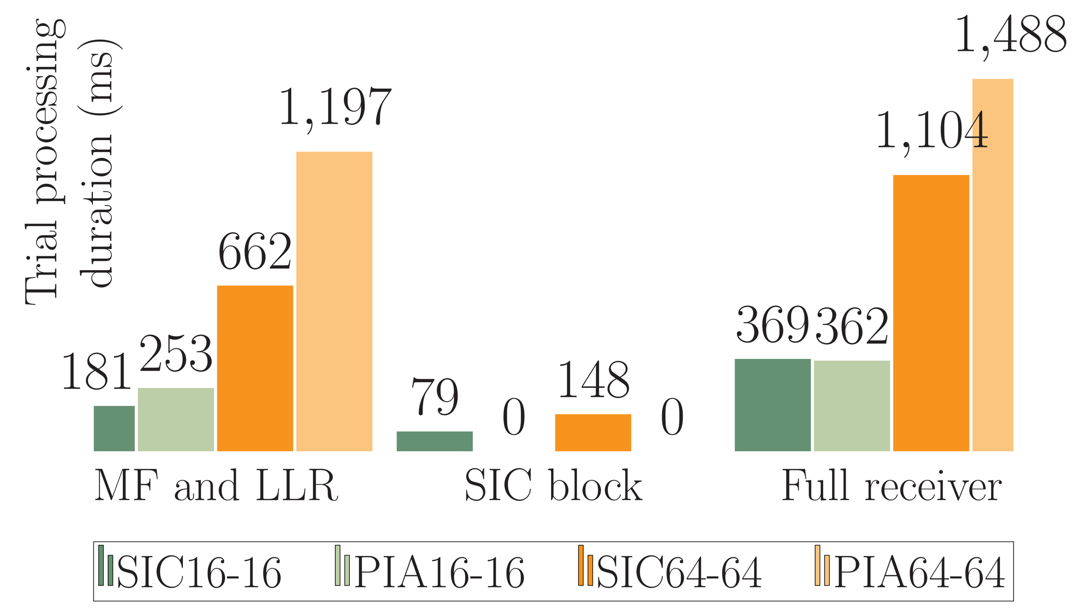


Open source simulator is written in C and is highly flexible:

- implement standard-complying features
- experiment with new ideas
- measure performance in terms of throughput, reliability, and complexity

Throughput and Computational Complexity





1. **The SIC receiver gains 4 Mbit/s in moderate and high SNR regime.**
2. **Our SIC receiver is 25% more time efficient than the PIA receiver.**

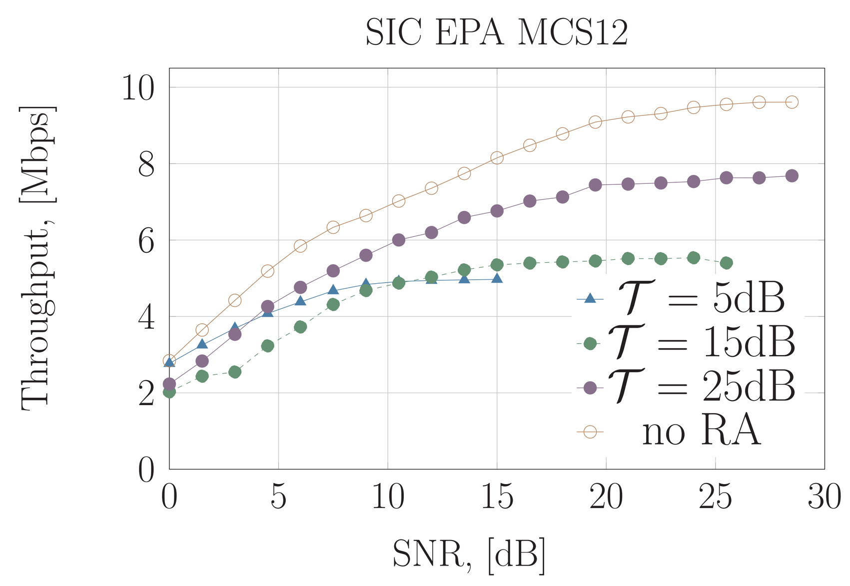
Link Adaptation for Interference-Aware Receivers

Rank Indicator (RI)

defines amount of spatial layers the receiver is able to efficiently support in current channel conditions.

The condition number $\kappa(\mathbf{H})$ a measure of efficiency of multi-layer transmission:

$\kappa(\mathbf{H}) < \mathcal{T}$, RI=2; $\kappa(\mathbf{H}) \geq \mathcal{T}$, RI=1.



Both receivers achieve high throughput when no rank adaptation is applied.

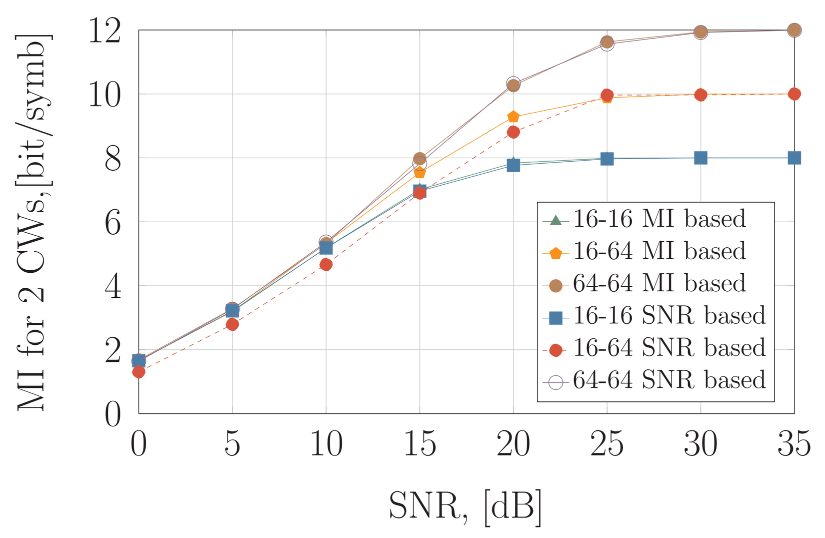
Precoder Matrix Indicator (PMI)

For TM 4 with 2 active antenna ports there are 2 precoding options:

$$\mathbf{P} \in \left\{ \frac{1}{2}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}, \frac{1}{2}\begin{bmatrix}1 & 1\\ j & -j\end{bmatrix} \right\}.$$

↪ **How to choose the optimal P?**

- max Mutual Information
- max SNR on 1st CW
  ↪ It is sufficient to compare the real and imaginary parts of correlation coefficient of $\mathbf{H}$



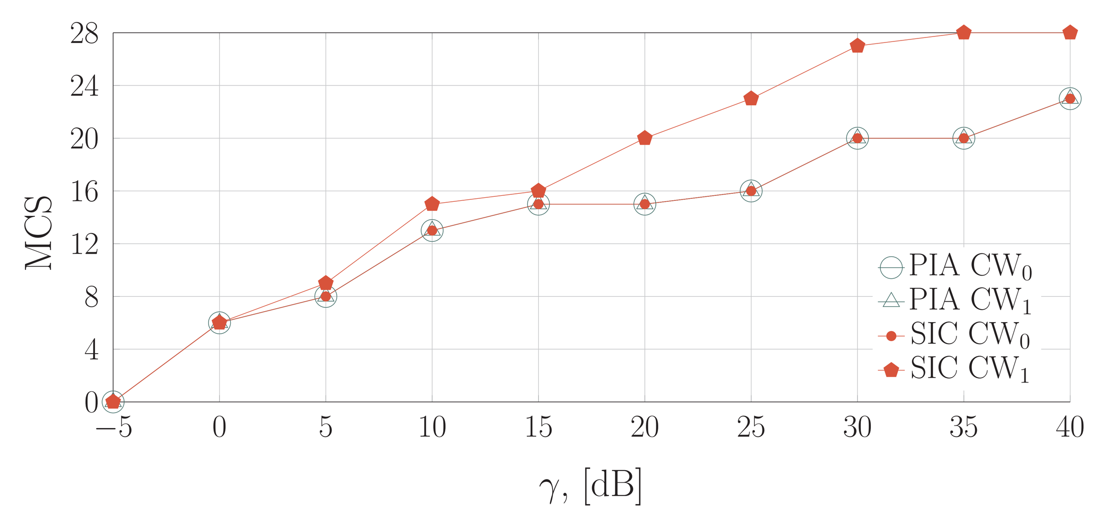
Channel Quality Indicator (CQI)

is a combination of the modulation order and the coding rate that can be supported by an instantaneous channel when BLER does not exceed 10%.

↪ **A unified solution for all propagation environments?**
↪ **How to estimate wideband or subband CQI?**

- Mutual Information [Schwarz and Rupp, 2011] (requires calibration, heavy look-up tables, depends on the channel model and the receiver architecture)
- post-processed SINR (challenging for ML-based MIMO receivers)

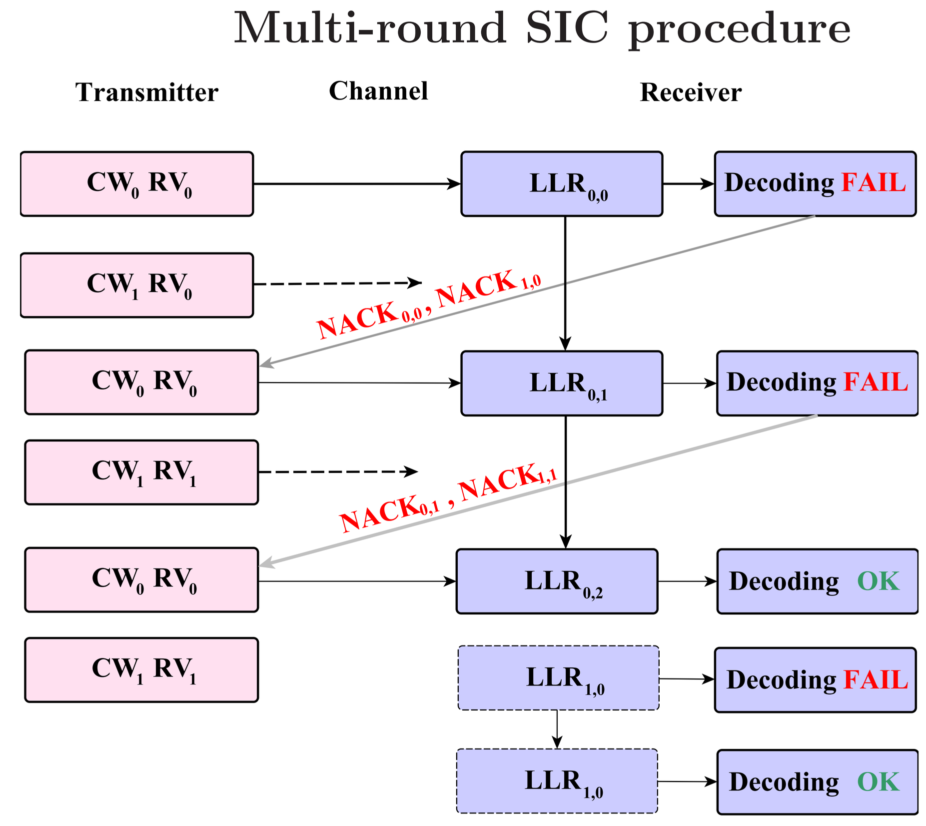
Our approach: approximate IA streams with MMSE receiver, and IF streams with IF receiver.



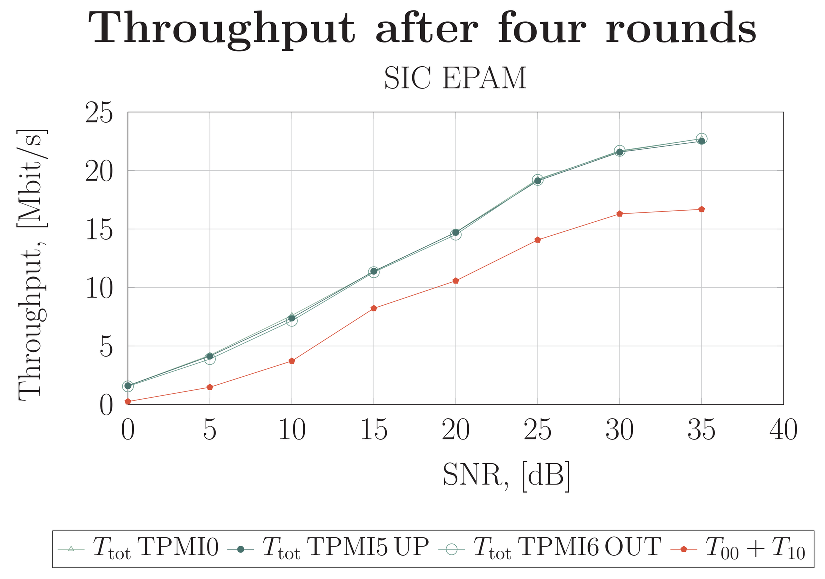
CQI values are higher for the interference-free stream than for the streams with interference.

Hybrid Automatic Repeat Request (HARQ)

Multi-round SIC procedure



Throughput after four rounds



The performance does not depend on the precoder used for the single codeword transmission.

Future Work

- test with full LTE stack and real-time transmission
- extend the obtained fundings to 5G New Radio
  ↪ 1 CW for 1 to 4-layer transmission
  ↪ 2 CWs for 5 to 8-layer transmission

Our Approach: practically feasible Block QR decomposition to reduce a 4×4 channel such that the interference is reduced to a 2×2 matrix and the existing LLR metrics can be used.