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Flexible and Robust Interference Management for the Congested EM Environment: Theory and Applications

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UDRC Themed Meeting

Outline

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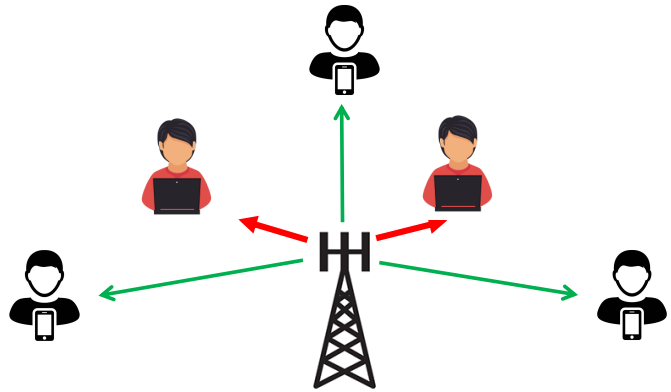
Major Challenges in Wireless Networks

The electromagnetic (EM) environment is increasingly congested. A major challenge in (civilian/military) wireless networks is the **management of radio-wave interference**:

- **Flexibility**: flexible to various levels of interference, user deployments and network loads.
- **Robustness**: robust to uncertainty of channel knowledge.

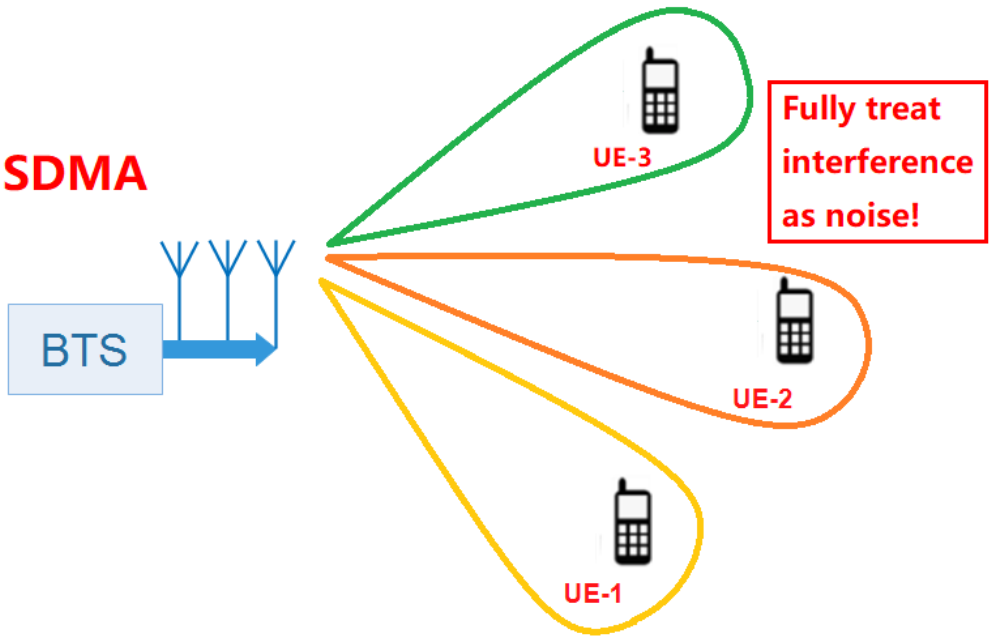


However, the fundamental limits of multi-antenna wireless networks with partial Channel State Information at the Transmitter (CSIT) are still unknown.

The Conventional (5G) Approach

Multiplex users in **spatial domain** using **Multi-User Linear Precoding** (MU-LP)

- Used in **Space Division Multiple Access (SDMA)**, MU-MIMO, network MIMO, millimeter-wave MIMO and massive MIMO



Information Theoretic Optimality

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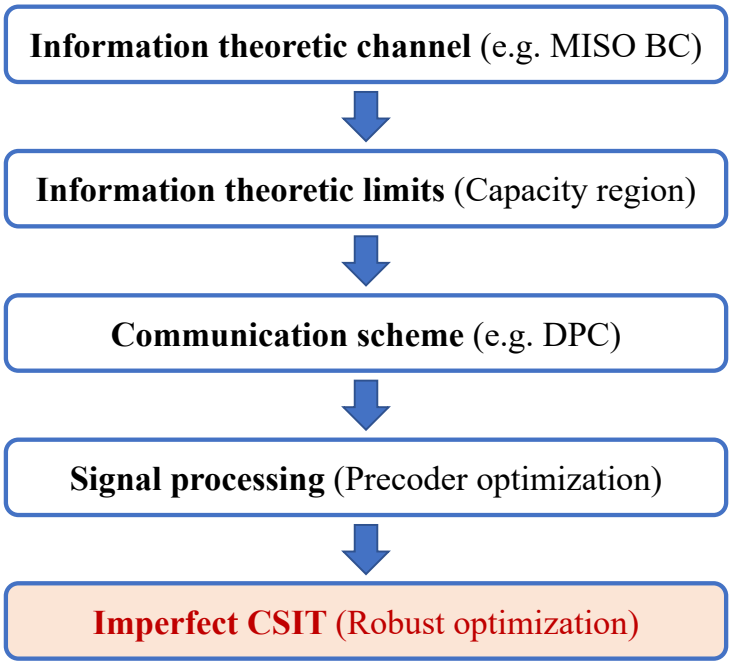
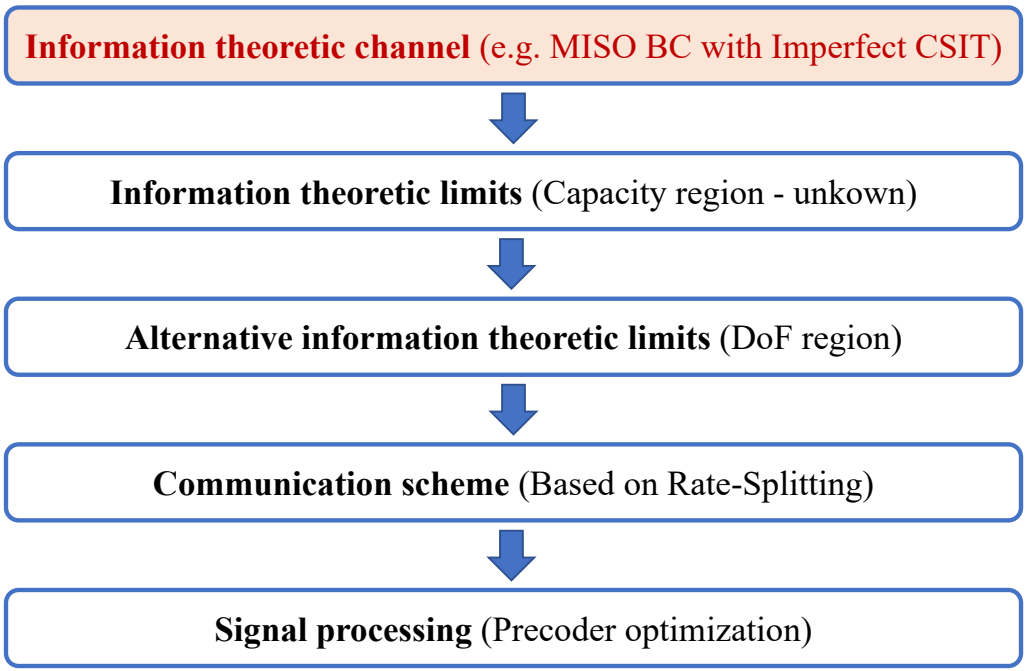




$$\mathbf{x} = \sum_{k=1}^{K} \mathbf{p}_k s_k$$

4G/5G approach

BUT perfect CSIT to start with!

$$\mathbf{x} = \mathbf{p}_c s_c + \sum_{k=1}^{K} \mathbf{p}_k s_k$$

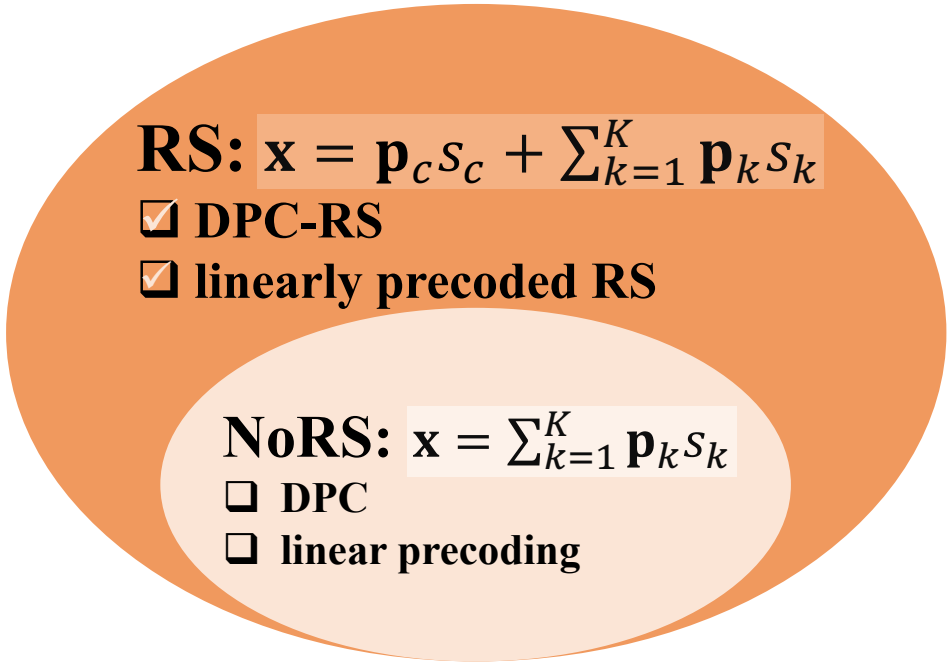
Rate-Splitting approach

Optimal (in a DoF sense)!

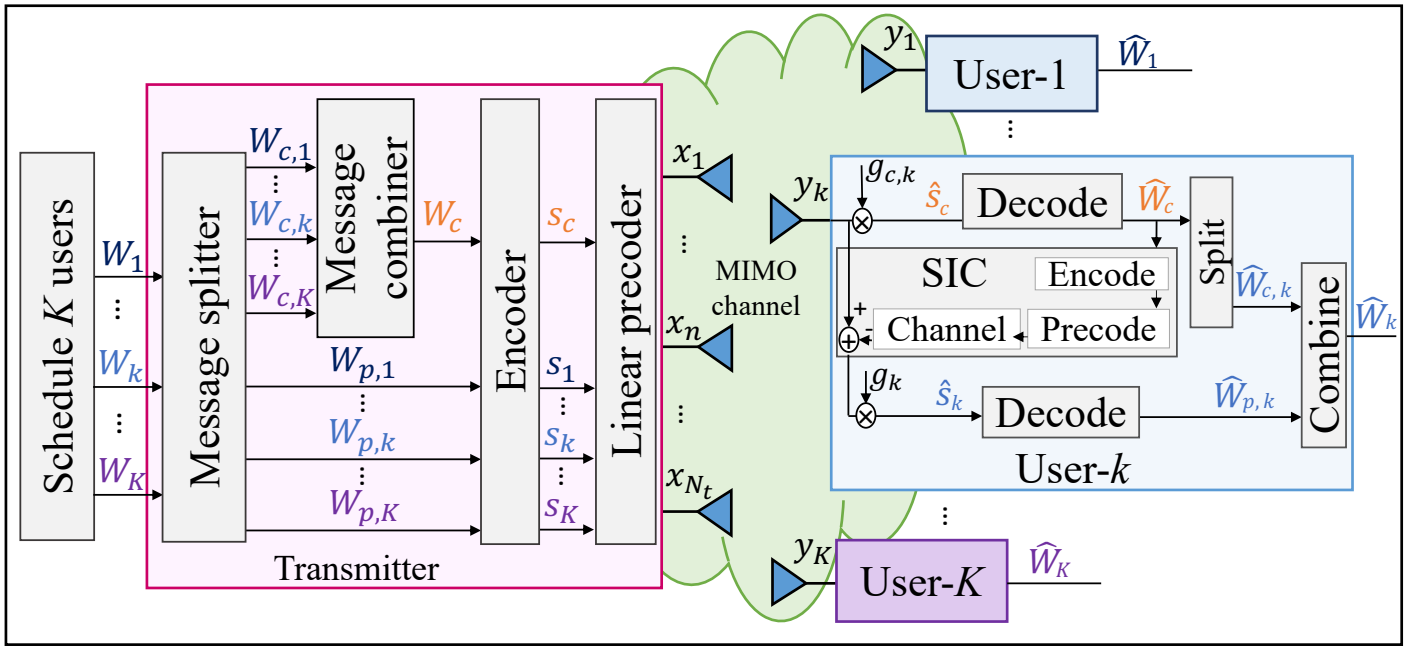
A bigger picture

- A more general problem

- A more general class of communication strategies



Split message W_k into two parts: **common** $W_{c,k}$ and **private** $W_{p,k}$.



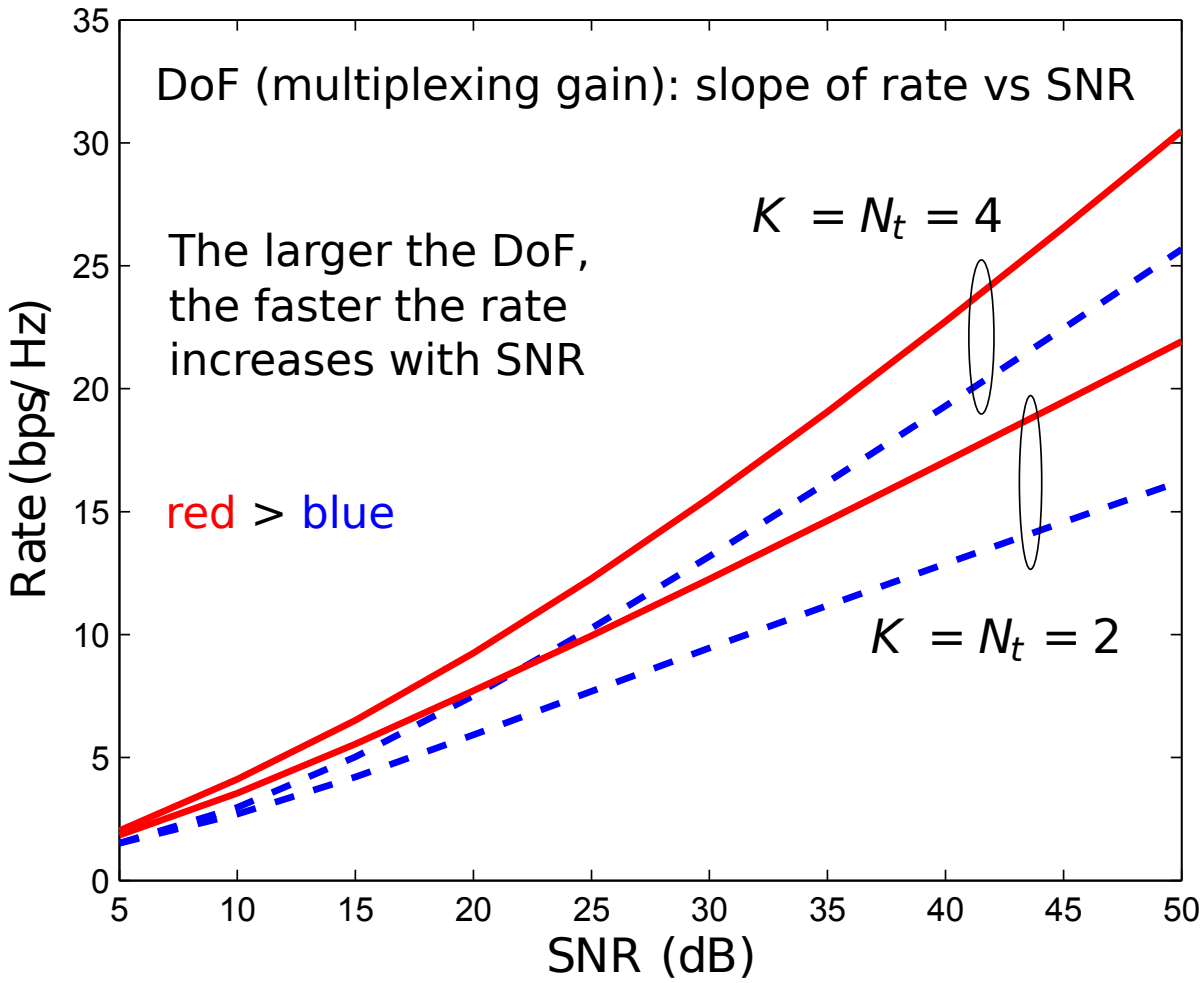
Rate of user-k has been **split**: rate of s_k + part of the rate of s_c

From K messages, we create $K+1$ streams.

All users decode s_c first, before decoding s_k (for user k)

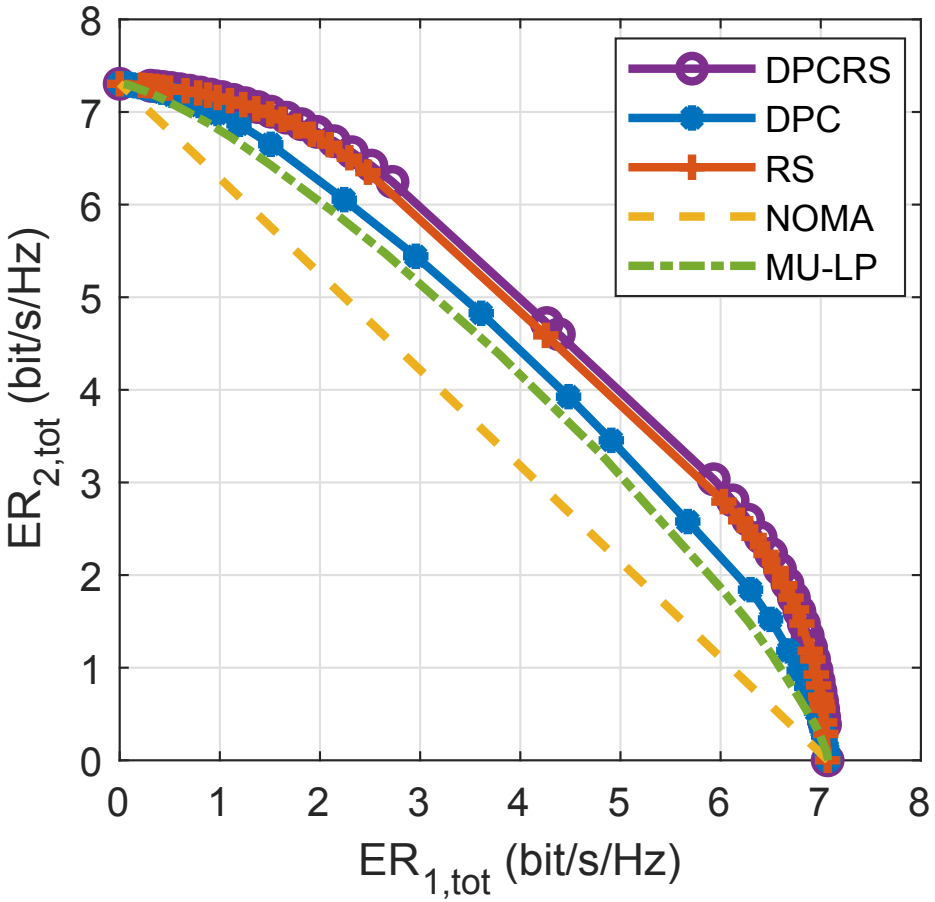
Users decode parts of the messages of other users and treat other parts as noise.

Degrees-of-Freedom (DoF) - Multiplexing Gains



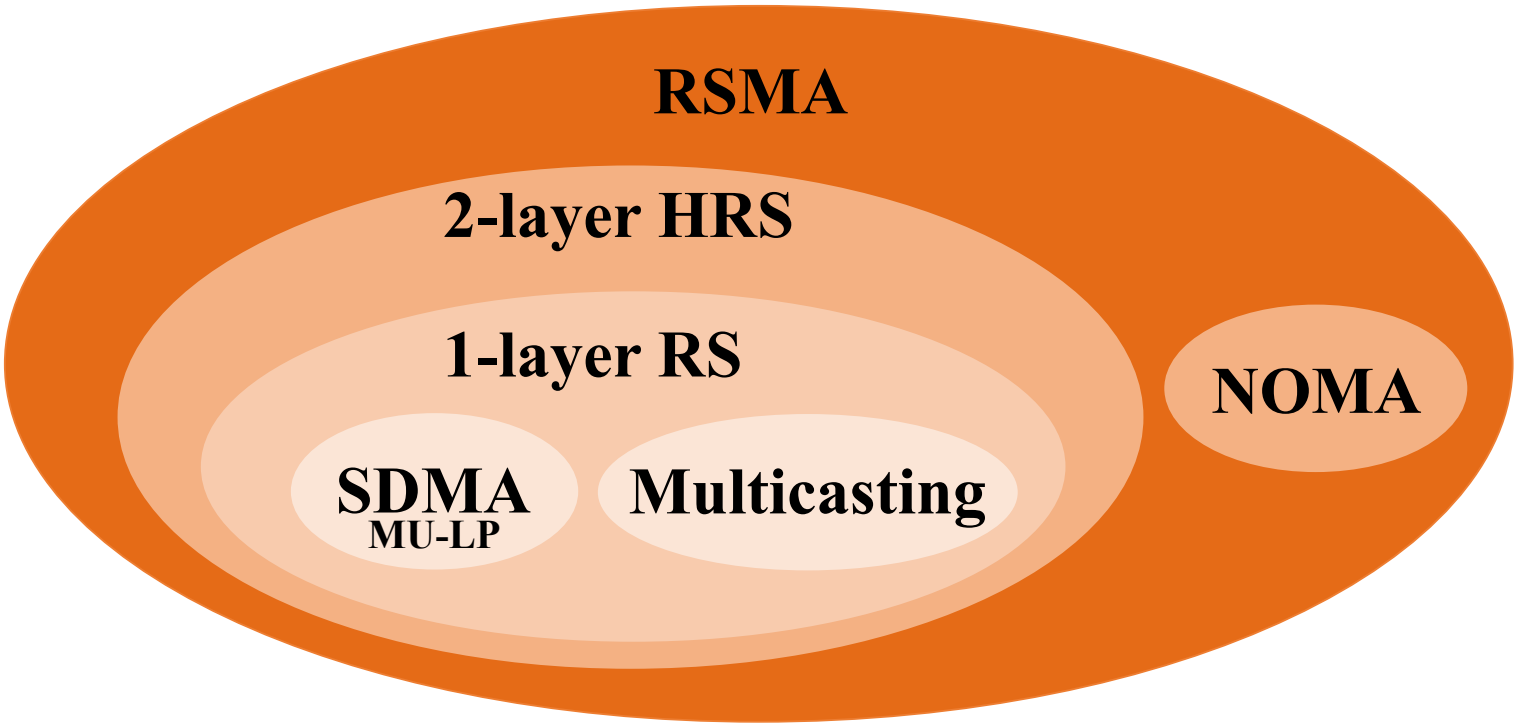
Rate: sum-rate $\sum_k R_k$, weighted sum-rate $\sum_k u_k R_k$, min rate $\min_k R_k$,...

Ergodic rate regions: $N_t = K = 2$, imperfect CSIT ($\sigma_e^2 = P^{-0.6}$)



RS schemes outperform MU-LP, NOMA and DPC!

A General and Flexible Multiple Access

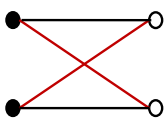


partially decode interference and partially treat interference as noise

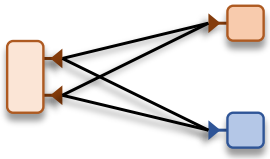
Outline

RS Applications

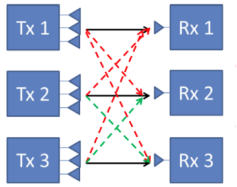
Interference Channel
[Carleial78], [Han and Kobayashi81]



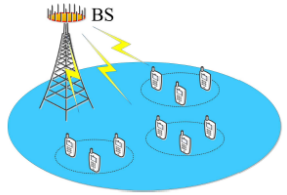
MU-MISO with Partial CSIT
[Yang et al.13], [Hao et al.15] ... etc.



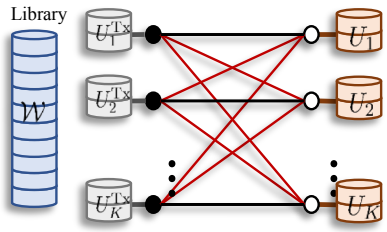
Multi-Cell MISO with partial CSIT [Hao and Clerckx16]



Massive MIMO with partial CSIT [Dai et al.16]



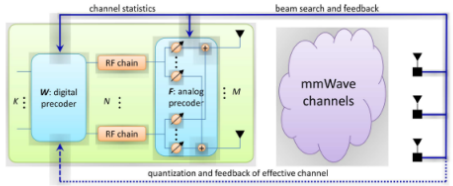
Robust Cache Aided Interference Management [Piovano et al.2017]



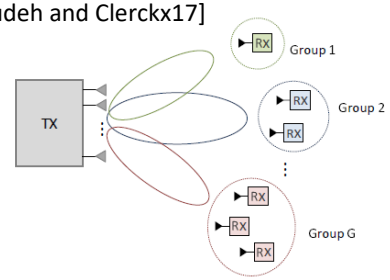
Rate Splitting

and its applications

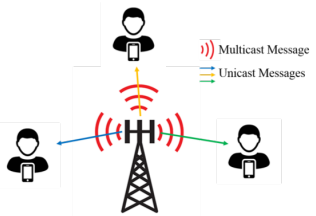
mmWave with limited feedback [Dai and Clerckx17]



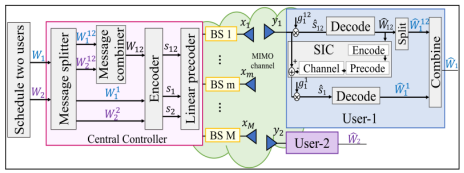
Multigroup Multicasting
[Joudeh and Clerckx17]



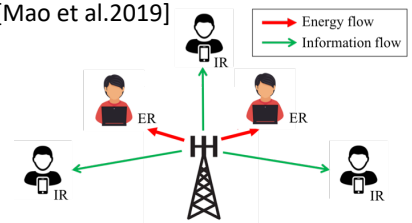
Joint unicast and multicast
[Mao et al.2018]



Coordinated Multipoint Joint Transmission
[Mao et al.2018]

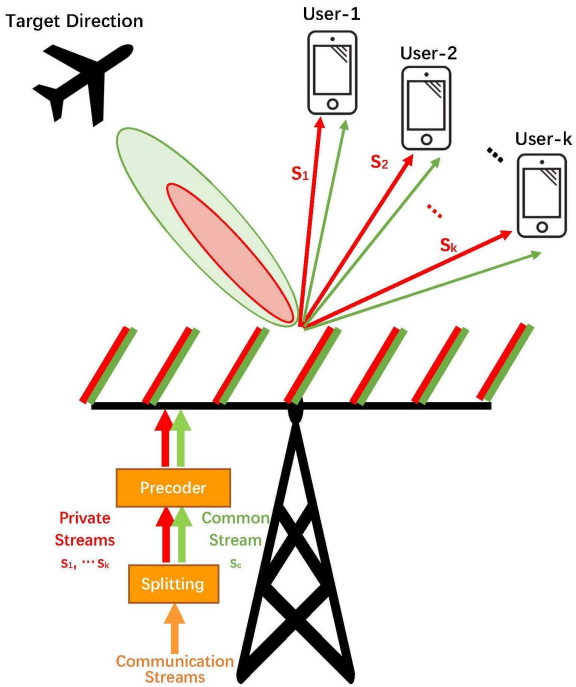


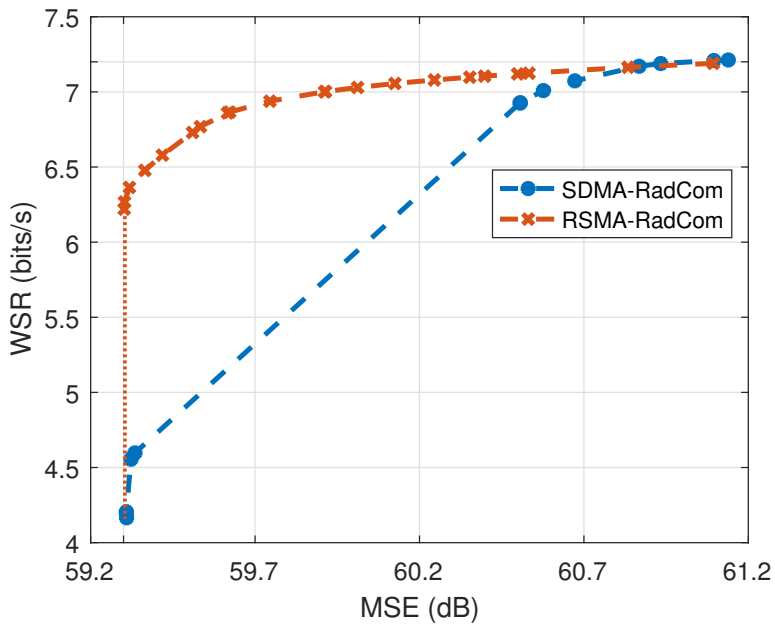
Simultaneous Wireless Information and Power Transfer (SWIPT)
[Mao et al.2019]



How to make the **best use of the spectrum** for the dual purpose of **sensing** and **communication**?

$\Rightarrow$ Find the strategy that achieves the best tradeoff between WSR and MSE.

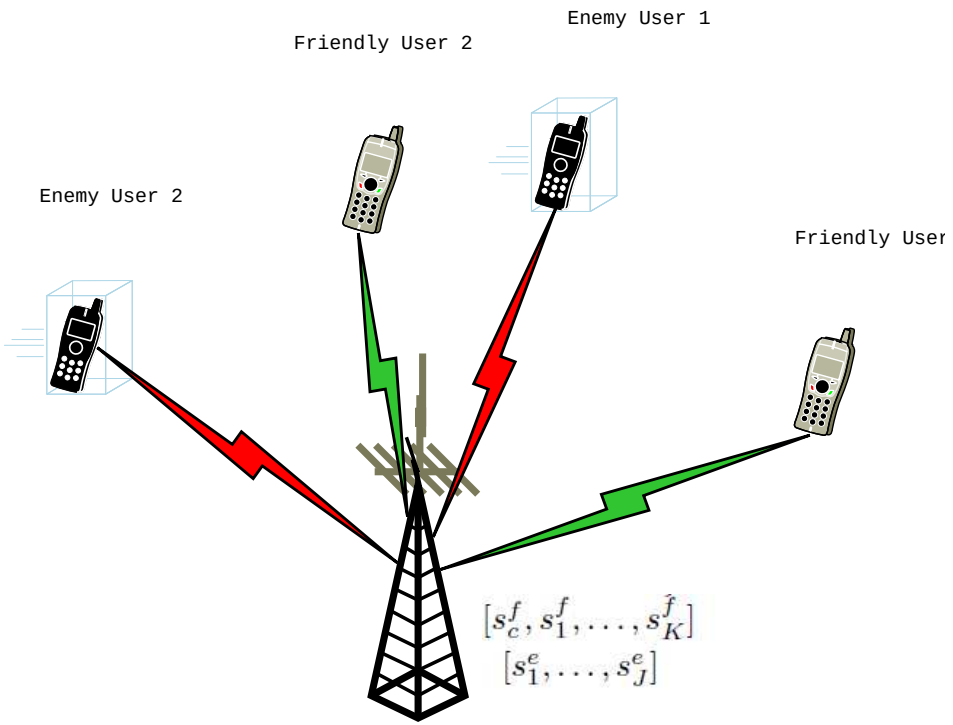




Superiority of RS: efficiently manage radar-communication interference, lead to larger WSR-MSE region

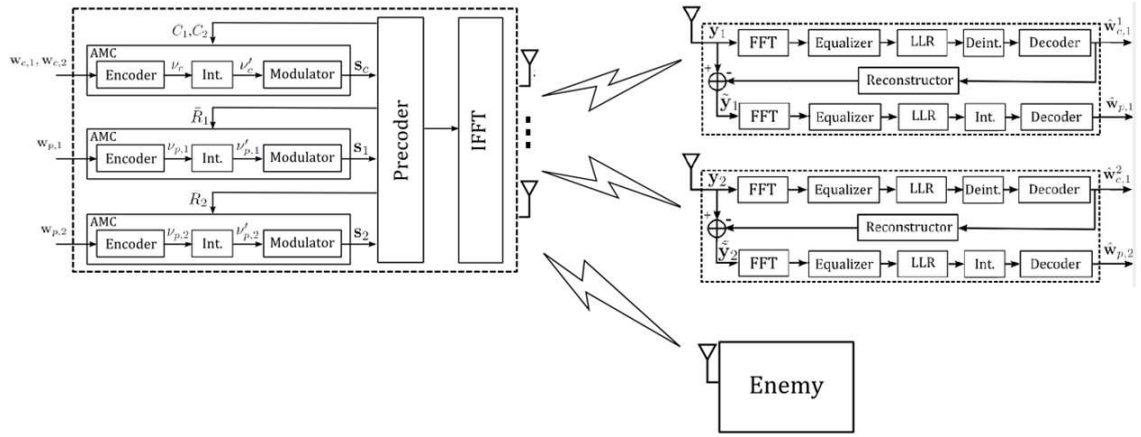
How to make the **best use of the spectrum** for the dual purpose of **jamming** and **communication**?

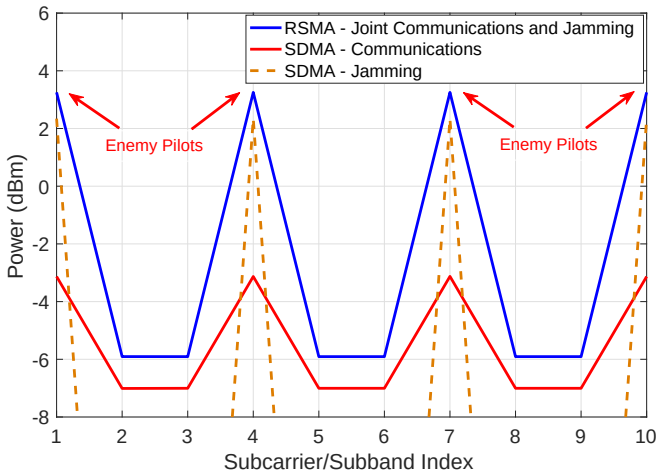
$\Rightarrow$ Find the strategy that achieves the best tradeoff between rate and jamming energy.

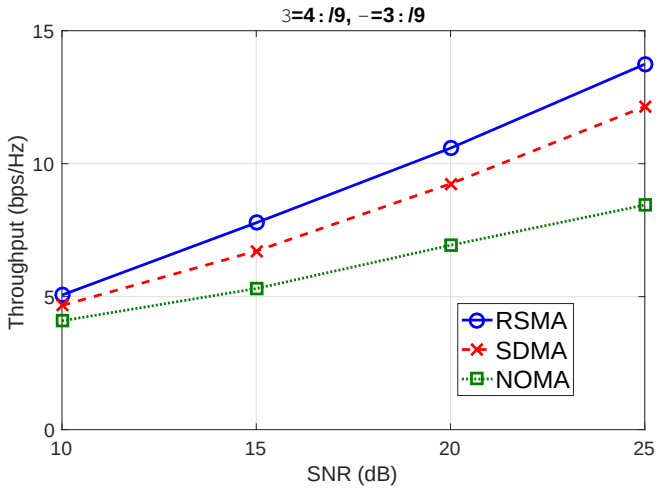


Waveform design for precise spatio-temporal signalling

$\Rightarrow$ Example : OFDM waveform design







Superiority of RS: performs simultaneous communication and jamming efficiently, achieves larger throughput

Outline

General Observations of RS/RSMA:

- **Partially** decode interference, **partially** treat interference as noise
- **Robust** interference management strategy
- **Flexible** non-orthogonal transmission strategy
- Powerful enabler of **unified** multiple access
- Fundamental changes to PHY and MAC layers
- Numerous potential applications in **defence**: precise spatio-temporal signalling, interference management, joint sensing/jamming and communications

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