Transmission strategies for interfering networks with finite rate and outdated channel feedback

Marc Torrellas, Adrián Agustín, Josep Vidal, and Olga Muñoz
Signal Processing and Communications Group, TSC, UPC

Motivation

Interference management is one of the key enablers envisioned for spectral efficiency boosting of next generation wireless systems. For systems working at high SNR, many strategies are tentative:

Avoid by means of orthogonalization

- **time:** TDMA
- **frequency:** FDMA

→ poor performance for high number of users

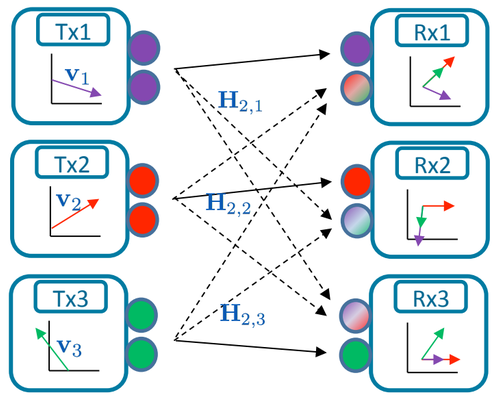
- **space:** Zero-Forcing

→ antennas must scale with the number of users

More efficient strategies: Interference Alignment

Interference Alignment (IA)

In the Interference Channel (IC) each transmitter serves only one receiver. Example: 3-user IC, 2 antennas (dimensions) per node, 1 symbol per user

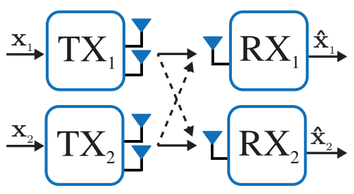


$$\mathbf{y}_j = \mathbf{H}_{j,j}\mathbf{v}_j\mathbf{x}_j + \underbrace{\left[\mathbf{H}_{j,j+1}\mathbf{v}_{j+1},\quad \mathbf{H}_{j,j-1}\mathbf{v}_{j-1}\right]}_{\text{aligned}} \begin{bmatrix}\mathbf{x}_{j+1}\\ \mathbf{x}_{j-1}\end{bmatrix}$$

Thanks to the interference alignment, each Rx can separate desired from interference signals (3 signals in 2 dimensions!)

Retrospective Interference Alignment (RIA)

Extension of IA for using only **delayed CSIT** (info about state of past channels). Suitable for high dynamics environments.
Example for the 2-user (2,1) IC (3 slots, 2 symbols per user):

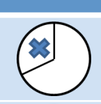
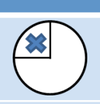
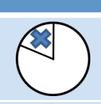
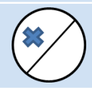


slot t	$y_1(t)$	$y_2(t)$
1	$\mathbf{h}_{11}^T(1)\mathbf{V}_1\mathbf{x}_1$	$\mathbf{h}_{21}^T(1)\mathbf{V}_1\mathbf{x}_1 \equiv L_1(\mathbf{x}_1)$
2	$\mathbf{h}_{12}^T(2)\mathbf{V}_2\mathbf{x}_2 \equiv L_2(\mathbf{x}_2)$	$\mathbf{h}_{22}^T(2)\mathbf{V}_2\mathbf{x}_2$
3	$h_{11}(3)L_1(\mathbf{x}_1) + h_{12}(3)L_2(\mathbf{x}_2)$	$h_{21}(3)L_1(\mathbf{x}_1) + h_{22}(3)L_2(\mathbf{x}_2)$
Decoding	$\begin{bmatrix}\mathbf{h}_{11}^T(1)\\ h_{11}(3)\mathbf{h}_{21}^T(1)\end{bmatrix}^{-1}\begin{bmatrix}y_1(1)\\ y_1(3)-h_{12}(3)y_1(2)\end{bmatrix}$	$\begin{bmatrix}\mathbf{h}_{22}^T(2)\\ h_{22}(3)\mathbf{h}_{12}^T(2)\end{bmatrix}^{-1}\begin{bmatrix}y_2(2)\\ y_2(3)-h_{21}(3)y_2(1)\end{bmatrix}$

Thanks to delayed CSIT, in slot 3 the past **overheard interference** can be reconstructed. At the end, 2 lin. combinations of 2 desired symbols obtained per user!!

IA gives everybody *half the cake*

The multiplexing gain or degrees of freedom (DoF) represent the efficiency: number of symbols delivered per user and channel use

# users	3	4	5	$K \to \infty$
TDMA				$\frac{1}{K}$
RIA				$\frac{1}{K}\frac{4}{6\ln 2-1} \approx \frac{1.26}{K}$
IA				$\frac{1}{2}$

For single-antenna terminals, IA gives each user half the DoF of the single-user case

DoF of the 3-user MIMO IC [1]

N/M	1	2	3	4	5	6
1	[0.4, 0.5] □					
2	2/3 ○	1 ○				
3	1 ○	6/5 ●	3/2 ○			
4	1 ○	4/3 ○	12/7 ●	2 ○		
5	1 ○	5/3 ○	2 ○	20/9 ●	5/2 ○	
6	1 ○	2 ○	2 ○	12/5 ○	30/11 ●	3 ○

○ state-of-the-art
● solved in this thesis
□ remains open

M: # of transmit antennas
N: # of receive antennas

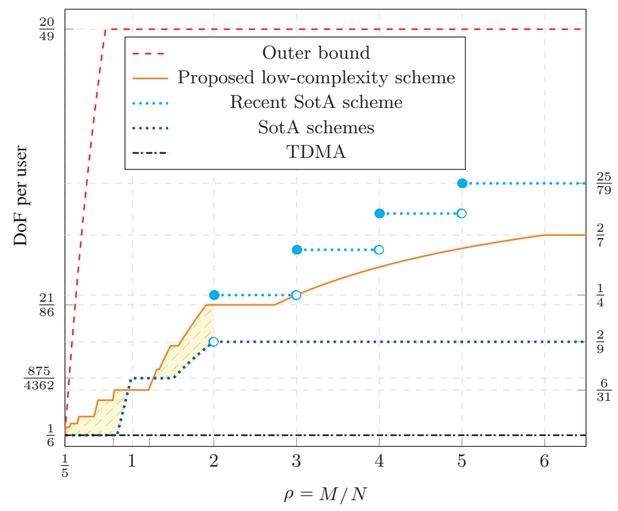
Optimal DoF attained for all
$$(M, N) = (p, p+1)$$
The same for
$$(M, N) = (p+1, p)$$
due to the reciprocity concept

Only SISO case remains open

DoF of the MIMO IC with delayed CSIT [2]

The IC with delayed CSIT has been studied in terms of DoF, by proposing 3 transmission strategies. Example for $K = 6$ users:

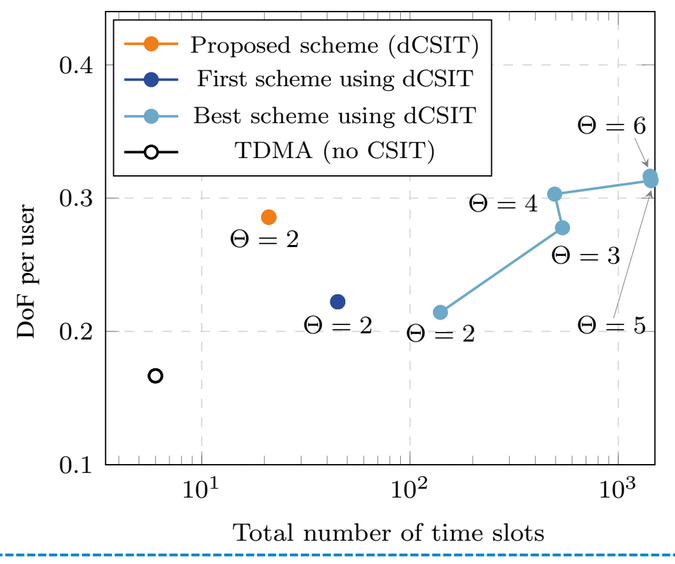
For dashed regions, our scheme improves the DoF achieved by any previous state-of-the-art



DoF-delay trade-off [2]

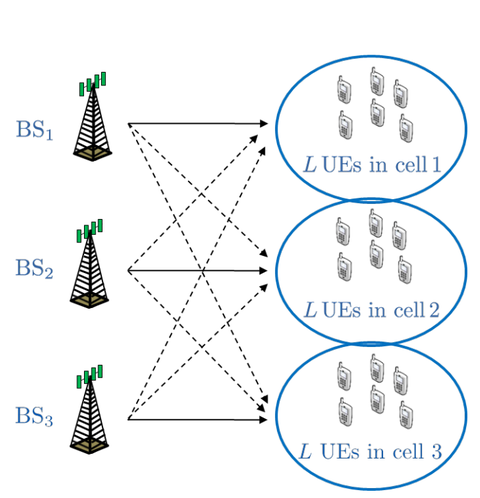
Most delayed-CSIT based techniques require long transmissions, thus increasing complexity and latency of the communication

In the example, it is shown that our low-complexity proposed scheme does not achieve the best DoF gains, but brings most of the benefits of delayed CSIT at a lower latency

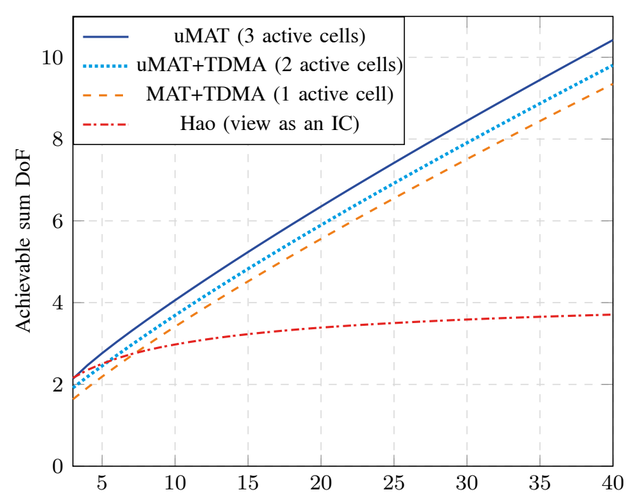


The IBC with delayed CSIT [3]

We propose uncoupled MAT (uMAT): a scheme exploiting embedded BCs in the IBC by means of MAT (optimal scheme for the BC)



L-user 3-cell Interference Broadcast Channel



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[1] "The DoF of the 3-user$(p, p+1)$ MIMO Interference Channel", IEEE Trans. on Communications, Nov. 2014
[2] "Achievable DoF-delay trade-offs of the K-user MIMO Interference channel with delayed CSIT", IEEE Trans. Inf. Theory, Sept 2016
[3] "Uncoupled MAT scheme for the MISO Interference Broadcast Channel", *in preparation*, Feb. 2016
Full list of publications and PhD thesis can be found at https://spcom.upc.edu/index.php?user=marc