Gains vs. cost of RRH clustering in 5G CRAN

Muhammad Mahboob Ur Rahman, KTH

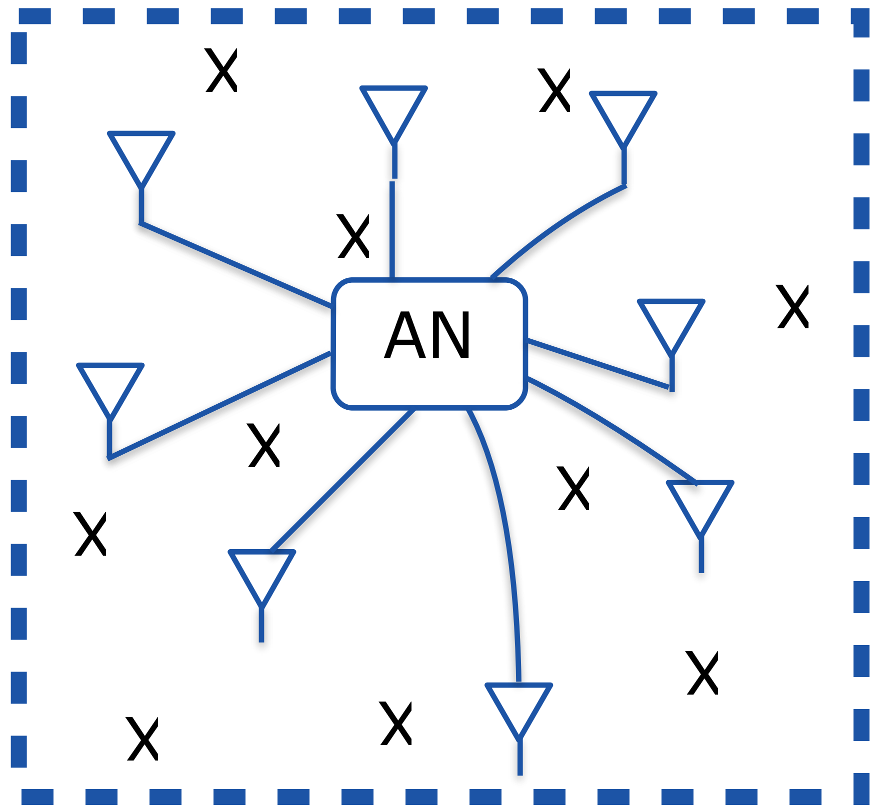
June 25, 2015 @ Alcatel-Lucent labs, Stuttgart

Acknowledgements

- work done while being at KTH
- thanks to my collaborators: Prof. James Gross, Hadi Ghauch, Sahar Imtiaz
- acknowledge funding and support from Huawei, Finland

CRAN

- no central base station - RRH's distributed all over the AD
- RRH's connected to AN via fast backhaul
- on the downlink, users need to be served, on slot basis
- offers novelties for resource allocation



Motivation for RRH clustering

- Sole **purpose** of cooperation is interference management.
- **Cost** is data sharing, local/global CSI sharing, carrier synchronization, cluster formation overhead etc.

This work: evaluate the gains in sum rate due to RRH clustering followed by ZFBF/CB precoding, cost is piloting overhead

Related work:

- CoMP, JT, CB (clustering of neighboring cells)
- HetNets (clustering of small cells)
- CRAN (clustering of RRHs)

Outline

- Problem statement: Gains vs. cost of coordination among RRHs in 5G CRAN
- Algorithms implemented
- Piloting overhead: The cost for coordination
- Performance evaluation
- Conclusions

Assumptions & Performance metric

Assumptions:

- N (M-antenna) RRHs, K (single-antenna) users
- LOS, correlated channels with Rician fading
- saturating traffic at AN
- perfect and global CSIT is available at AN
- K <= MxN (i.e., no user selection), rank(H) = K
- Zero-forcing/coordinated beamforming precoding by AN
- Equal power allocation among transmit antennas
- No user mobility

Performance metric:

- Shannon's mapping from SINR to data rate
- sum rate is the main performance metric

Overview of the work done

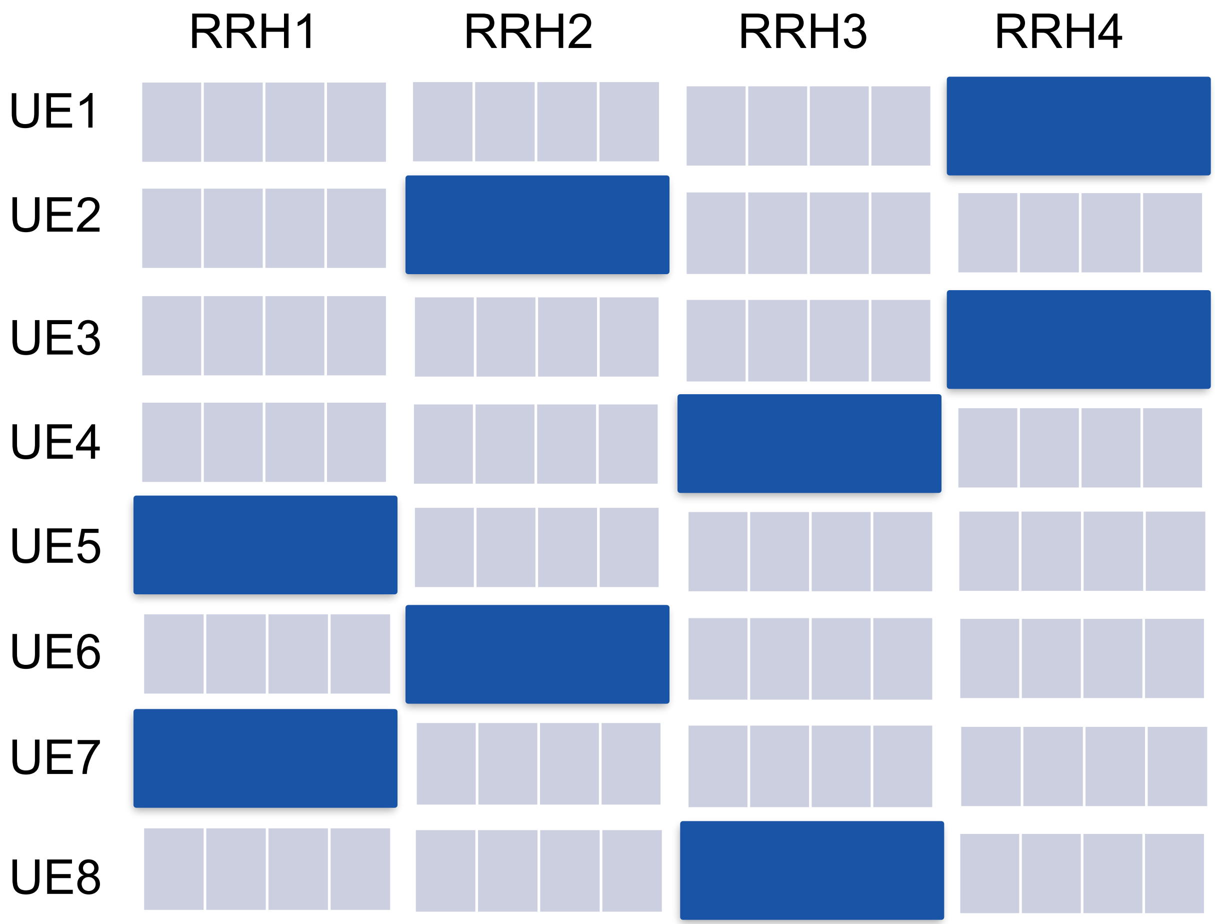
Problem: investigate the trade-off between the performance gain due to RRH clustering against the coordination overhead

Our approach: do user association (J<=M users per RRH), followed by RRH clustering, followed by transmit precoding

Three cases:

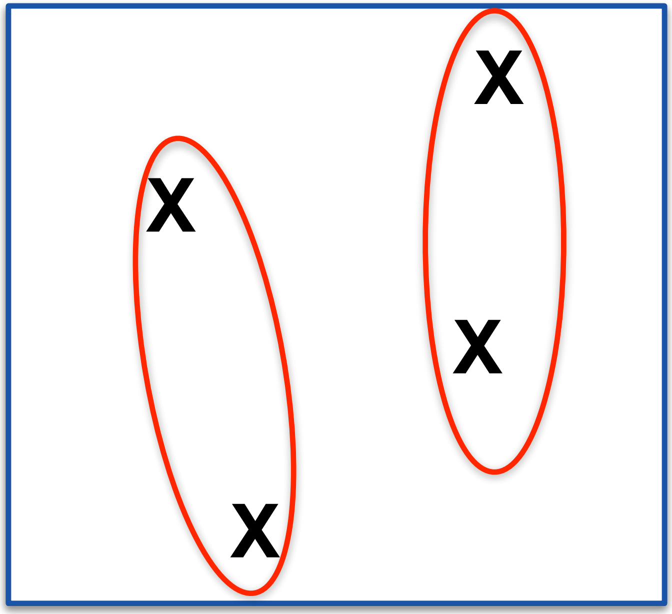
- **No coordination (NC) among RRHs**
  - ZFBF precoding per RRH
- **Local coordination (LC) among RRHs**
  - ZFBF precoding per cluster
  - coordinated beamforming (CB) per cluster
- **Global coordination (GC) among RRHs**
  - ZFBF precoding per Antenna domain

User association algorithm



RRH clustering algorithm

N=4, B=2, C=2



Piloting overhead: The cost of coordination

- Coordination overhead is driven by either, over the air, carrier synchronization overhead, or, CSI acquisition overhead
- Carrier synchronization overhead
  - driven by the stability specs of users'/RRHs' clocks
- CSI acquisition overhead
  - driven by the users' speed
- Let PF represent the piloting frequency of the system
- Then, the overhead is: KxPF training symbols/sec
- The cost-adjusted objective function is:

$$R_{\Sigma} = \left(\frac{W - \Omega}{W}\right) \sum_{k=1}^{K} \log_2(1 + \gamma_k(\Omega))$$

Performance evaluation - Simulation Setup

AD construction:

N=24, M=4, AD side-length=250 m, ISD=50m, K=480, K_sel=48 (after user selection)

Channel and path-loss model:

$$h_{mn;k} = \frac{\eta_{mn;k}\sqrt{\zeta_{mn;k}}}{\sqrt{d^{\alpha}_{mn;k}}}$$

$$PL_{mn;k}(dB) = 36.3 + 37.6\log_{10} d_{mn;k}(m)$$

Performance evaluation - Simulation Setup

Spatial correlation:

Kronecker product model with exponentially decaying correlation

Transmit-side correlation:

Intra-RRH correlation:

$$[\mathbf{R}_{Tx,n}]_{p,q} = \rho_t^{|p-q|}$$

Inter-RRH correlation:

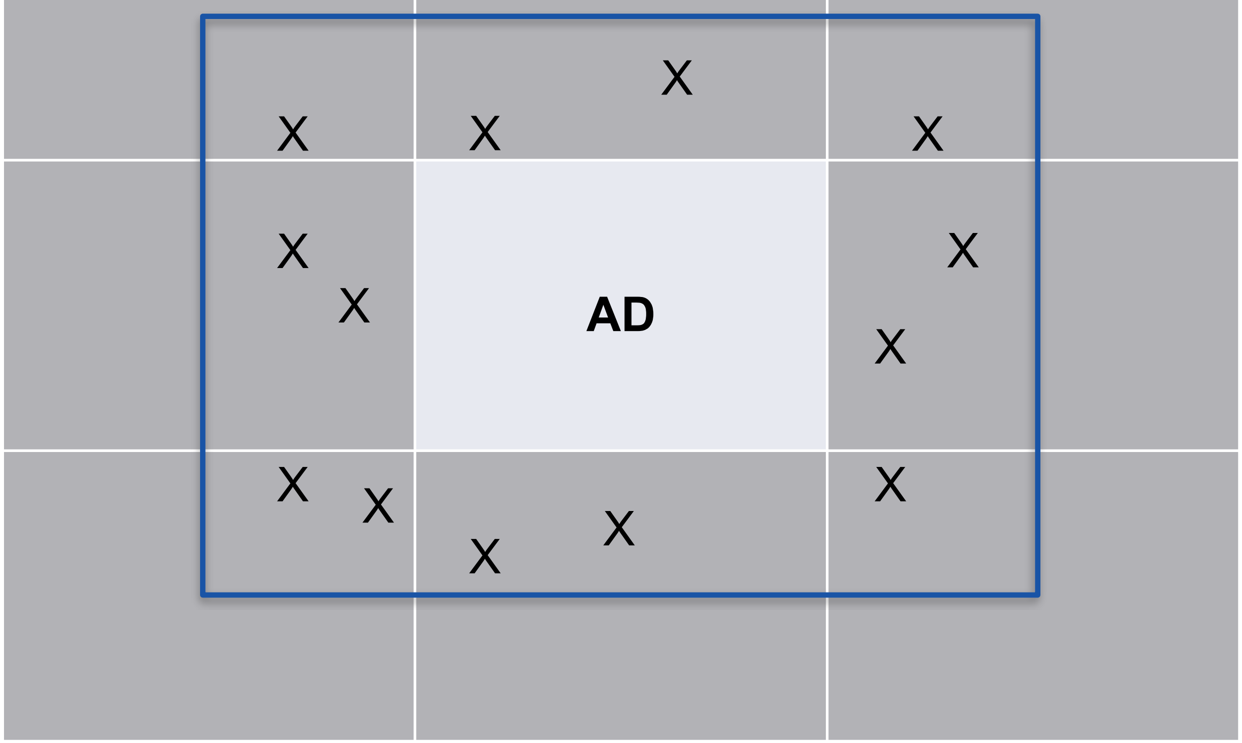
$$[\mathbf{R}_{Tx}]_{i,j} = \rho_t'^{\lceil d_{ij}/d_{min} \rceil}$$

Receive-side correlation:

$$[\mathbf{R}_{Rx}]_{i,j} = \rho_r^{\lceil d_{ij}/d_{min} \rceil}$$

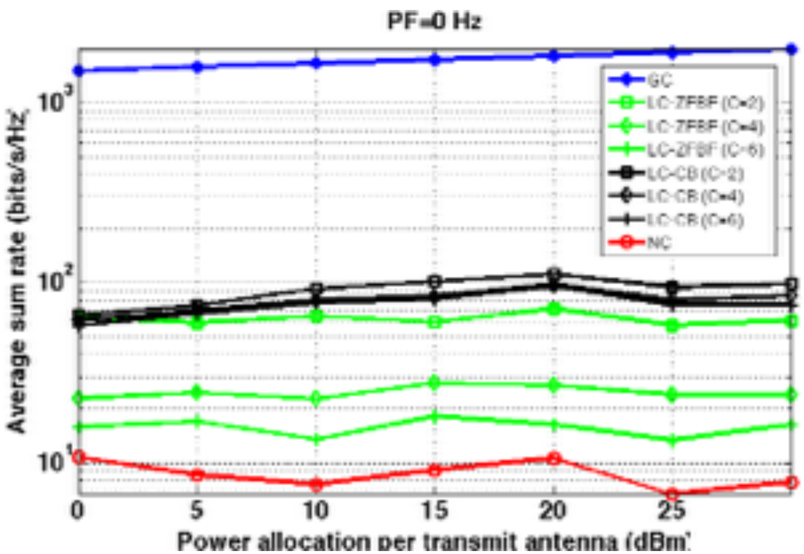
Inter-AD interference model

N_int=3N additional RRHs around the periphery of considered AD, which serve their own K_int=(N_int*M)/2 users using Global ZFBF.

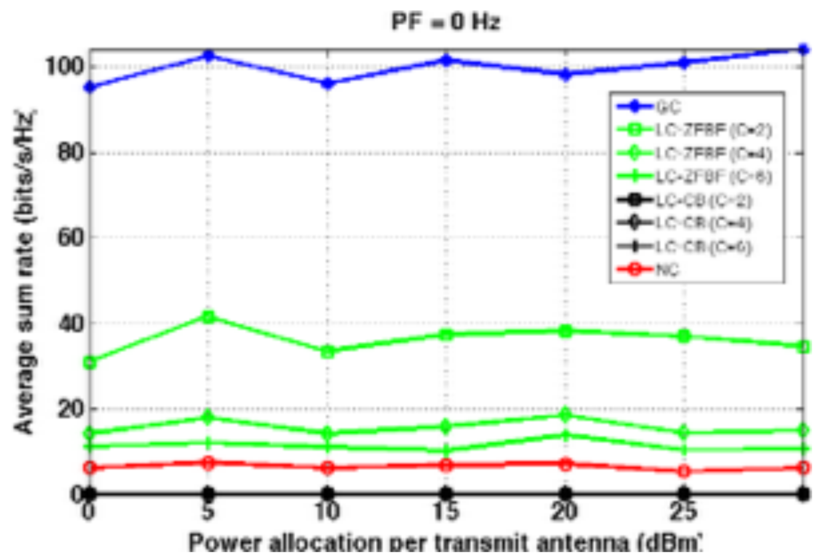


Performance results - sum rate vs. PTx

external interference is off



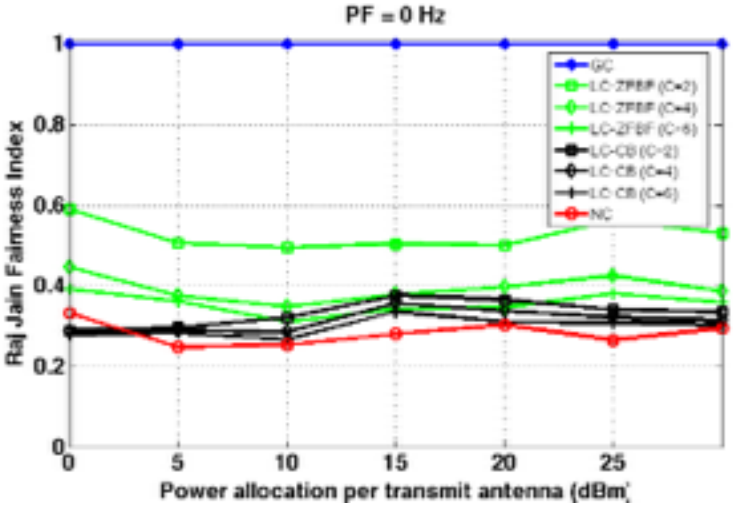
external interference is on



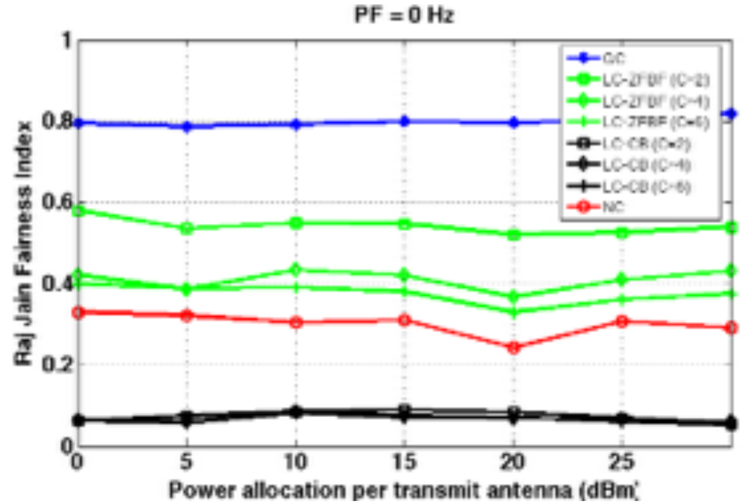
CB performs worst when external interference is present, perhaps due to single-antenna at the users

Performance results - RJ Fairness index vs. PTx

external interference is off

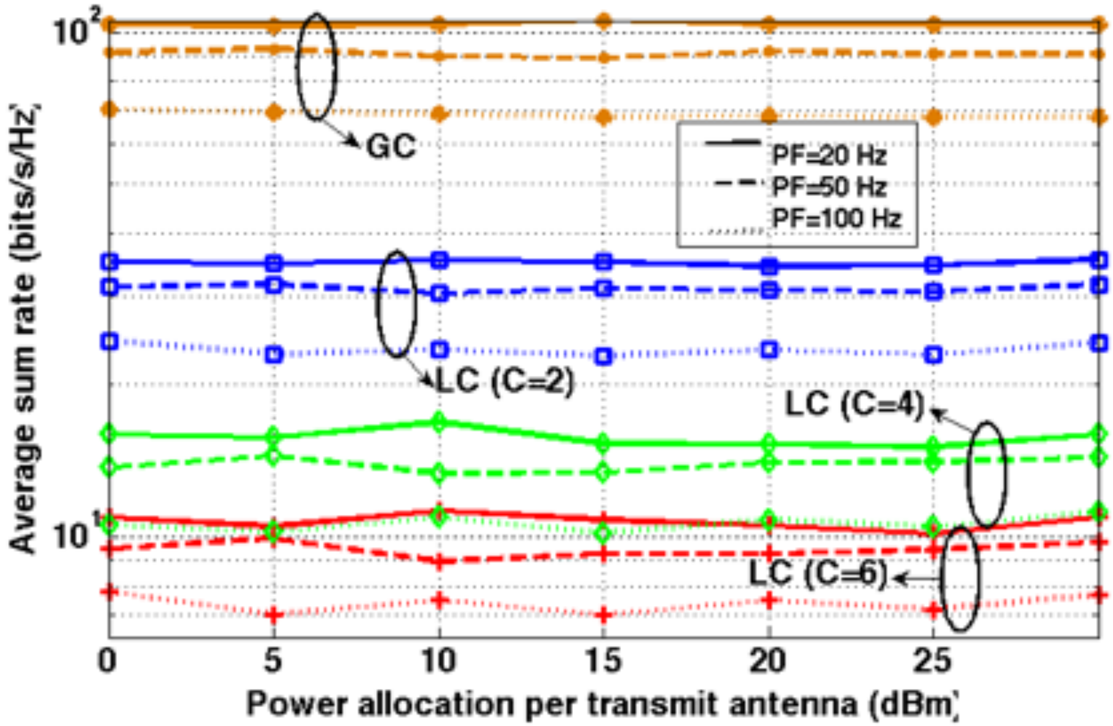


external interference is on

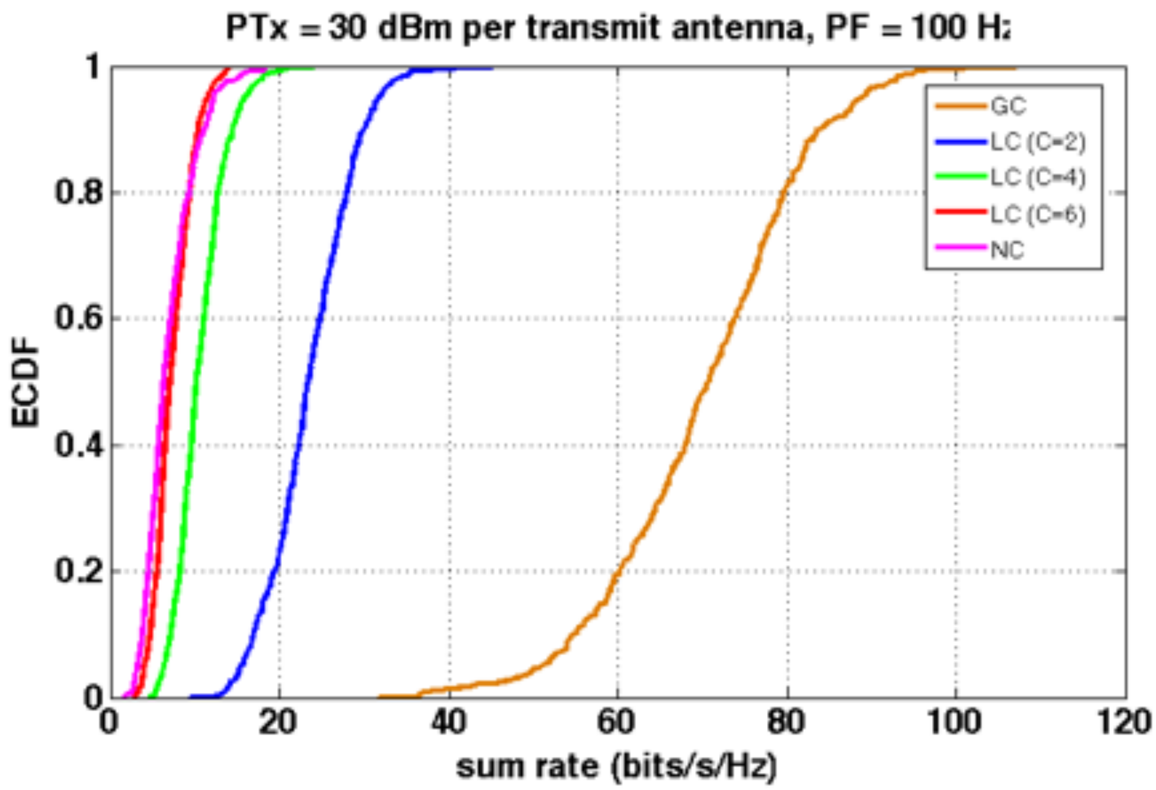


From now onwards, we will omit CB scheme.

Performance results - sum rate vs. PTx

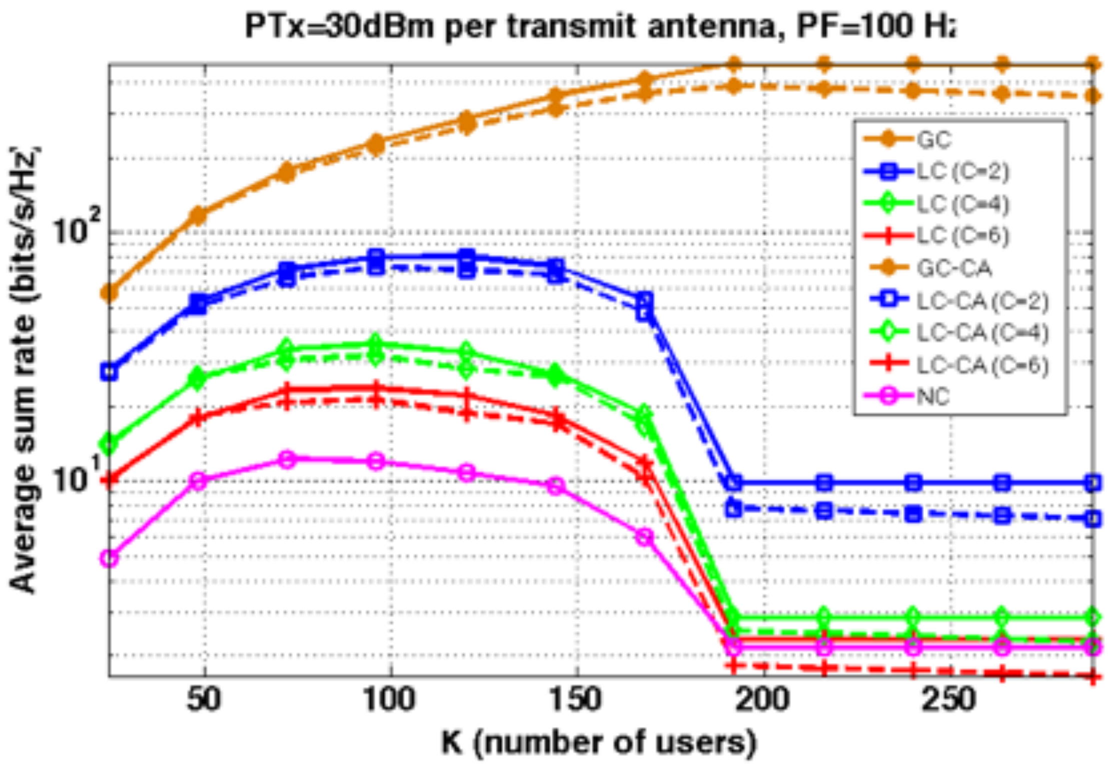


Performance results - ECDF of sum rate



Performance results - sum rate vs. K

N=24, M=8, J=1:8,



Conclusions

- CB scheme is highly sensitive to external interference
- GC scheme outperforms both LC scheme and NC scheme
- For LC scheme, decrease in number of clusters C leads to increase in sum rate