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A System-level Assessment of Uplink CoMP in LTE-A Heterogeneous Networks

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LTE-A and CoMP

- LTE-Advanced: higher capacity and bitrates in a cost-efficient way
 - Increased peak data rate, DL 3 Gbps, UL 1.5 Gbps and higher spectral efficiency
 - Increased number of simultaneously active subscribers
 - Improved performance at cell edges
- Most Important Features
 - Carrier Aggregation
 - MIMO, Multiple Input Multiple Output
 - Relay Nodes
 - Coordinated Multi Point operation (CoMP)



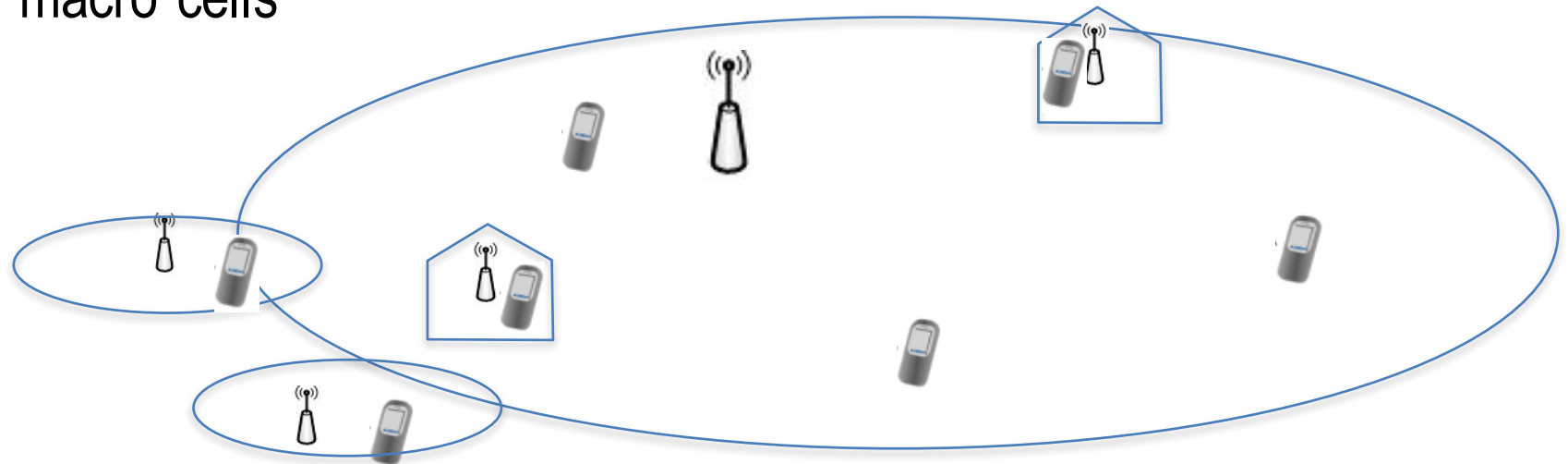
CoMP features

- CoMP: multiple points coordinate with each other so that transmissions signals from/to other points incur minimal or even constructive interference
 - Increase the throughput where signal quality is lower (cell edge)
 - Increased, more even utilization of network
 - Interference reduction
- Downlink CoMP: a set of transmitting antennas provide coordinated transmission to a UE
- Uplink CoMP: a set of receiving antennas provide coordinated reception from UE



Deployment Scenario

- Heterogeneous Networks (HetNets)
 - Mix of macro, small, pico, femto cells
- Increase network capacity
- Expand cell coverage and add indoor coverage
- Reduce transmit power and interference
- Offload macro cells



Our Contribution

- Investigate the impact of uplink CoMP in four different HetNet scenarios
- Understand the impact of different resource balance between CoMP and non-CoMP users

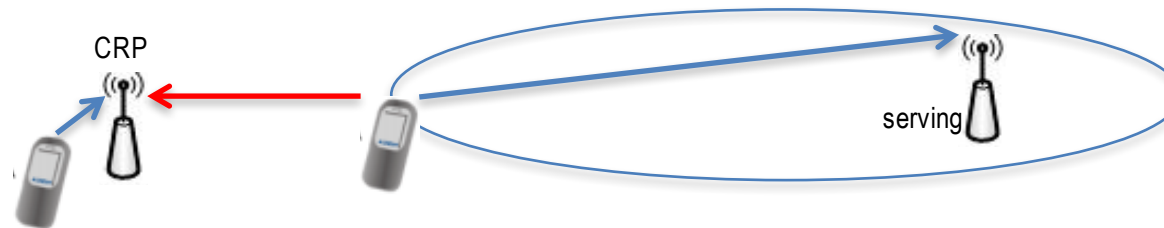


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Uplink CoMP Reception Points

- Uplink CoMP relies on measurements reported to the UE through standard signalling channels



- A comparison is made between RSRP values at
 - serving cell
 - a candidate CoMP Reception Point (CRP) cell
- If the RSRP of the CRP cell is higher than the RSRP of the serving cell minus a quantity called *CoMP margin* (measured in dB), then the candidate is selected as CRP
- Up to three CRP cells can be selected by a UE



Resource Balance

- Each cell is assumed to split its resources (PRB) in two pools:
 - PRBs used by served non-CoMP users
 - PRBs used by CoMP users for which the cell is a CRP
- We call the latter: **CPP** (CoMP Pool Percentage)
- Resources in each pool are then allocated according to PF scheduling

- Rules:
 - CPP is 0 for cells that do not participate to CoMP
 - if the CPP of a cell is not completely allocated for lack of CoMP users, its PRBs are available to be scheduled for non-CoMP users

Does the value of CPP have different impact in different scenarios?



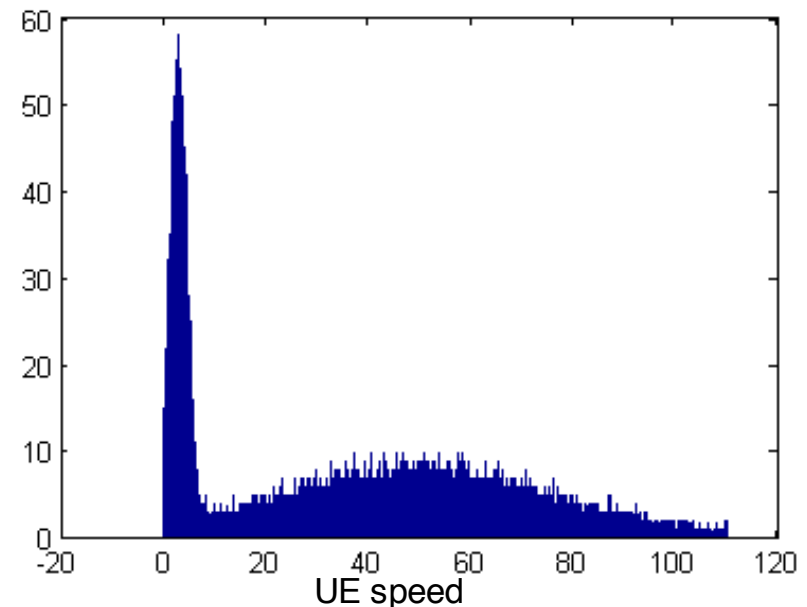
Uplink CoMP scenarios

- We consider 4 scenarios, with different serving/CRP roles played by macro and small cells
 - HET: no restriction
 - SMALL: any cell can be a serving cell, but only small cells can be CRP
 - INTRA: CoMP is enabled just for one of the non-serving cells of the same multi-cell eNB where the serving cell is located. Small cells cannot be CRP.
 - INTER: CoMP is enabled for any macro cells of any eNB. Small cells cannot be CRP.



Simulation model

- Simulations were run on a system-level simulator written in MATLAB and compatible with 3GPP specifications
- 25-km² area with 15 macro cells and 50 small cells.
 - each macro eNB has a three-sectorial antenna, irradiating a macro cell in each sector
 - Small cells irradiate in an omni-directional pattern
- 1,000 UEs are in the area, moving in a random-direction pattern with hot spots around small cells.



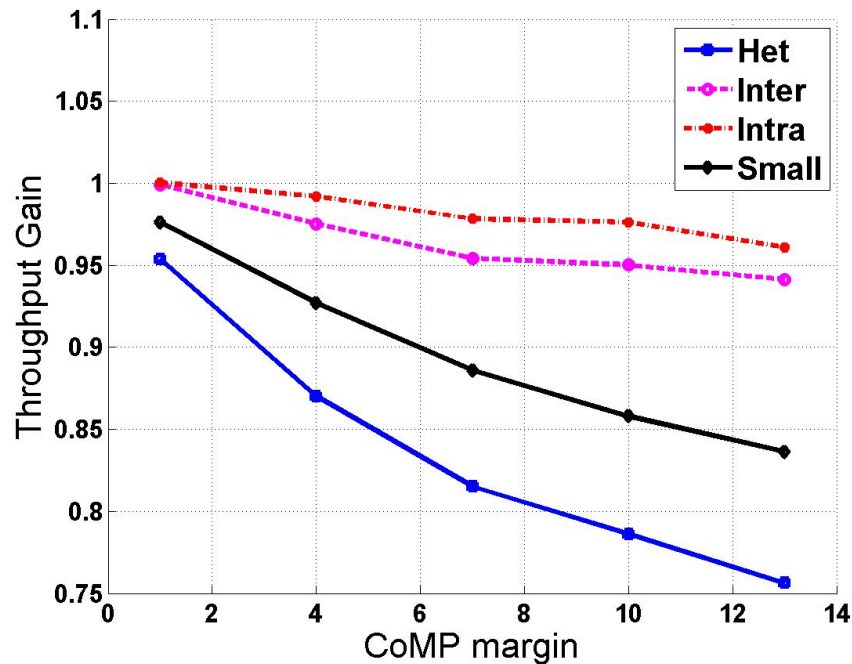
Metrics of interest

- *Average Uplink Throughput gain*: ratio between the uplink throughput when CoMP is active and the uplink throughput CoMP is disabled.
 - We expect the overall cell throughput to decrease when CoMP is used
- Number of users per cell type

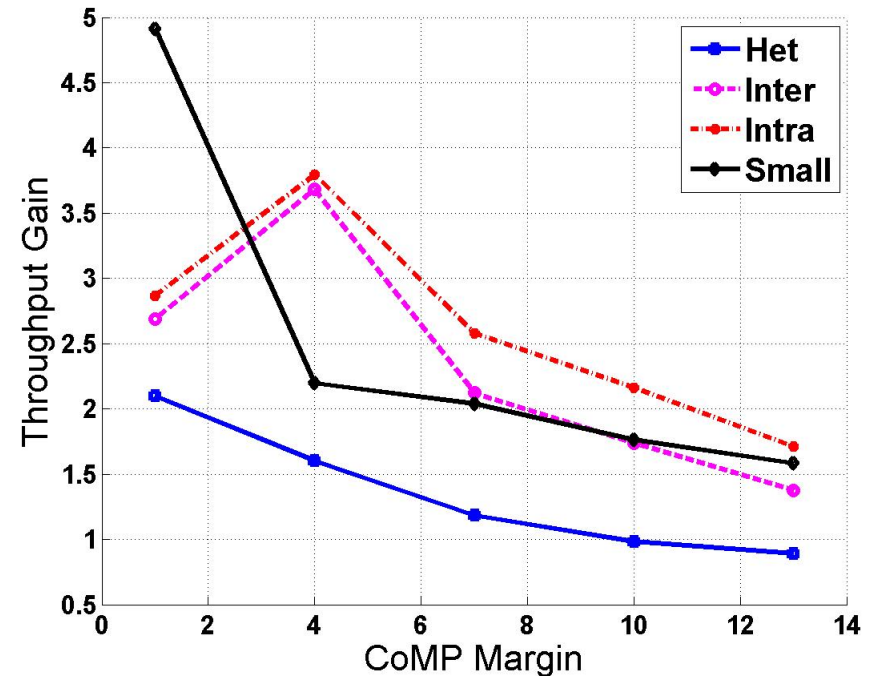


All-scenario comparison

All users



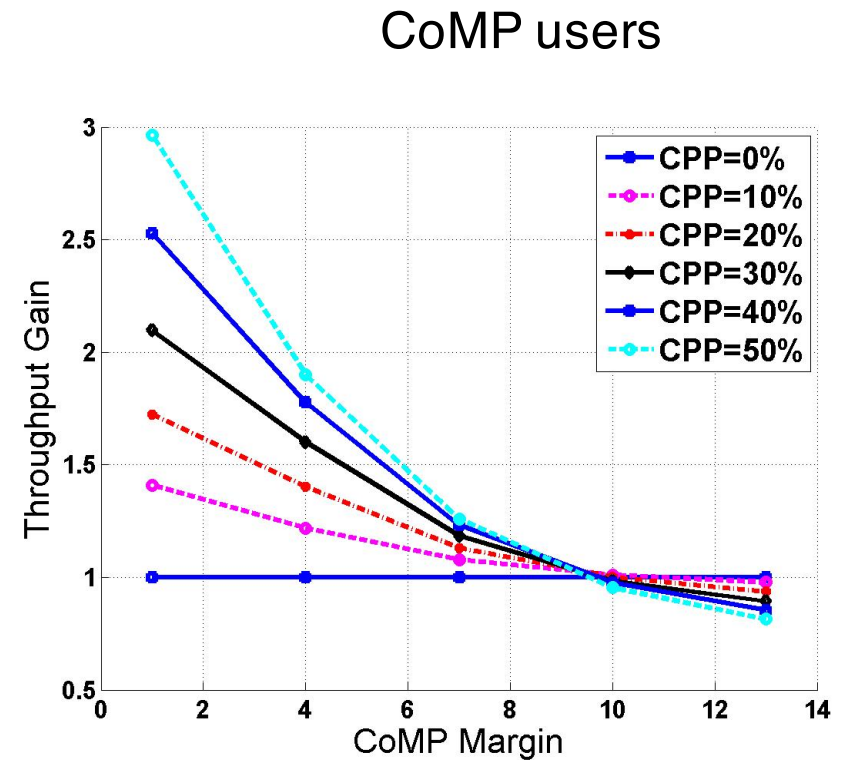
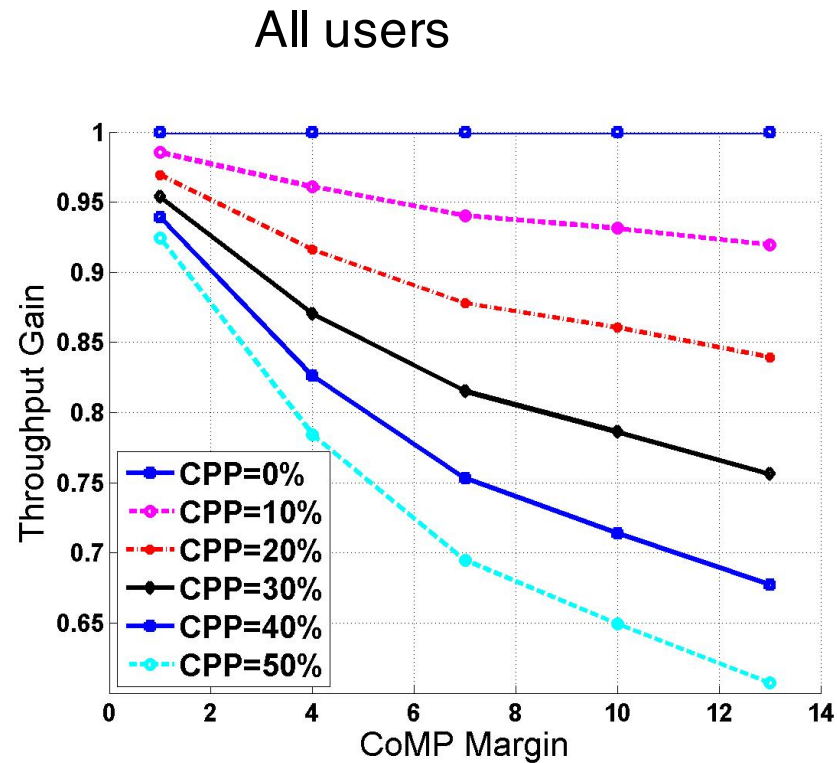
CoMP users



Throughput Gain with 30% CPP as a function of CoMP margin



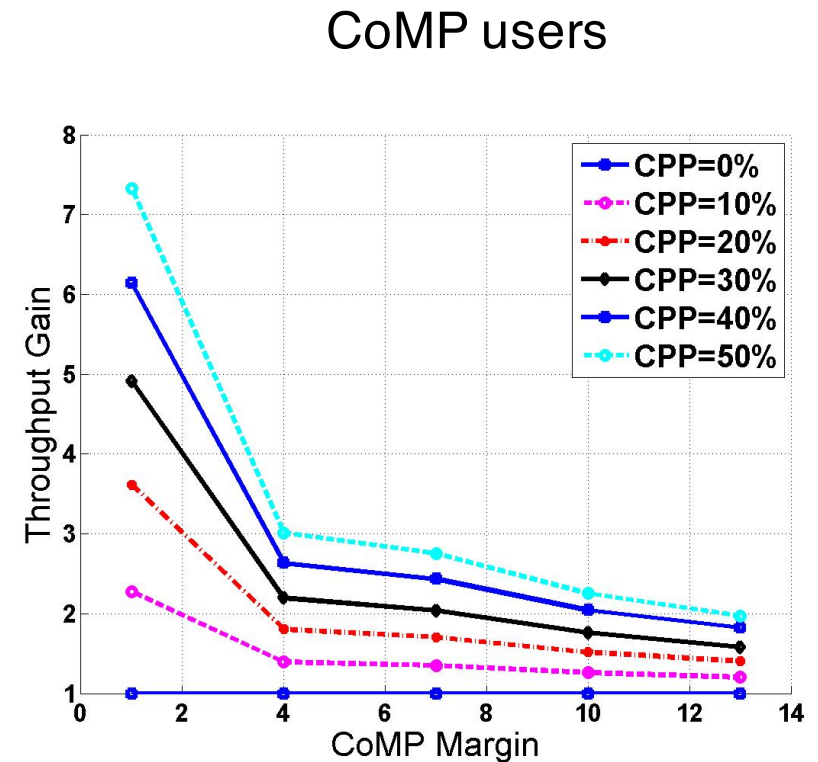
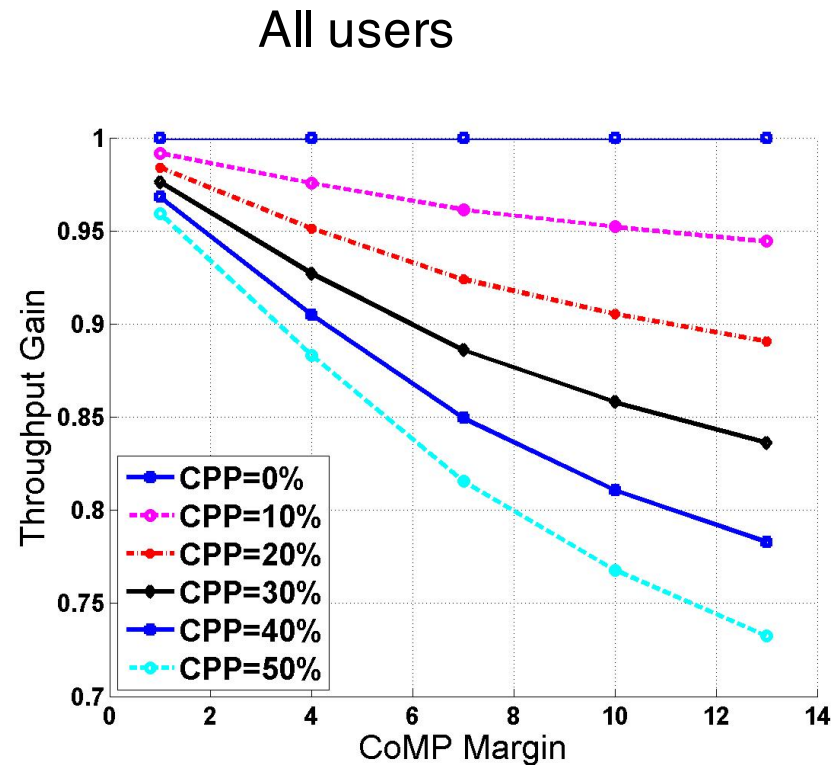
Het scenario



Throughput Gain as a function of CoMP margin (dB) in the Het scenario



Small scenario

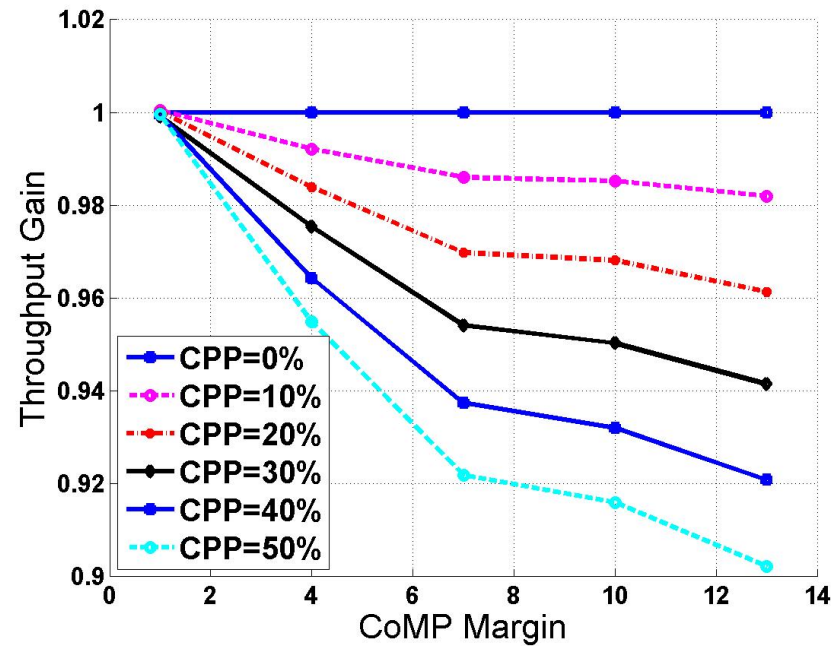


Throughput Gain as a function of CoMP margin (dB) in the Small scenario

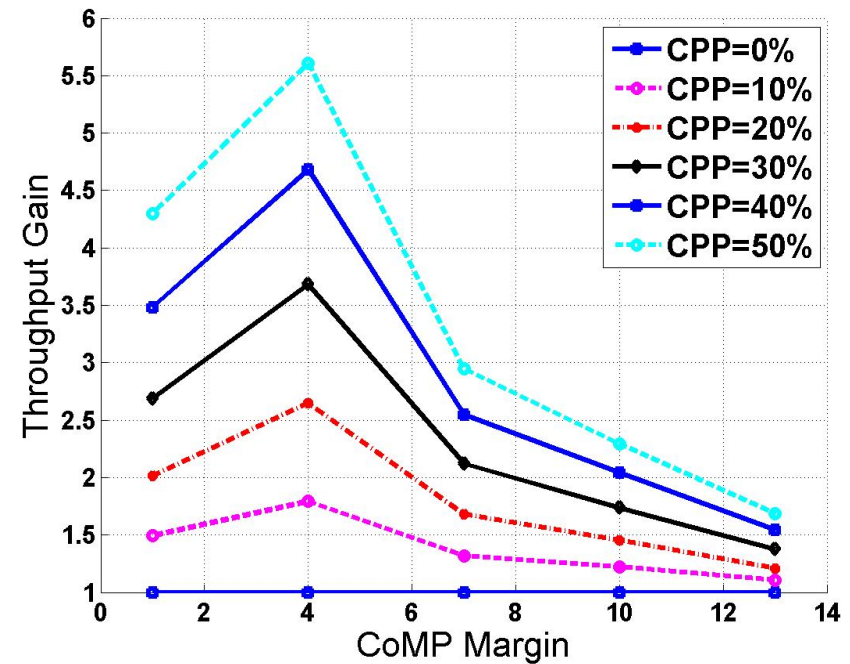


Inter scenario

All users



CoMP users

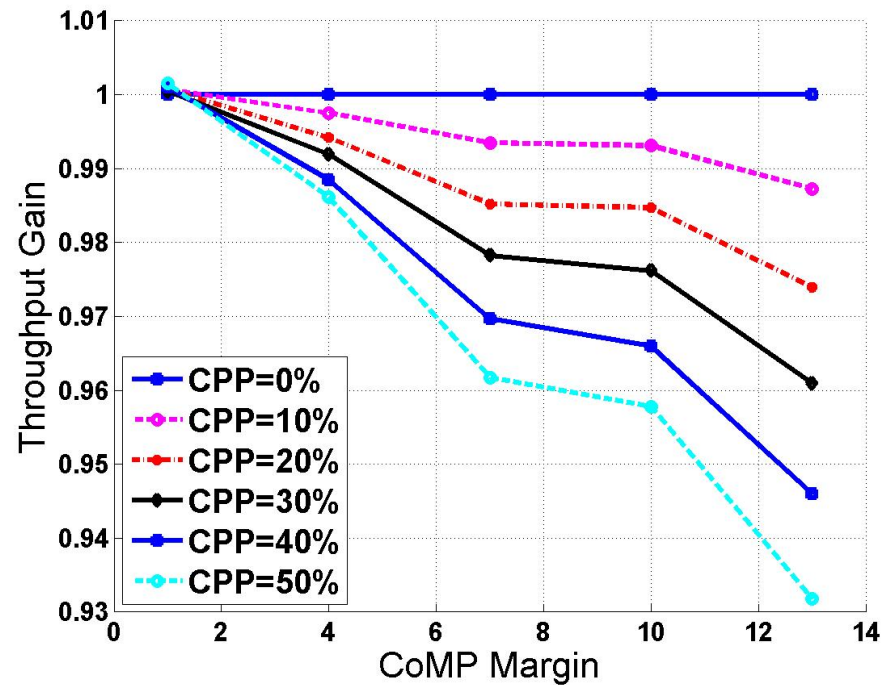


Throughput Gain as a function of CoMP margin (dB) in the Inter scenario

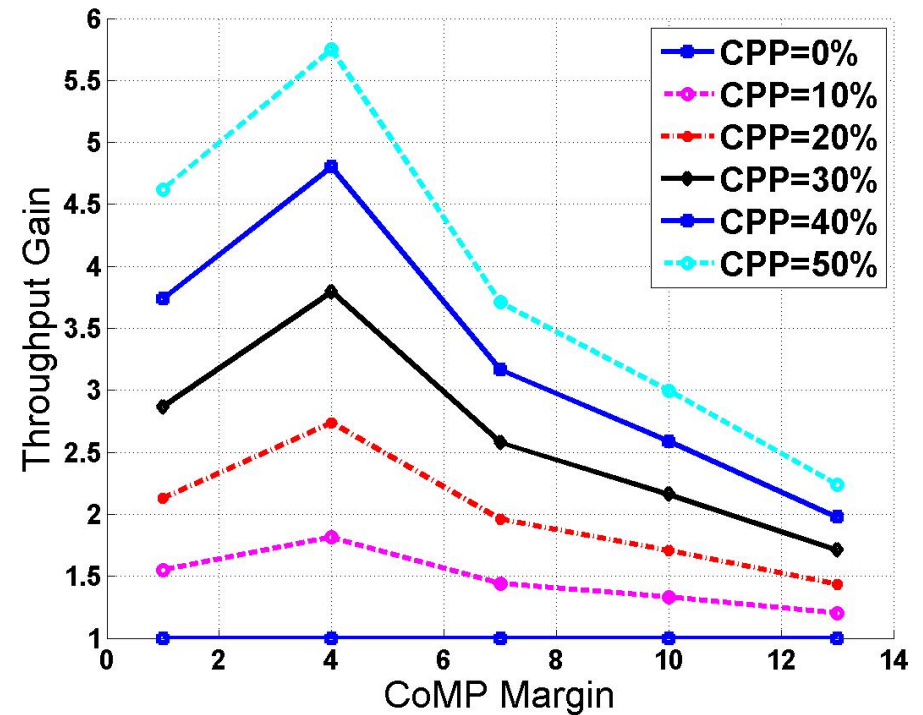


Intra scenario

All users



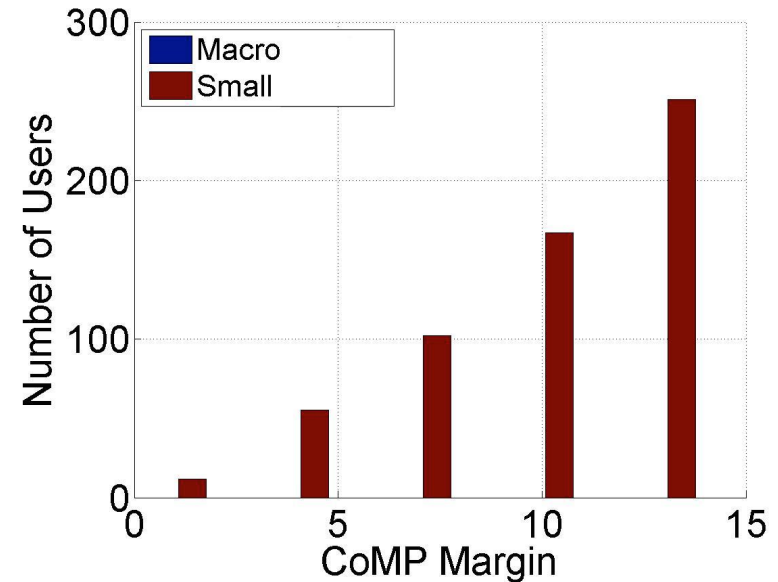
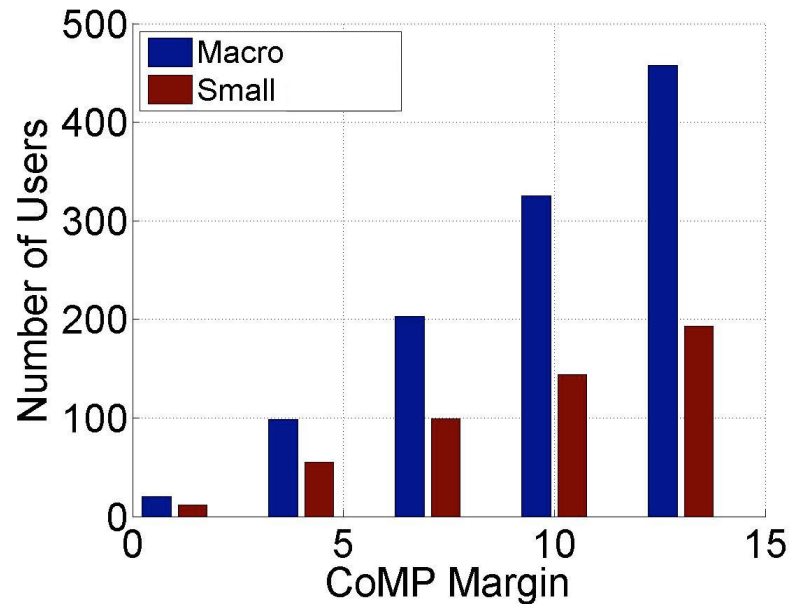
CoMP users



Throughput Gain as a function of CoMP margin (dB) in the Intra scenario



Number of Users



Number of users connected to a specific cell type as a CRP cell, for the Het and Small scenario



Conclusions

- Scenario-aware policies are needed for the use of CoMP
- The balance of resources between CoMP and non-CoMP should be:
 - selected dynamically
 - depend on the type of cells

