Joint Placement and Power Control of LTE Femto Base Stations in Enterprise Environments

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Outline

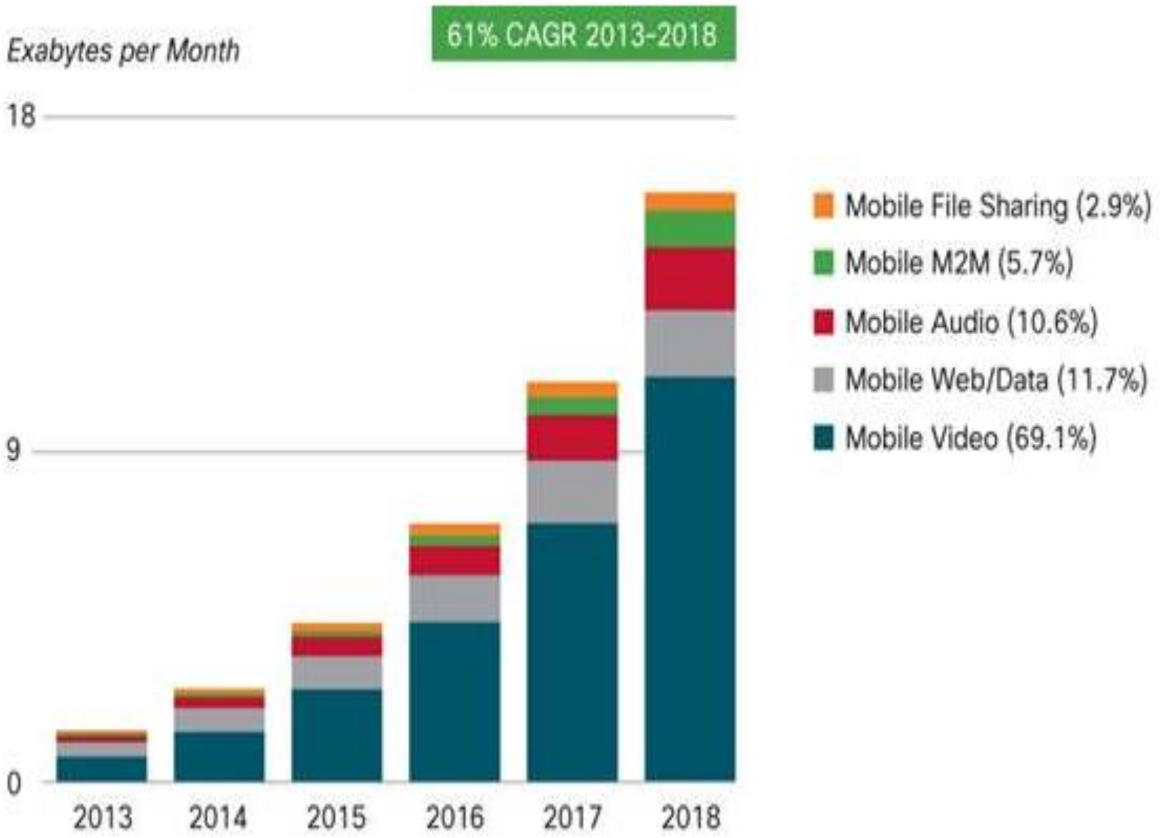
- ✓ Motivation
- ✓ LTE HetNet architecture
- ✓ Interference problem in HetNets
- ✓ Proposed Joint placement & power control of LTE Femto cells
- ✓ Performance Results
- ✓ Conclusions & Future work

Motivation

Trend 1

- In future video traffic will contribute to 70% of total cellular traffic.

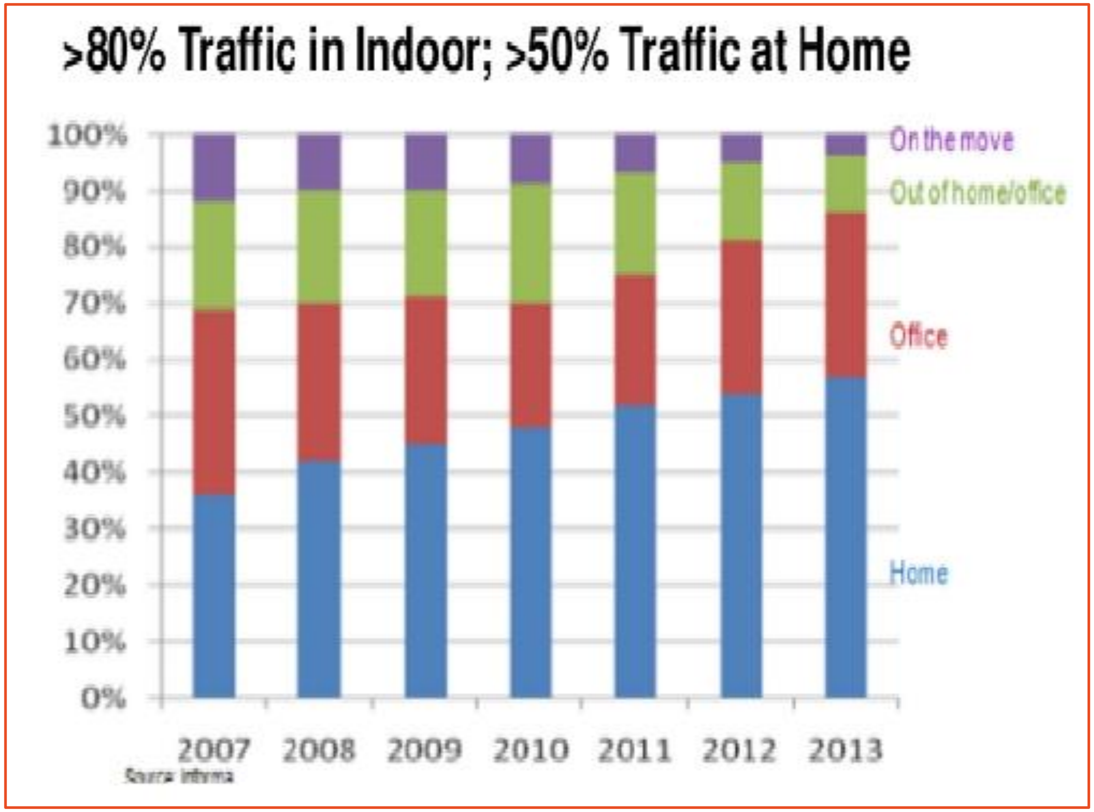
So, BW demand is ever increasing!



Figures in parentheses refer to traffic share in 2018.
Source: Cisco VNI Mobile, 2014

Motivation

Trend 2



Most of traffic is from Indoor users

Issues in indoors:

- Poor cellular coverage due to obstructions & high freq. bands
- So, poor data rates

Solution: Heterogeneous Networks (HetNets)

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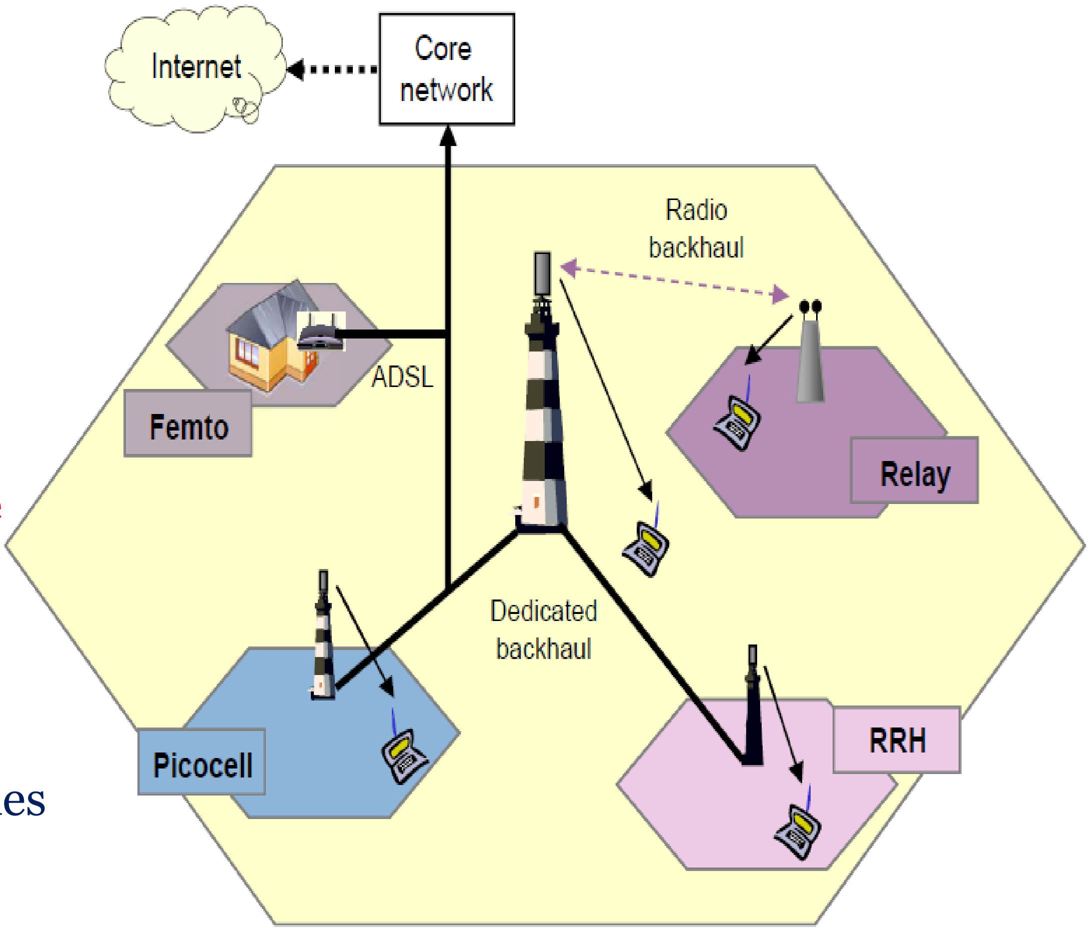
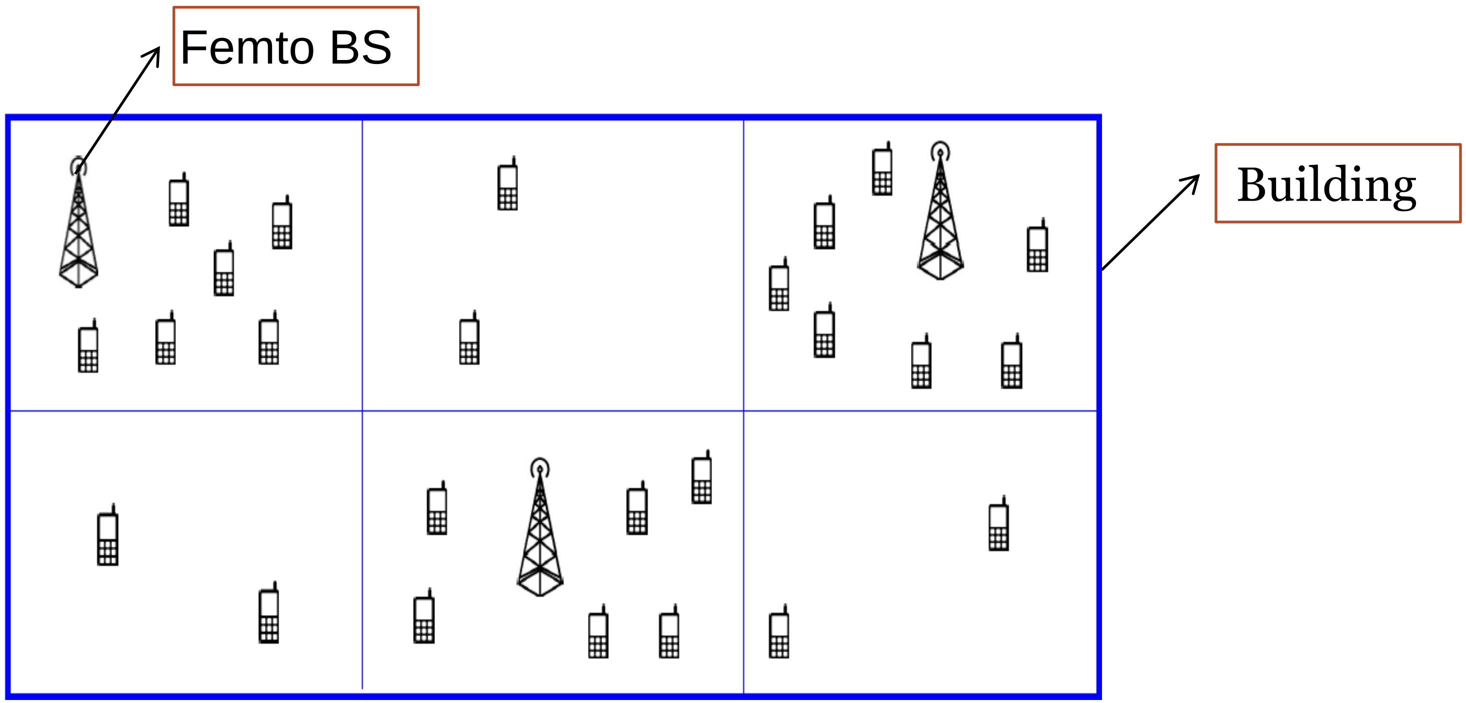
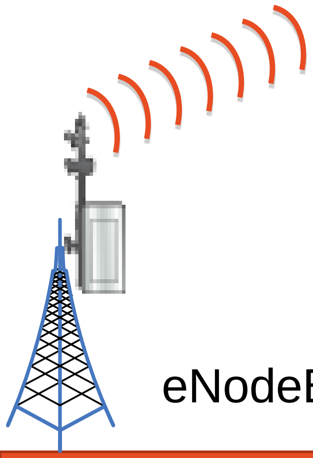
Small Cells in LTE

- Dense deployment in enterprises/hotspots
- Low power nodes
- Freq. Reuse 1 → high spectral efficiency, but need to contain cross-tier co-channel interference
- Boosts indoor coverage & data rates
- Open/Closed/Hybrid Access modes



Scenario: User density in enterprise building





Placement issue:

- Arbitrary placement of Femtos leads to co-tier & cross-tier interference

Problem Statement & Work Done

- Optimal placement of enterprise Femtos
  - Factors in Macro-Femto cross-tier co-channel interference
  - Considers signal attenuation due to walls and floors
  - Minimizes no. of Femtos to be deployed to cover the building
  - Determines optimal locations for placing the Femtos
  - Guarantees fixed minimum threshold SINR for all indoor regions
  - But, all the above things achieved by joint placement and power control
- Varying the threshold SINR in HetNets
  - Depending upon the user density vary the threshold SINR
  - Maintain the same Femto count as in fixed threshold SINR

➔ Proposed efficient placement and power control algorithm by solving two Mixed Inter Programming (MIP) problems

- ✓ OptCTSINR: Optimal constant threshold SINR
- ✓ OptVTSINR: Optimal varying threshold SINR

Channel Model and Notations Used

Path loss b/w Macro BS and indoor/outdoor UE at a distance of d:

$$PL_{Macro} = 40\log_{10}\frac{d}{1000} + 30\log_{10} f + 49 + n\sigma$$

Path loss b/w Femto and indoor UE at a distance of d:

$$PL_{Femto} = 37 + 30\log_{10} d + n\sigma + 18.3\, K^{\frac{(K+2)}{(K+1)-0.46}}$$

Channel gain for Macro and Femto are 20 dBi and 2 dBi, respectively

Notation	Definition
S	Set of all sub-regions inside the building.
W_a	1 if Femto is placed at inner sub-region a, zero otherwise
y_{ja}	1 if j^{th} inner sub-region of the building is associated with the Femto located at inner sub-region a, zero otherwise
g_{ja}	Channel gain between inner sub-regions j and a
q_j	User occupant probability in sub-region j
M	Set of all Macro BSs
P_a	Normalized transmit power of Femto BS a, $0 \le P_a \le 1$

Joint Placement and Power Control Formulation

Objective Function: Minimize the total number of Femtos deployed

$$\min \sum_{a \in S} w_a$$

Constraints:

- Assuming that a sub-region corresponds to an indoor user, it is allowed to associate with only one Femto BS inside the building.

$$\sum_{a \in S} y_{ja} = 1 \qquad \forall j \in S \qquad (1)$$

- Below constraint ensure the sub-region gets connected only when the Femto is placed in the location w_a.

$$y_{ja} - w_a \leq 0 \qquad \forall j, a \in S \qquad (2)$$

- The Femto power value is set only when the Femto is placed at the location w_a

$$P_a \leq W_a \qquad \forall a \in S \qquad (3)$$

(a) OptCTSINR MIP Formulation

- To ensure good coverage, the SINR of inner sub-regions must be maintained above the predefined threshold SINR, λ and is given by

$$\frac{inf * (1 - y_{ja}) + g_{ja} P_{max} w_a}{N_o + \sum_{b \in S \setminus a} g_{jb} P_{max} w_b + \sum_{e \in M} g'_{je} P_{Macro}} \geq \lambda \quad \forall j, a \in S$$

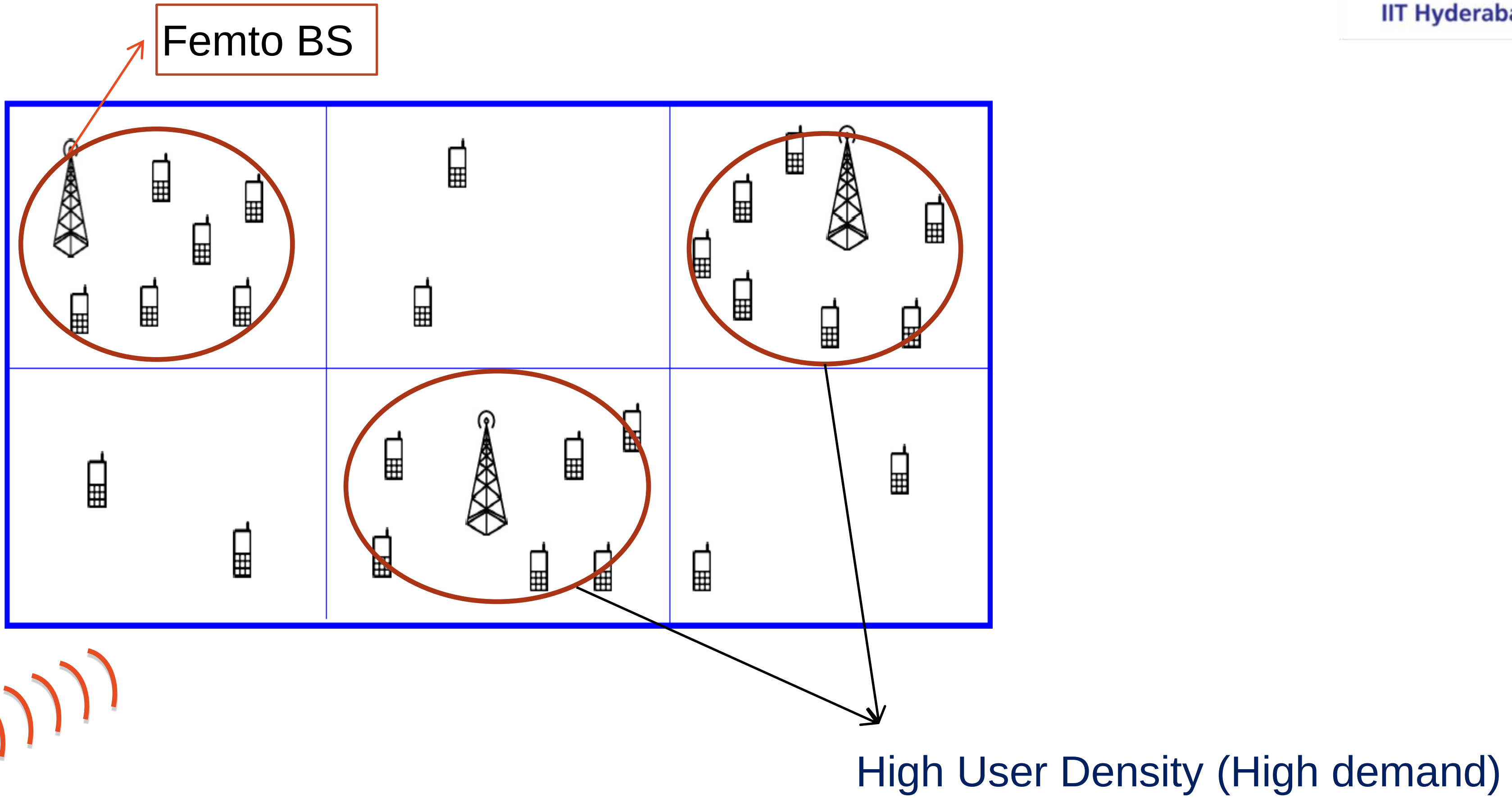
The above equation can be rewritten as,

$$inf * (1 - y_{ja}) + g_{ja} P_{max} w_a \geq \lambda (N_o + \sum_{b \in S \setminus a} g_{jb} P_{max} w_b + \sum_{e \in M} g'_{je} P_{Macro}) \quad (4)$$

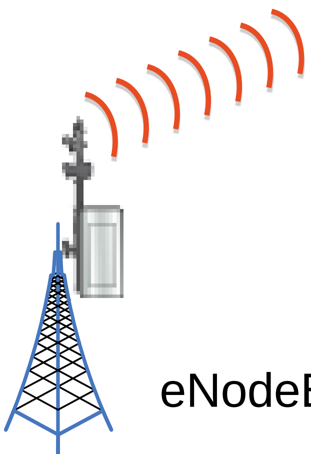
Finally, OptCTSINR MIP is formulated as follows,

$$\min \sum_{a \in S} w_a \quad s.t, (1), (2), (3), (4)$$

Scenario: User density in enterprise building



- Provide more bandwidth for regions having high user density



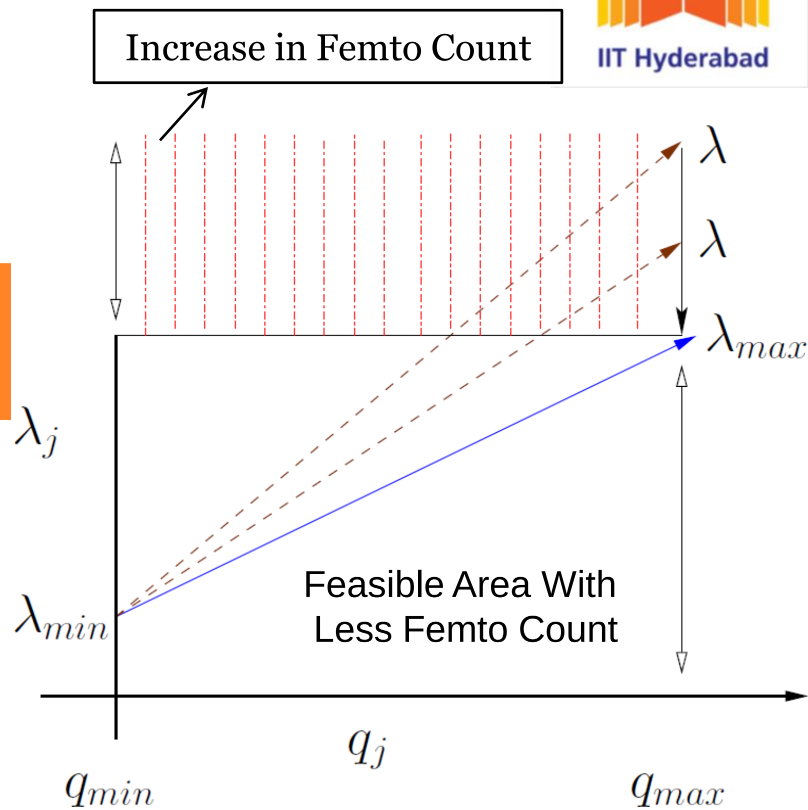
eNodeB @ 350 m away

(b) OptVTSINR MIP Formulation

- Here λ_j is the minimum $SINR_{Th}$ at sub-region j and it is defined in Eqn (5).

$$\lambda_j = \frac{(q_j - q_{min})(\lambda_{max} - \lambda_{min})}{q_{max} - q_{min}} + \lambda_{min} \qquad (5)$$

- To maintain $SINR_{Th}$ based on user ocupancy is given by,.



$$inf * (1 - y_{ja}) + g_{ja} P_{max} w_a \geq \lambda_j (N_o + \sum_{b \in S \setminus a} g_{jb} P_{max} w_b + \sum_{e \in M} g'_{je} P_{max}) \qquad (6)$$

Finally, OptVTSINR MIP is formulated as follows,

$$\min \sum_{a \in S} w_a \quad s.t, (1), (2), (3), (6)$$

Simulation Parameters

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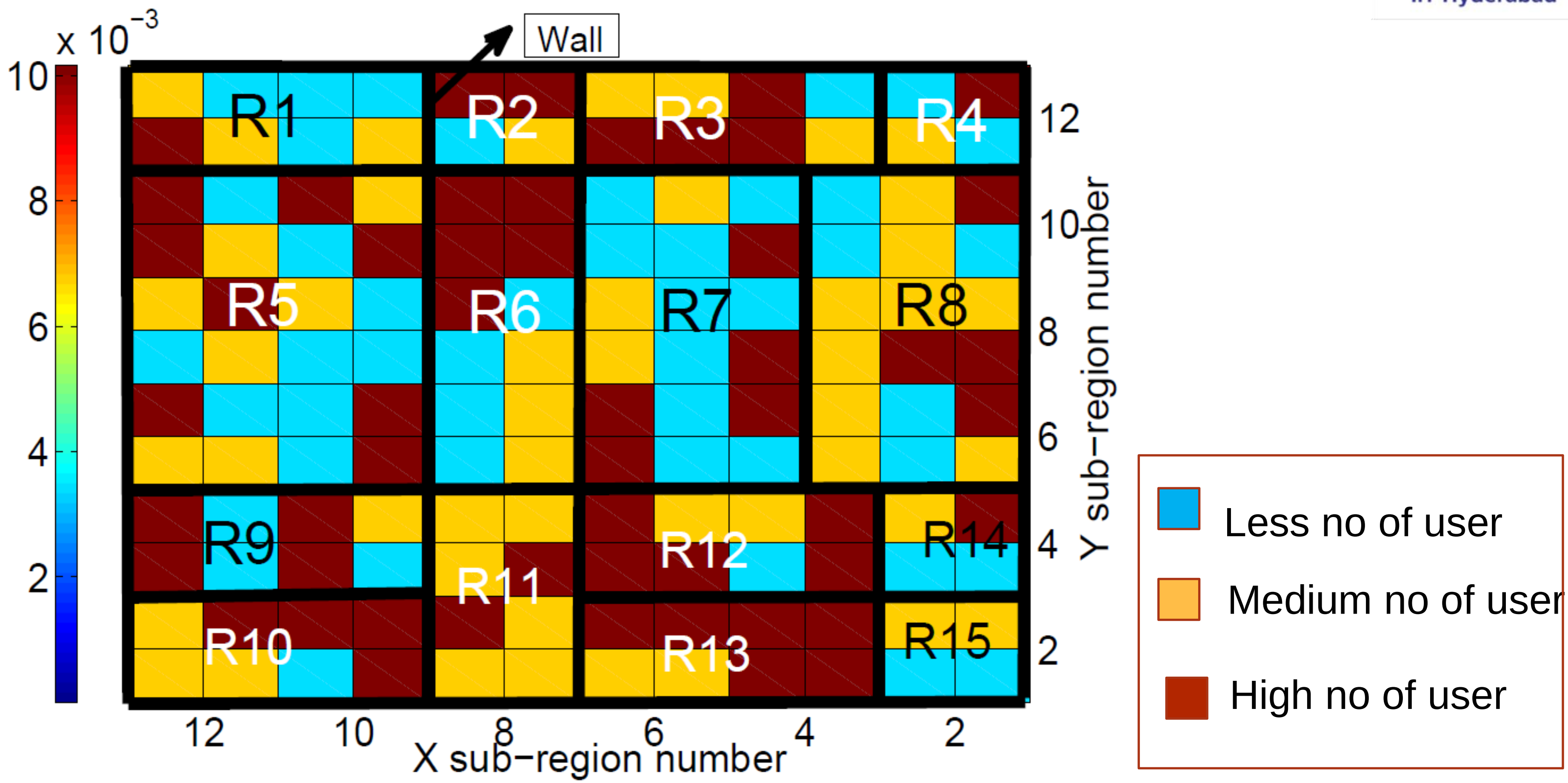
Parameters	Values
Building Dimensions	48 m X 48 m X 3m
Number of Rooms	16
Room Dimensions	12 m X 12 m X 3 m
Number of inner sub-regions	144
Inner sub-region dimension	4 m X 4 m X 3 m
Number of Floors	1
Floor and Wall loss	10 dB and 8 dB
Femto and Macro Tx Powers	20 dBm and 46 dBm
Macro BS height	30 m
Mathematical Solver used	GAMS Cplex (branch-and-bound framework)
LTE System Model	MATLAB based

User occupant probability inside building



- Average user occupant probability distribution across the building.

Sub-region association & SINR distribution for OptCT (-2 dB)

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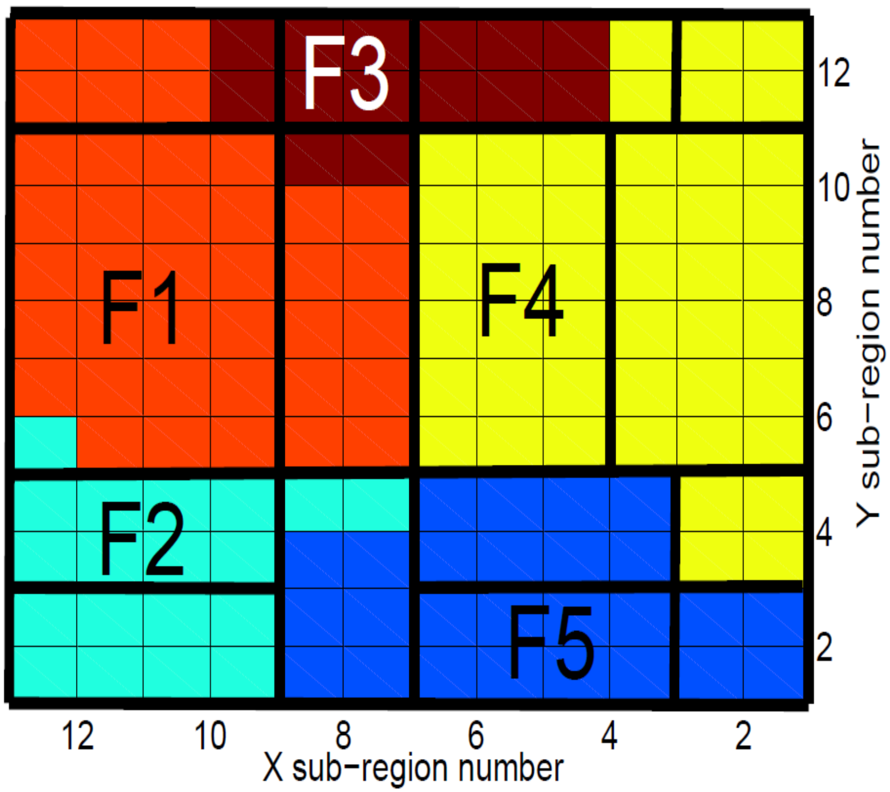
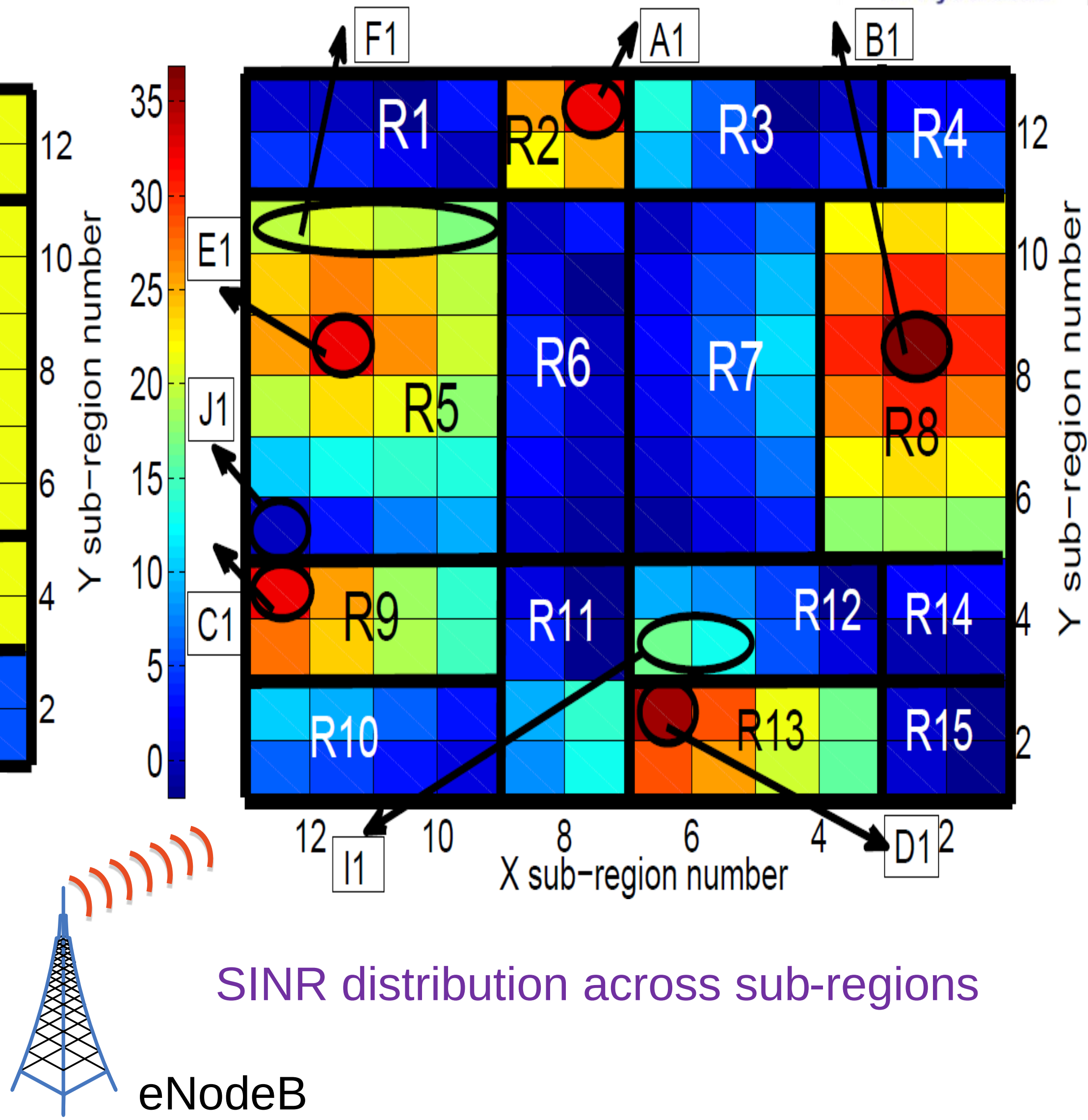
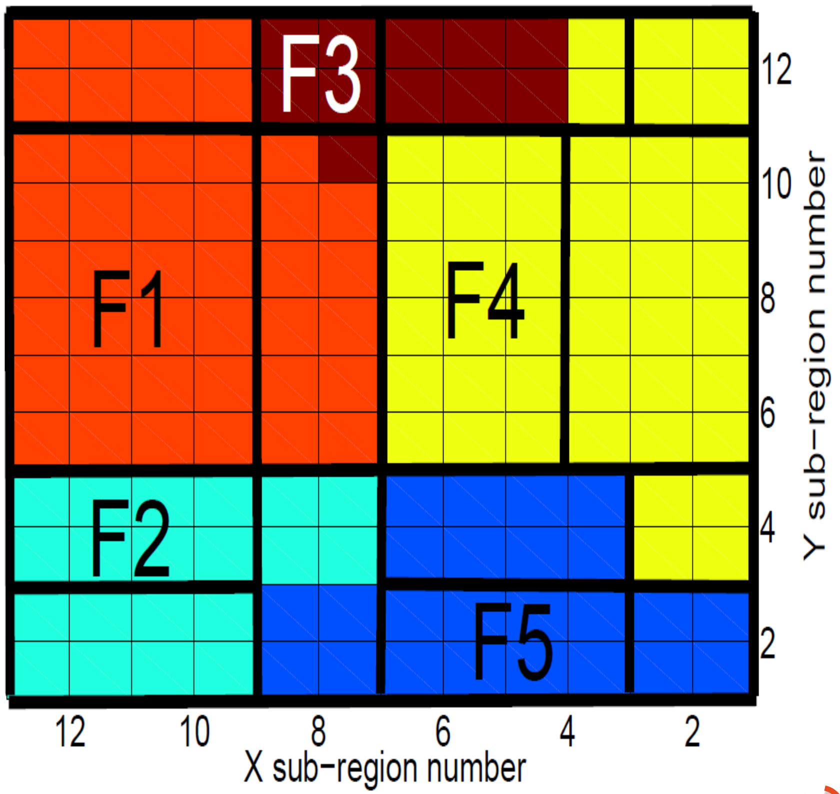


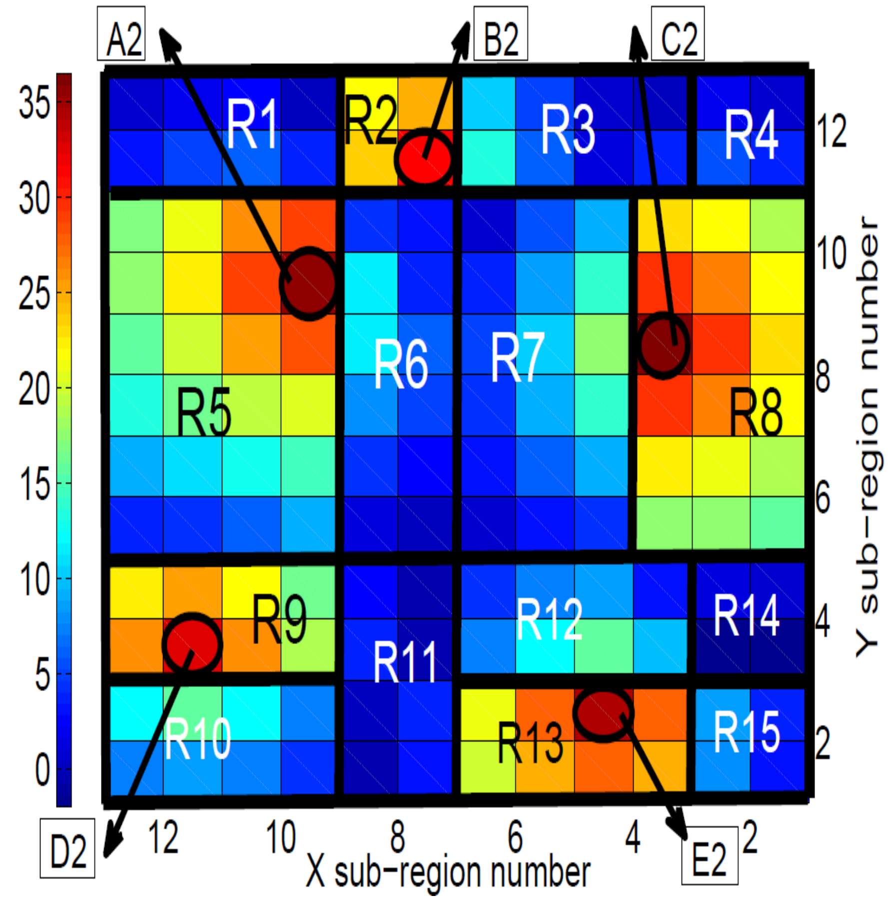
Femto sub-region association



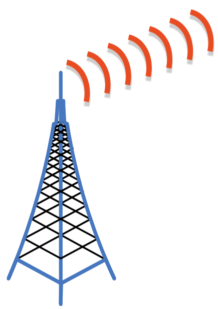
SINR distribution across sub-regions

SINR distribution across sub-regions for OptCTSINR (-2 dB) and OptVTSINR (-2 to +1 dB)





Femto sub-region association



SINR distribution across sub-regions

Sub-region association and SINR distribution for OptCTSINR (+1 dB)

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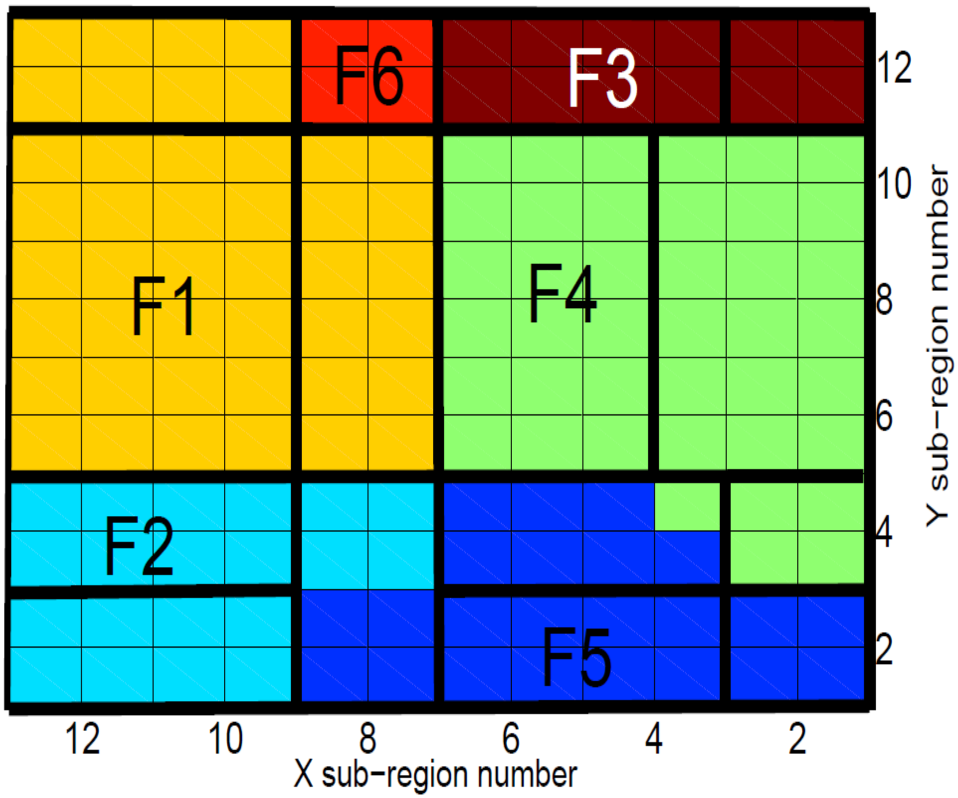
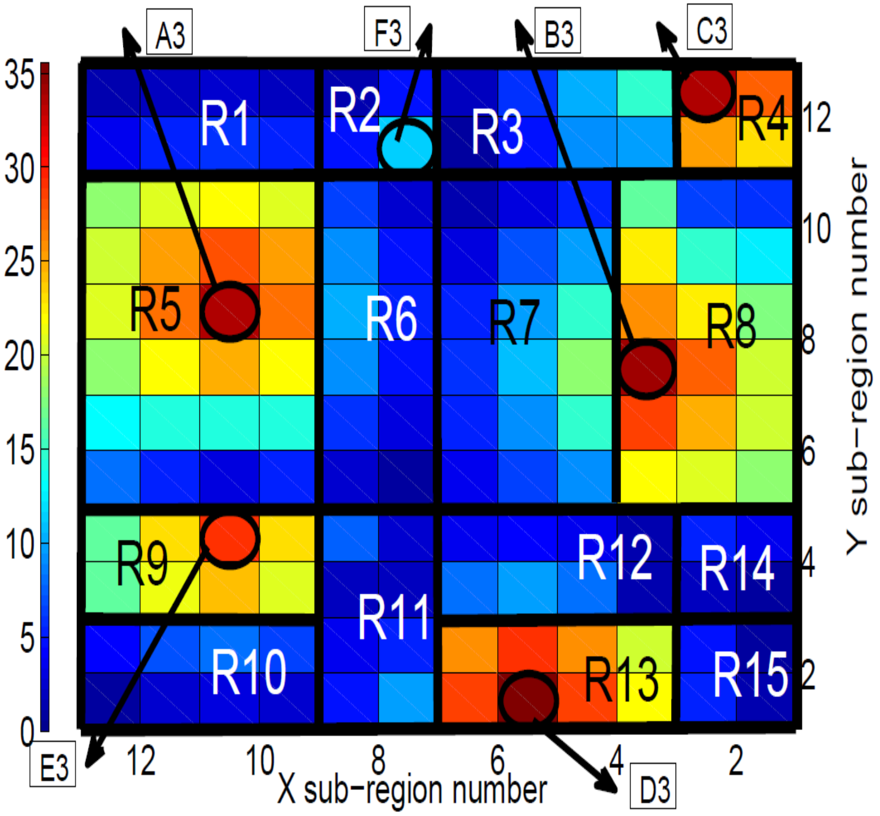


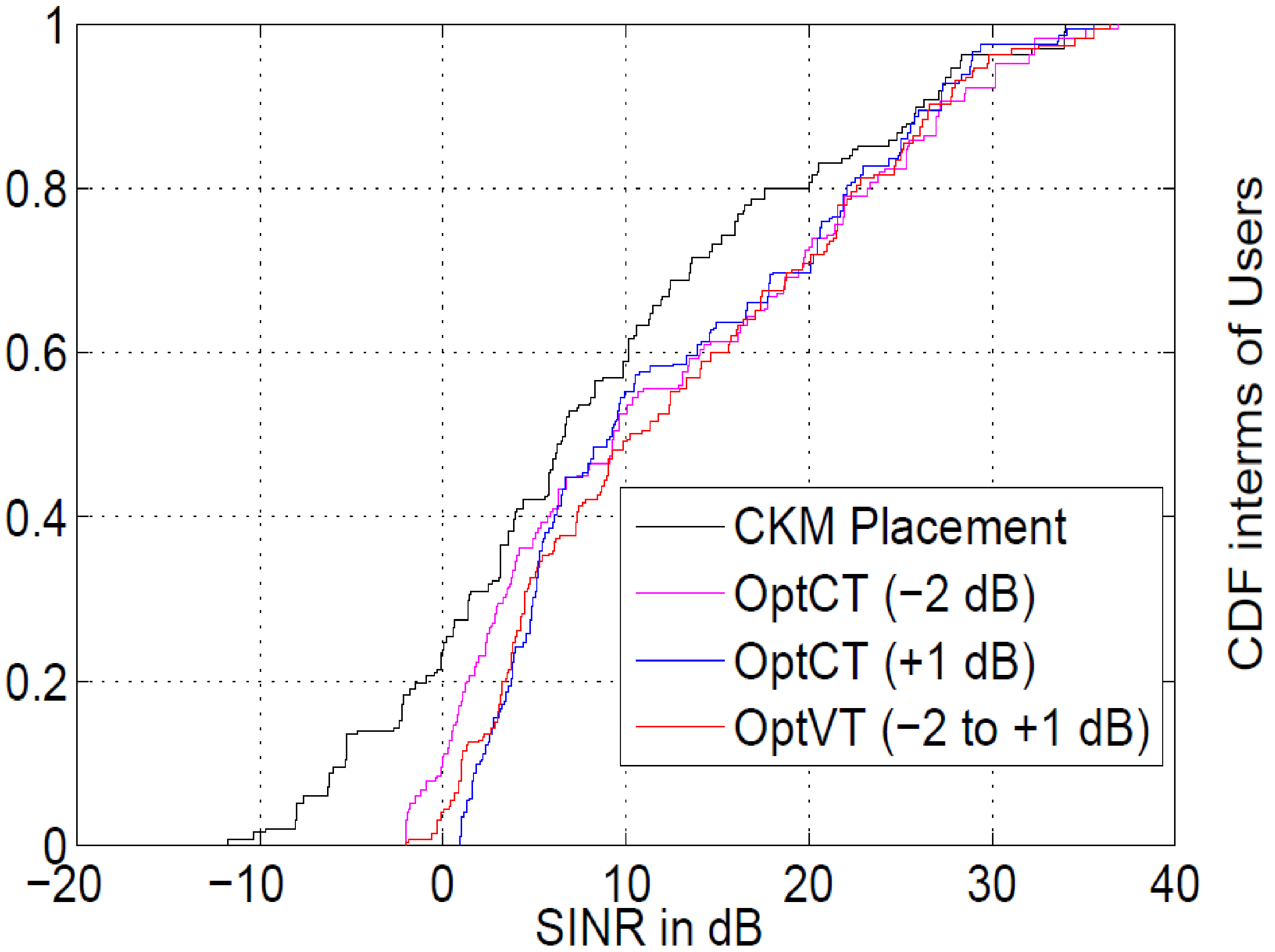
Femto sub-region association



SINR distribution across sub-regions

- In OptCTSINR (+1 dB), Femto count got increased to 6

SINR variation inside the building



- In CKM placement, 15% of the user inside the building has SINR value less than -5 dB.
- Compare to CKM placement, OptCT and OptVT out performs 39 % and 45 % in terms of better average SINR.

Summary and Future Work

- The efficient Joint Femto placement and power control aensures fair SINR allocation to the indoor UEs in LTE HetNets

- Current works
  - Studying for more complex buildings, with multiple floors
  - Consider Open/Hybrid access modes
  - Comparing the Joint placement and power control with Full power Femto
  - Measuring performance using system level simulations in NS-3

Acknowledgments

- This work was funded by IIT Hyderabad

Thank you!

Feedback ?

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