ENHANCED DISTRIBUTED RESOURCE ALLOCATION AND INTERFERENCE MANAGEMENT IN LTE FEMTOCELL NETWORKS

Vanlin Sathya, Harsha Vardhan G, Hemanth N,

Bala K and Bheemarjuna Reddy Tamma

Networked Wireless Systems Laboratory

Dept. of Computer Science and Engineering

Indian Institute of Technology (IIT) Hyderabad, India

Outline

- Motivation for LTE Femto Cells
- Interference Problems
- Existing solutions for Inter-cell Interference Management
- Proposed Solution: Variable Radius Algorithm
- Experimental Setup
- Performance Results
- Summary and Future Directions

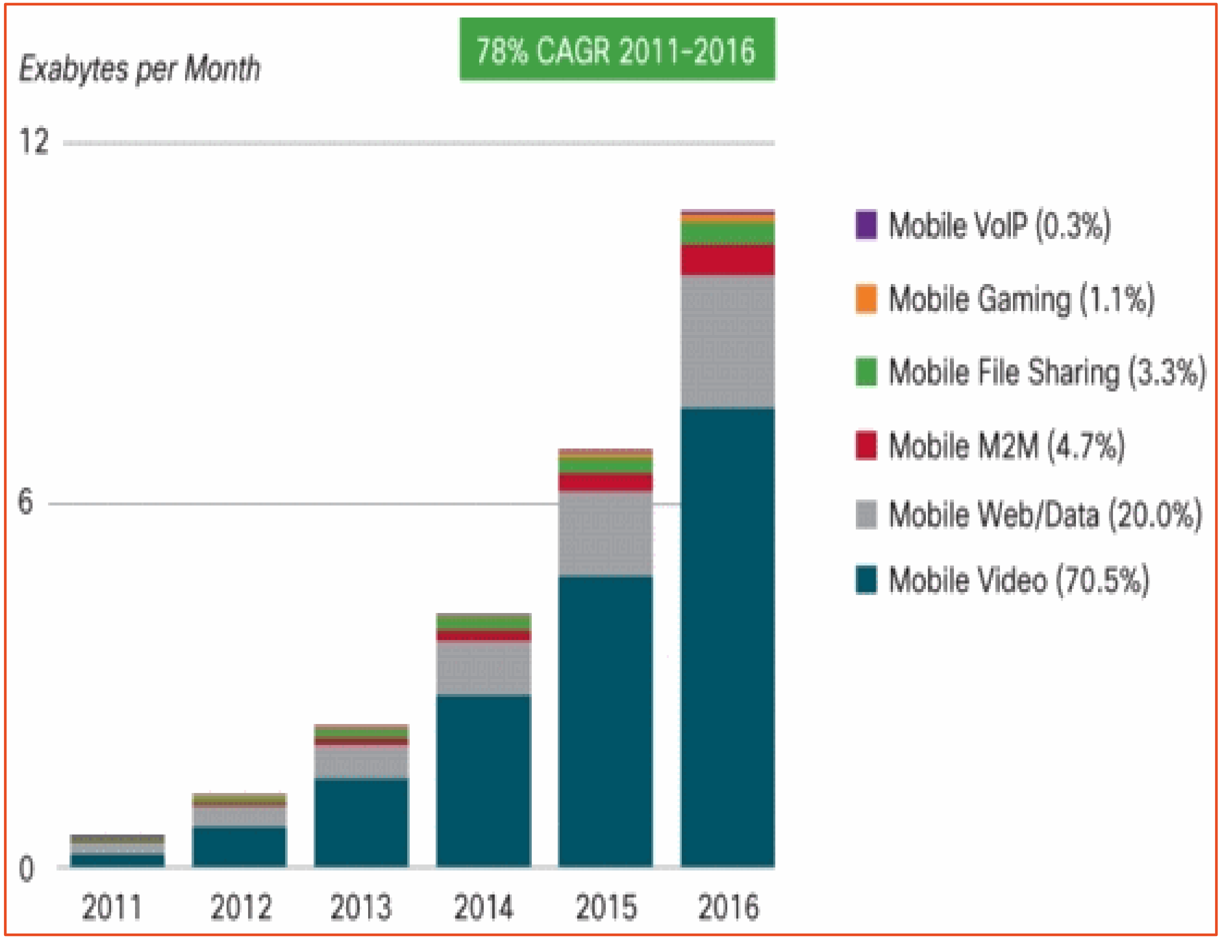
LTE Targets

- Higher performance
  - 100 Mbit/s peak downlink, 50 Mbit/s peak uplink
  - 1G/s for LTE-Advanced
  - Better cell edge performance
  - Reduced latency (to 10 ms) for better user experience
  - Scalable bandwidth up to 20 MHz
- Backwards compatible
  - Works with GSM/EDGE/UMTS systems
  - Utilizes existing 2G and 3G spectrum and new spectrum
  - Supports handover and roaming to existing mobile networks
- Reduced capex/opex via simple architecture
  - Reuse of existing sites and multi-vendor sourcing
- Diverse requirements
  - TDD (unpaired) and FDD (paired) spectrum modes with reuse 1
  - Mobility up to 350 kmph
  - Variety of terminals (phones, tablets, PCs, cameras → IoT)

Trend 1

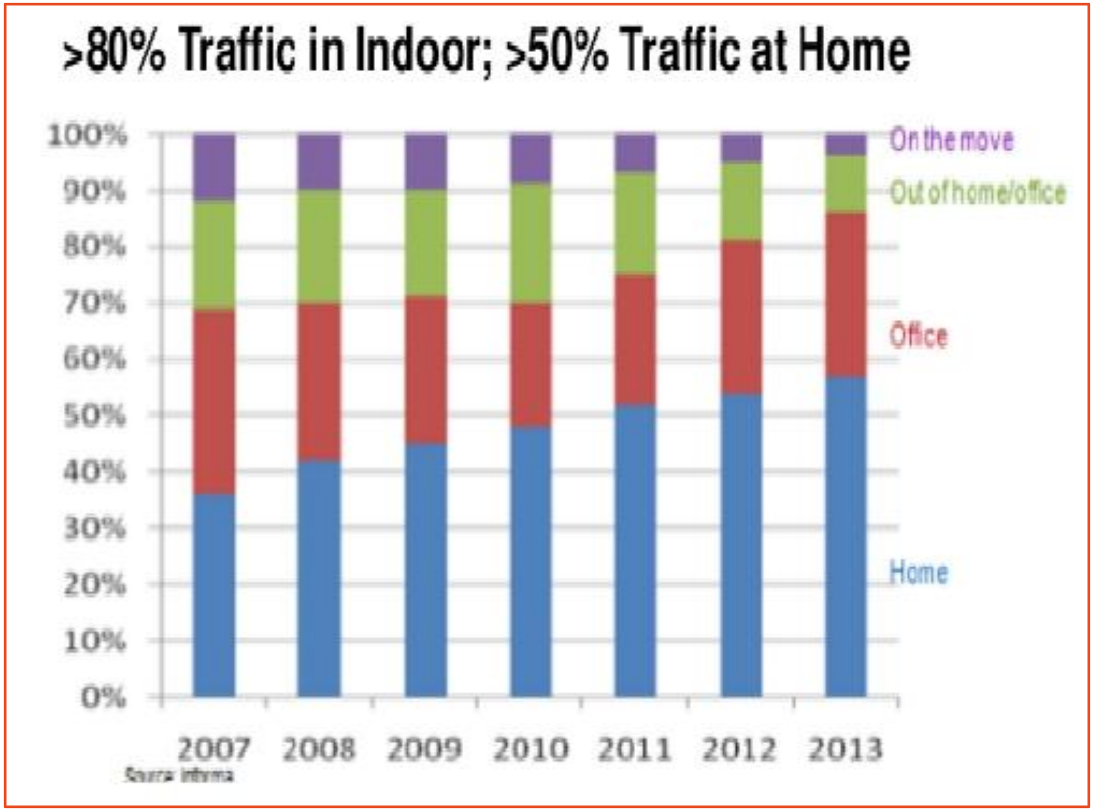
- In future video traffic will contribute to 70% of total cellular traffic.
- 20% of traffic will be because of mobile data.

So, BW demand is ever increasing.



Source: CISCO

Trend 2



Issues in indoors:

- Poor cellular coverage
- So, low data rates

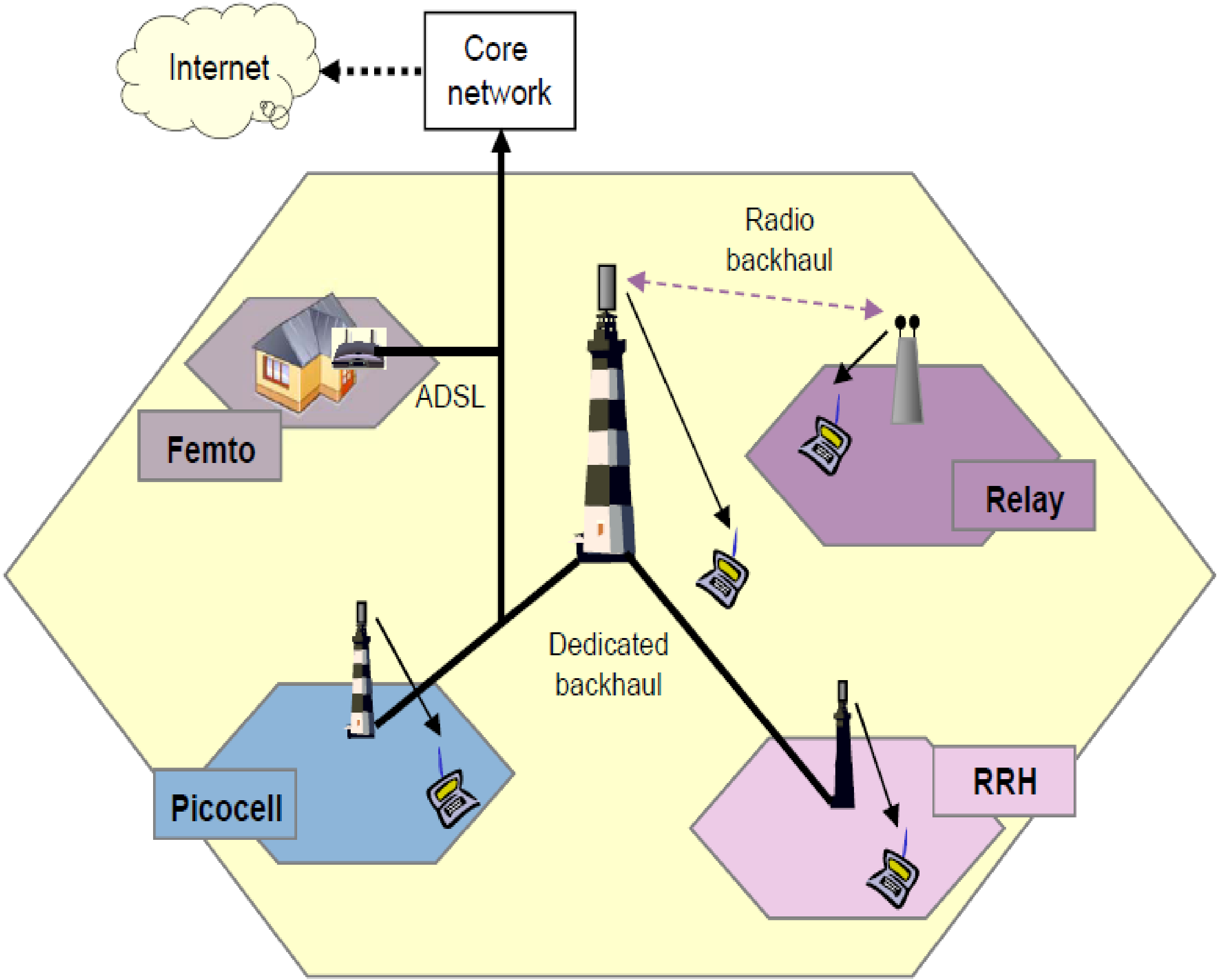
Most of traffic is from Indoor users

How to address growing Indoor traffic demands?

Crowdsourcing approach:

- End-users install small base stations (a.k.a. Femto cell nodes) inside their homes/offices
- Femtos (a.k.a. Home eNodeBs/HeNBs) are connected to EPC via broadband Internet connection of users
- End-users traffic is diverted through Femtos when they are inside their homes/offices
- Typical range of Femto is 30 m for homes and 100 m for enterprise deployments
- A home Femto can serve up to 7 end-users whereas enterprise Femto can serve up to 40 end-users
- So, win-win situation for both mobile operator and end-users

Heterogeneous LTE Network

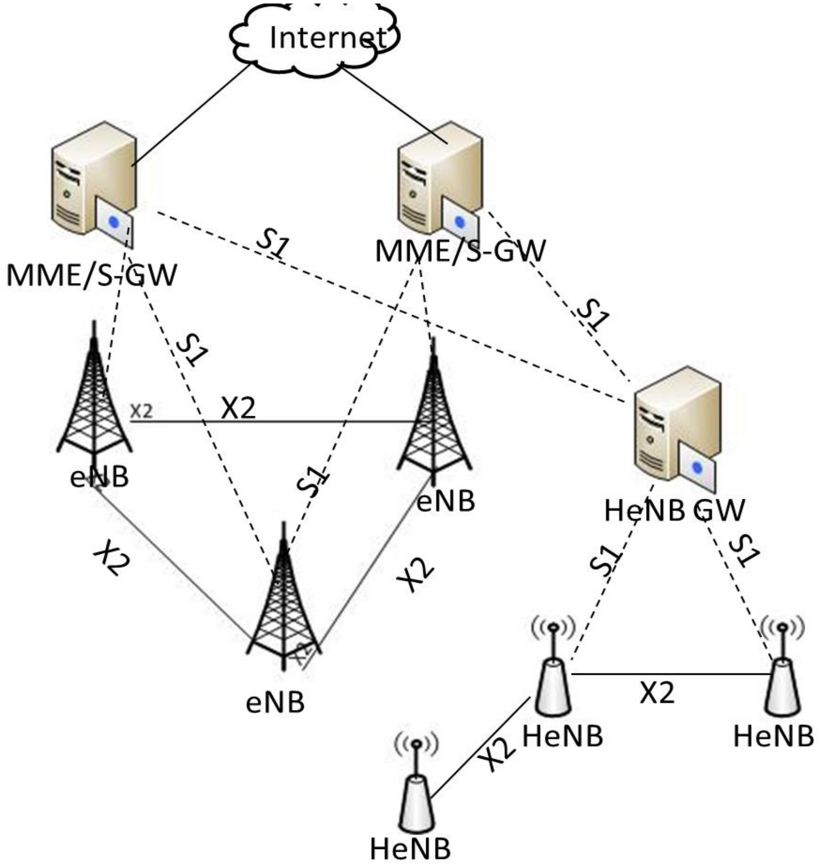


Small Cells:

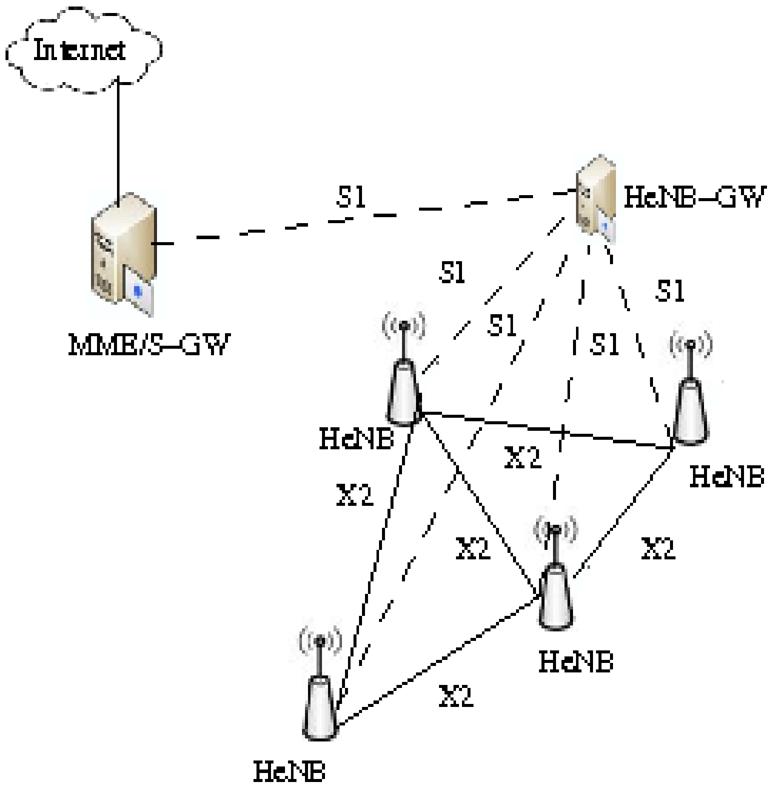
- Femto Cells
- Pico Cells
- Relays
- Remoto Radio Heads

But, if all use same frequency, it leads to interference

LTE HetNet System Architecture



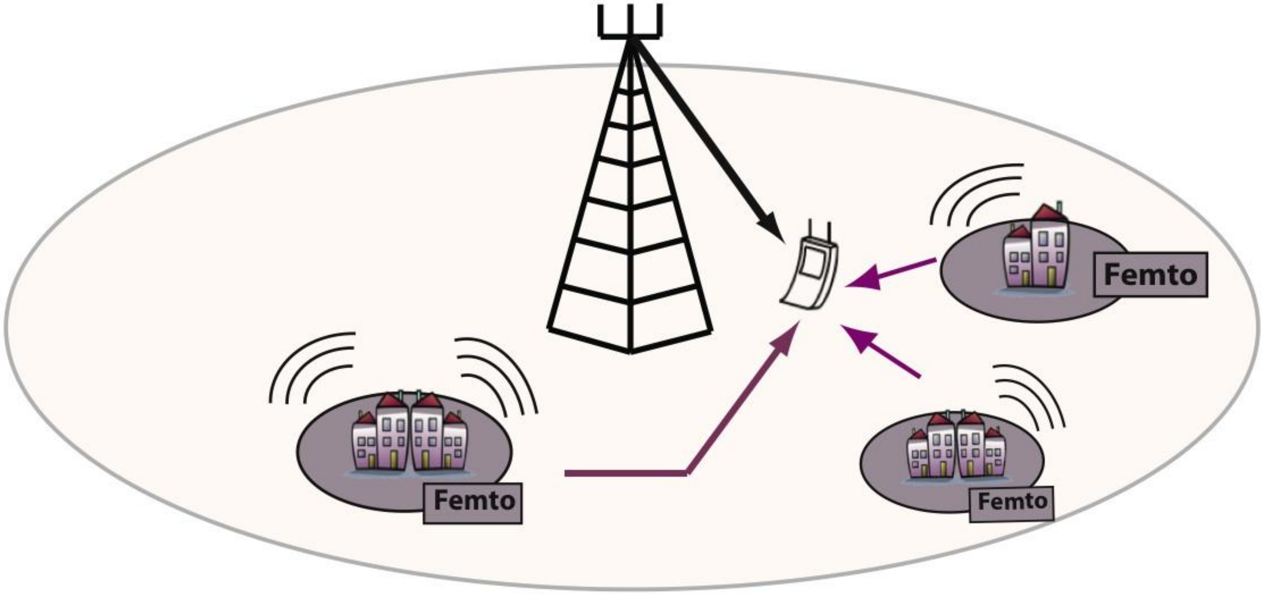
1) With Macro BSs in the Architecture



2) With out Macro BSs in the Architecture

Cross-tier Interference Problem

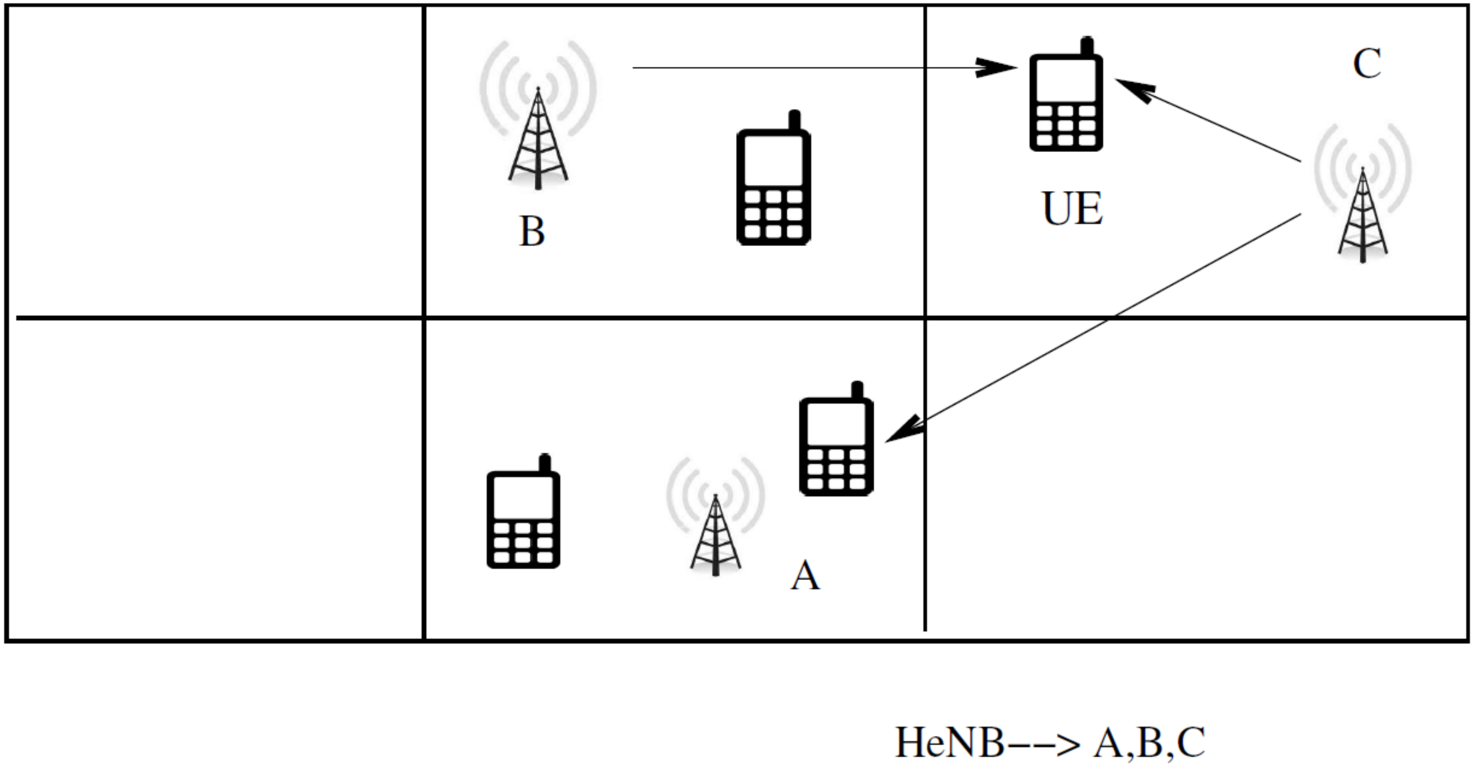
Example of cross-tier interference between the macro cell and femto cells located inside it



It is solved typically by allocated different spectrum for Macros and Femtos.

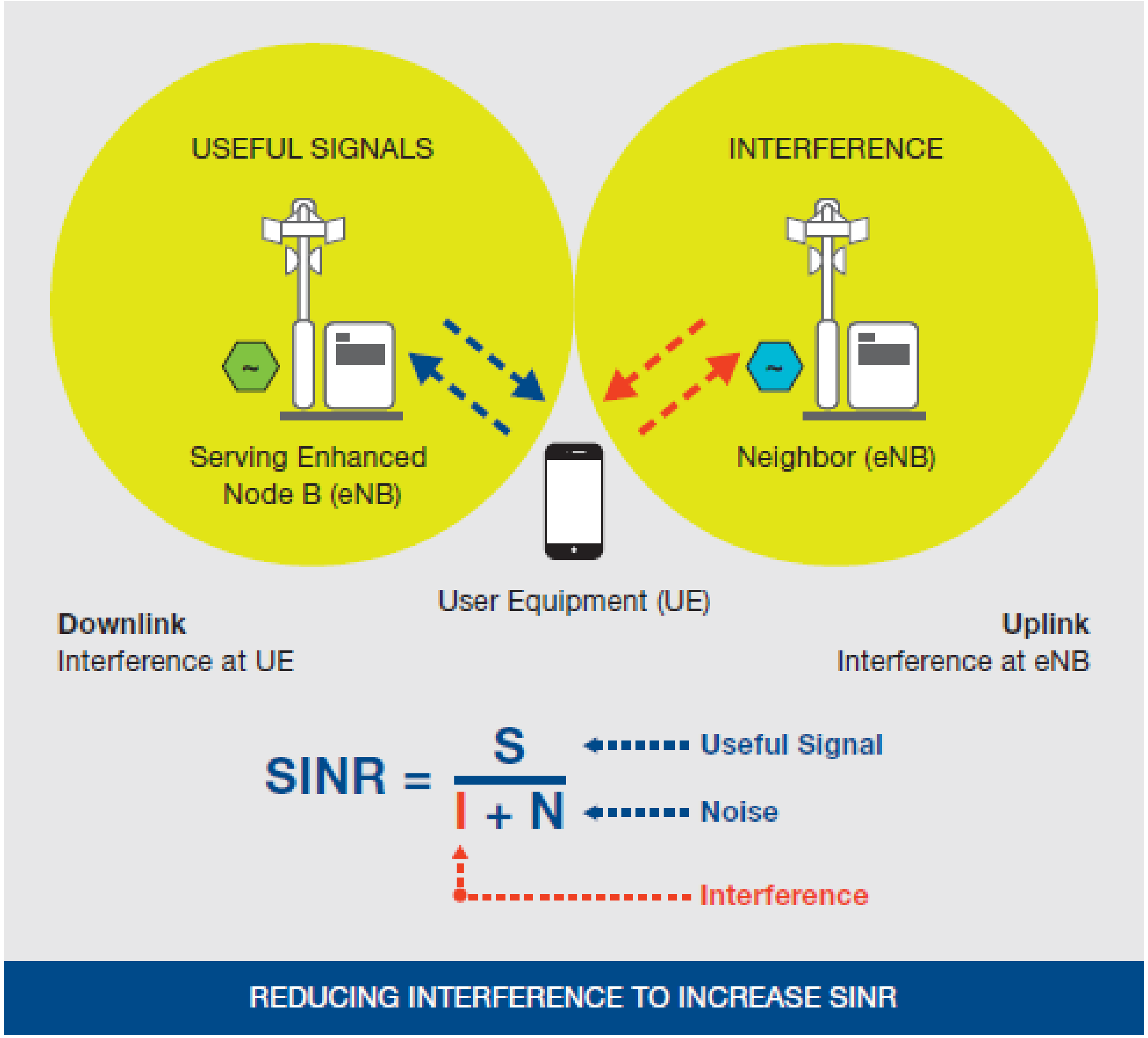
Co-tier Interference Problem

Example of co-tier interference among femto cells.



We propose a solution to address this co-tier interference problem among Femtos inside enterprise building in this work.

Effect of interference?



Source: ONF

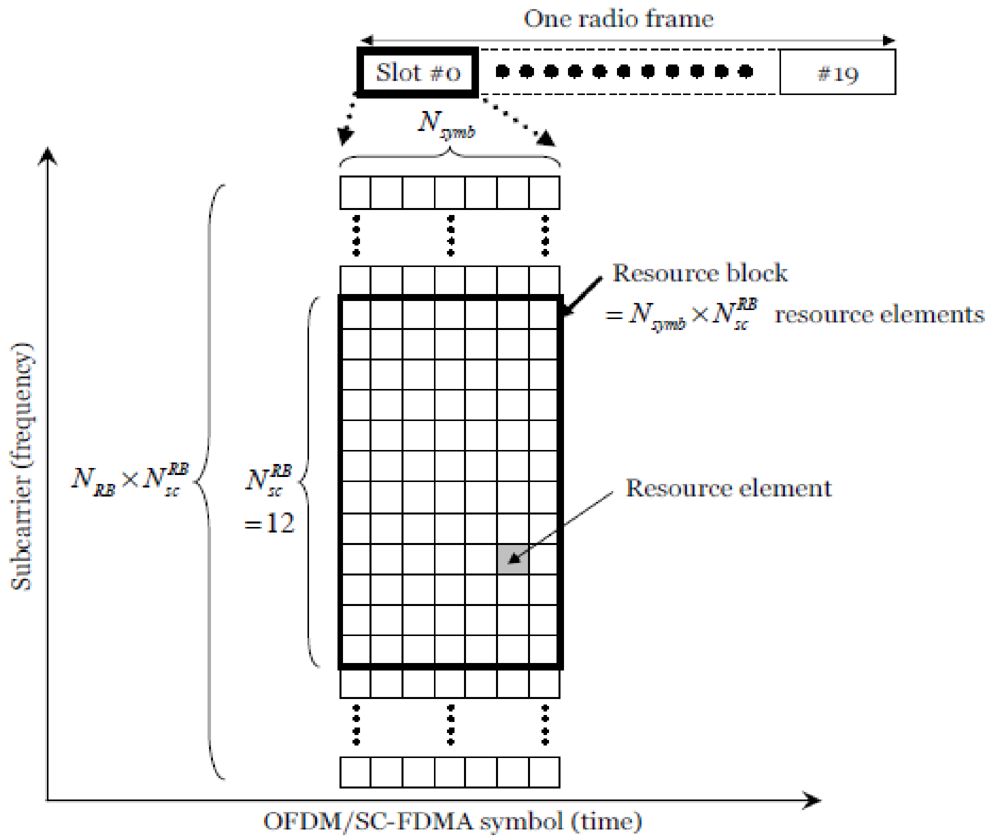
Good SINR → Good CQI → Higher Modulation Scheme → Higher Data Rate

Radio Resource Allocation Schemes

- ✓ Two types of frequency reuse techniques to reduce co-tier interference among Macros/Femtos.
  - Fractional Frequency Reuse (FFR)
  - Soft Frequency Reuse (SFR)

Radio Resources:

- Base Station allocates BW as Resource Blocks (RBs) to UEs
- One RB: 12 Sub-carriers * 7 OFDM symbols



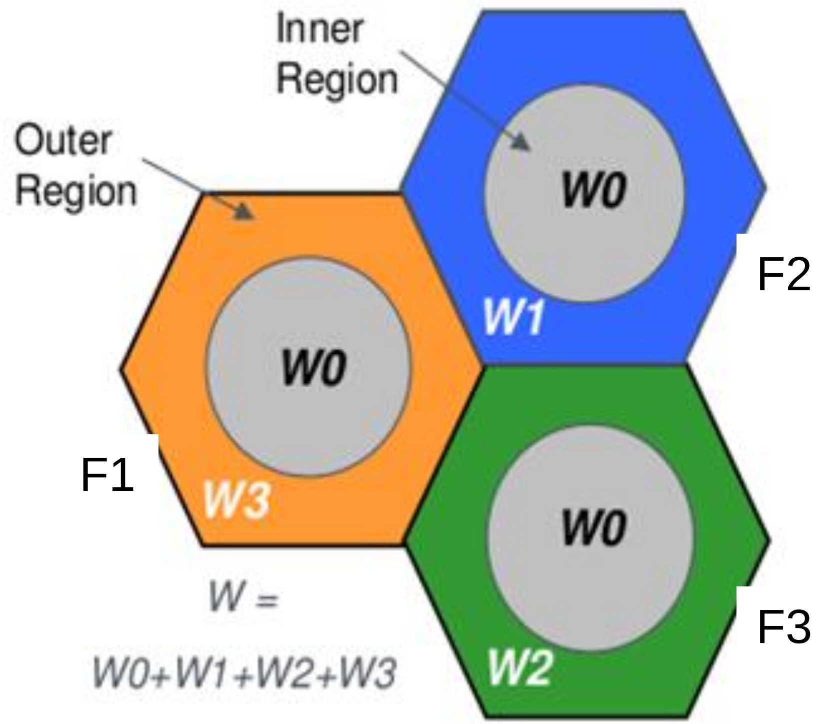
Fractional Frequency Reuse (FFR)

- Inner and Outer (cell-edge) regions in each cell.
- Low Tx power in Inner region compared to Outer region
- Frequency reuse 1 for Inner region spectrum band.
- Frequency reuse 3 for Outer region spectrum band.

Resource Allocation: (say @ F1)

- UE in Inner Region: Any of free W0+W3 RBs at low power
- UE in Outer Region: Any of free RBs from only W3 RBs at high power

Drawback of FFR: Spectrum is not used efficiently in each cell

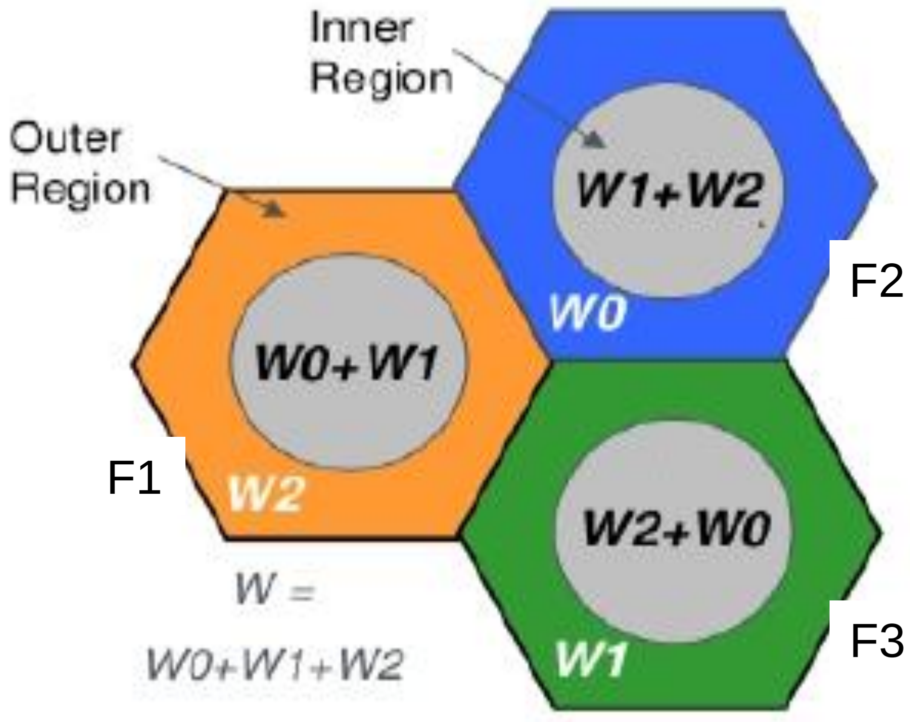


Soft Frequency Reuse (SFR)

- Like FFR, logical Inner and Outer regions in each cell
- SFR has effective frequency reuse factor of 1 per cell
- Interference between neighboring cells is reduced.

Resource Allocation: (say @ F1)

- UE in Inner Region: Any of free W=W0+W1+W2 RBs at low power
- UE in Outer Region: Any of free RBs in W2 RBs at higher power



Drawbacks of SFR

- Spectrum is statically distributed in each of femto cells inner and outer regions
- Load distribution within femto cell is not taken into account during allocation of spectrum band to different femtos
- Not possible to allocate spectrum bands differently for different cells due to interference issues
- Compare to Macro BSs because of ad-hoc and dense deployments, Femtos suffer from more co-tier interference problem
- So, SFR has to be optimized further for Femto Nets by using 3GPP ICIC mechanism

Inter-cell Interference-Coordination (ICIC in 3GPP Release 8)

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- Addresses co-tier interference problem among Macro BSs with frequency reuse 1 by using X2 interface
- BS talks over X2 with neighbors and allocates non-interfering subcarriers (RBs) to users in Outer region
- RB Allocation Scheme:
  - UE in Inner region: Any of free RBs like SFR discussed earlier → no restriction
  - UE in Outer region: Any of free RBs which are not being allocated by interfering cells for their Outer region UEs

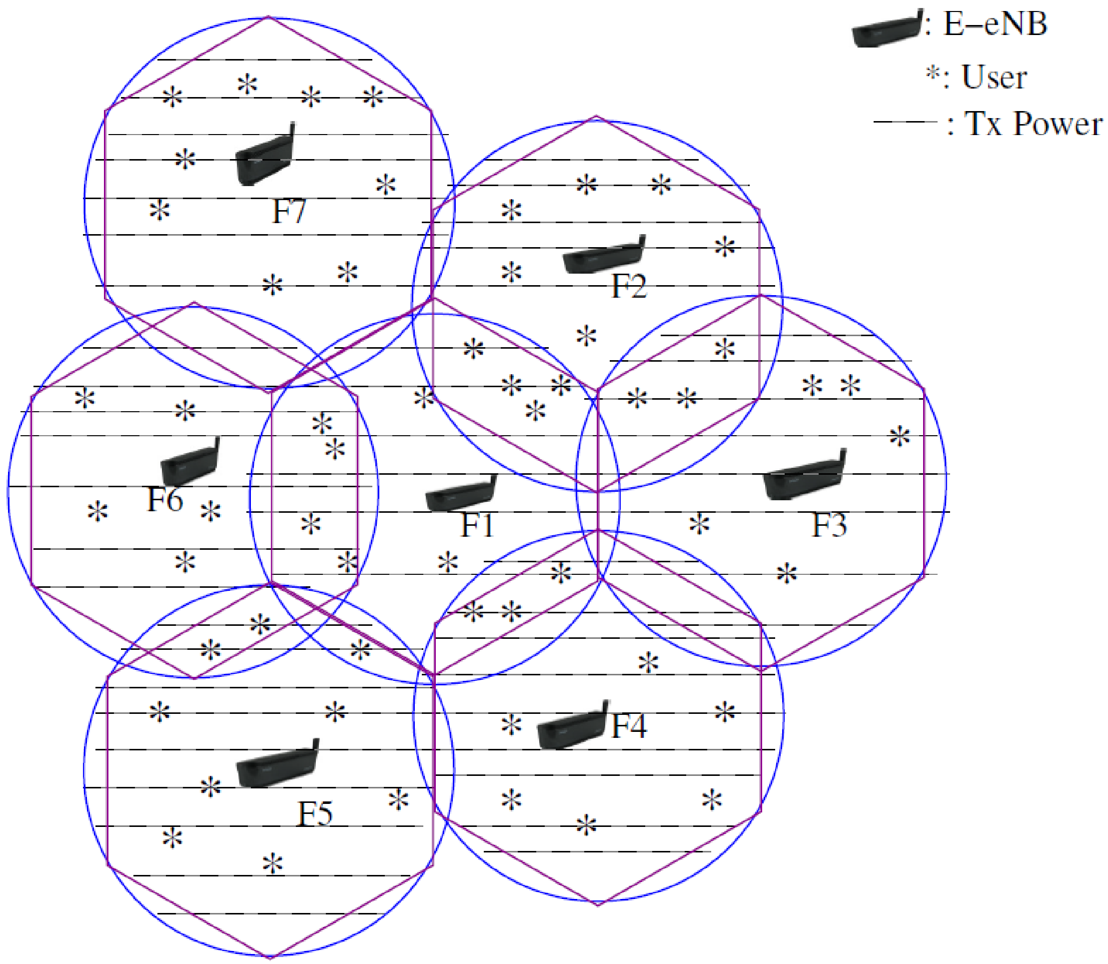
- Theoretically, it is impossible for UEs at the edge of two neighboring BSs to use same RBs
- Observation: Only need to coordinate with other BSs while allocating RBs for UEs in the Outer region

Issues with ICIC

- How is Inner/Outer region defined?
  - Beyond scope of 3GPP ICIC mechanism
  - So, many solutions are encouraged!
- Our Idea: dynamic increase/decrease of Inner (Outer) region by taking into account UE mobility, load variation, and interference from other Femto cells
  - Decrease Inner region conservatively (wish to have only Inner region for unrestricted RB allocation and improved system throughput)
  - Increase Inner region aggressively
  - We look into the problem of when to increase/decrease Inner region in our work
- In 3GPP Rel. 11, X2 interface is introduced between Femtos of enterprise Femto Nets in case of open access
- Later, eICIC mechanisms are proposed to further address interference problem

PROPOSED SOLUTION

Femto cells with overlapping areas



Proposed Work: VR Algorithm

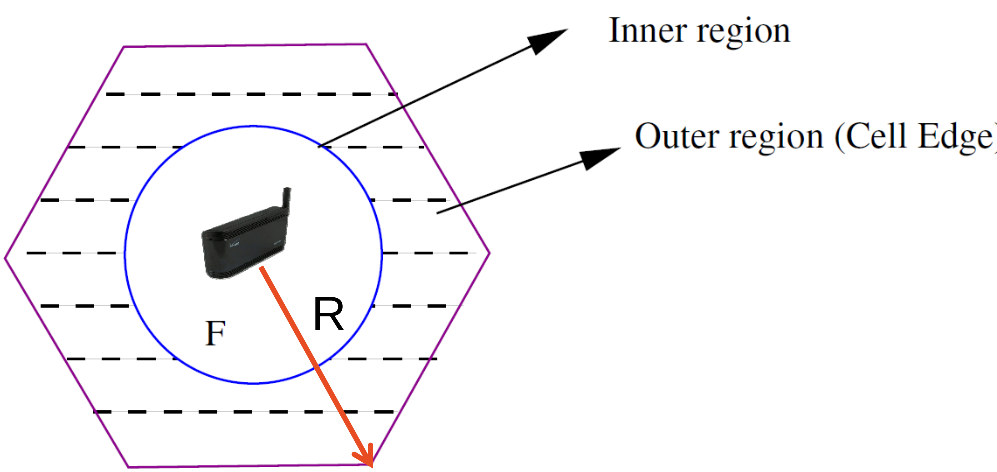
- Like in SFR/ICIC, in VR Algo for enterprise Femto cells,
  - Inner region: Reuse is One
  - But Outer region: Reuse may be more than one and depends on RBs usage in interfering Femto cells
- In order to increase system throughput, the inner (hence outer) region is varied dynamically
- RBs are not allocated statically for Inner/Outer regions, but shared dynamically
- Initially, Femto has only

One region→ Inner region

with radius $r \leftarrow R$

- Cell edge UEs may get low

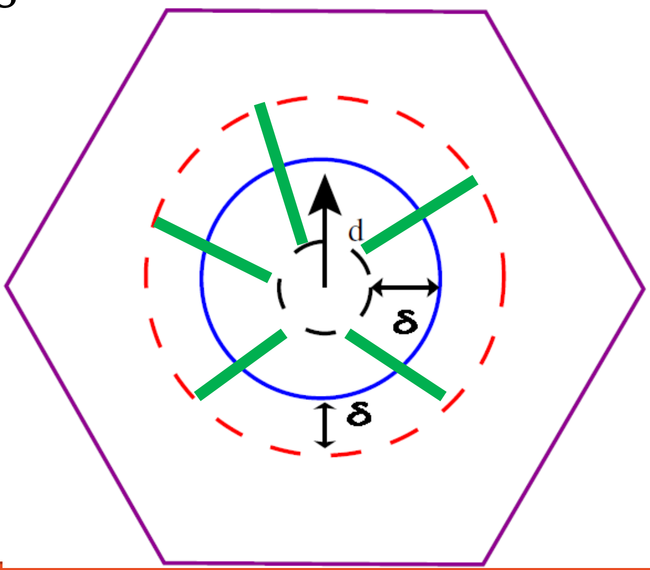
SINR, so report low CQIs



VR Algorithm: Decreasing Inner region

- Average CQI at distance *d* from the Femto center
  - Draw inner and outer circles with radius (d-δ) and (d+δ)
  - Average out CQI values of UEs present in strip with 2δ width
- At d=R, suppose condition average CQI >= *CQI_Threshold* fails
- Sort avg. CQIs in increasing order (decreasing *d* values)
- Find largest *d (say* γ) with its average CQI > *CQI_Threshold*
- New Inner region radius is

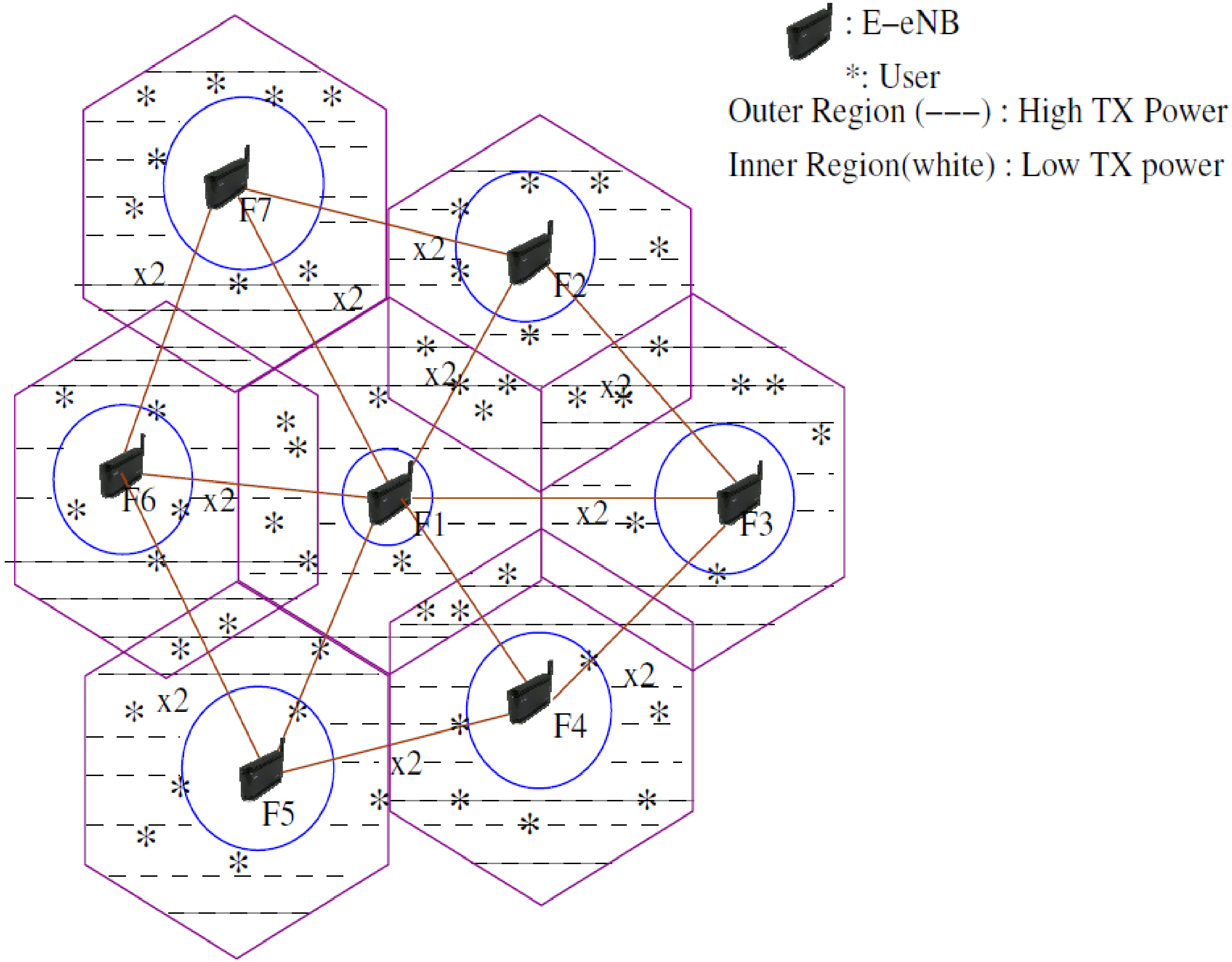
  $r \leftarrow (r + \gamma)/2$
- So, decreasing Inner region conservatively



d – Radius of Inner Region

2 δ – Width of the strip in which Avg CQI Calculated

Example: Decreasing Inner region(s)



VR Algorithm: Increasing Inner region

- Define Fail Ratio (FR) of Outer region as

  FR= Rejected Requests (RR) / Accepted Requests (AR),

  where RR ← Rejected UE Requests for RBs

  AR ← Accepted UE Requests for RBs

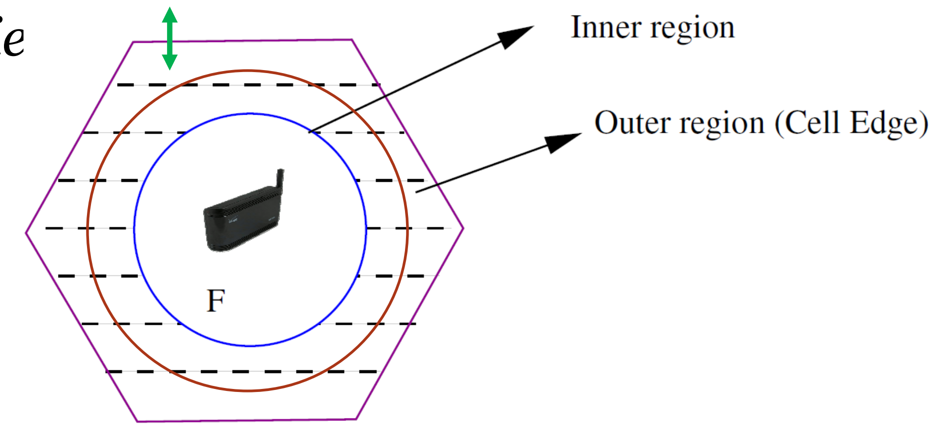
- Due to mobility and load variations, FR may become greater than *FR_Threshold* for Outer region

- Check whether Inner region could be increased by δ' *by* bringing in RR-AR/2 UEs from Outer to Inner region → living with interference among Femtos to increase FR

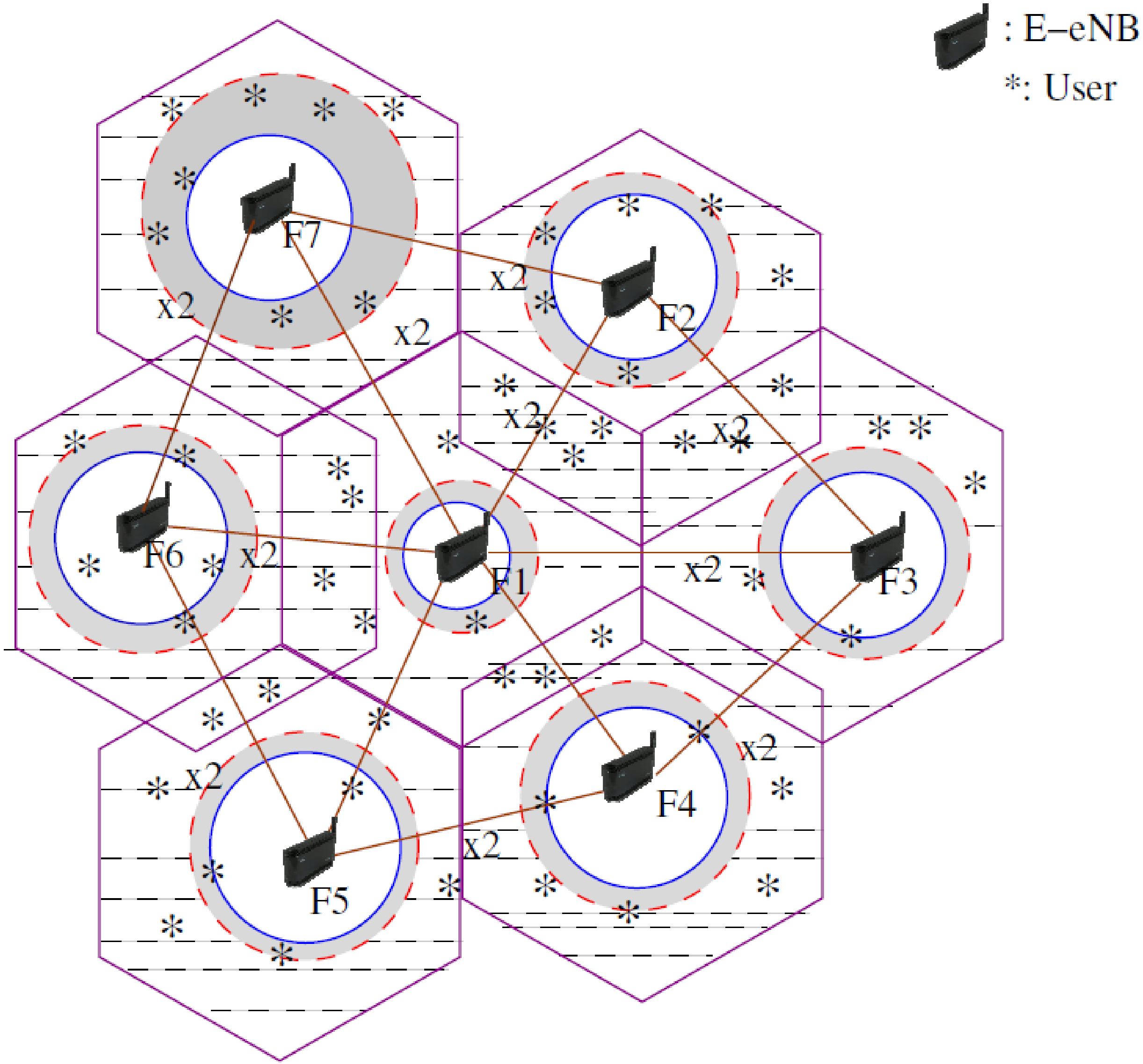
- If so, FR < *FR_Threshold is satisfie*

- New Inner region radius is

  $r \leftarrow r + \delta'$



Example: Increasing Inner region(s)



Experimental Setup

- The NS-3 simulator is used
  - ✓ Six apartment buildings, each containing a Femto BS deployed randomly.
- In real life, even static users will have some mobility, so set UE speed to 0.1m/s
- However, as we are not studying handovers in this work, we restricted the motion of each UE within a single room.

Simulation Parameters

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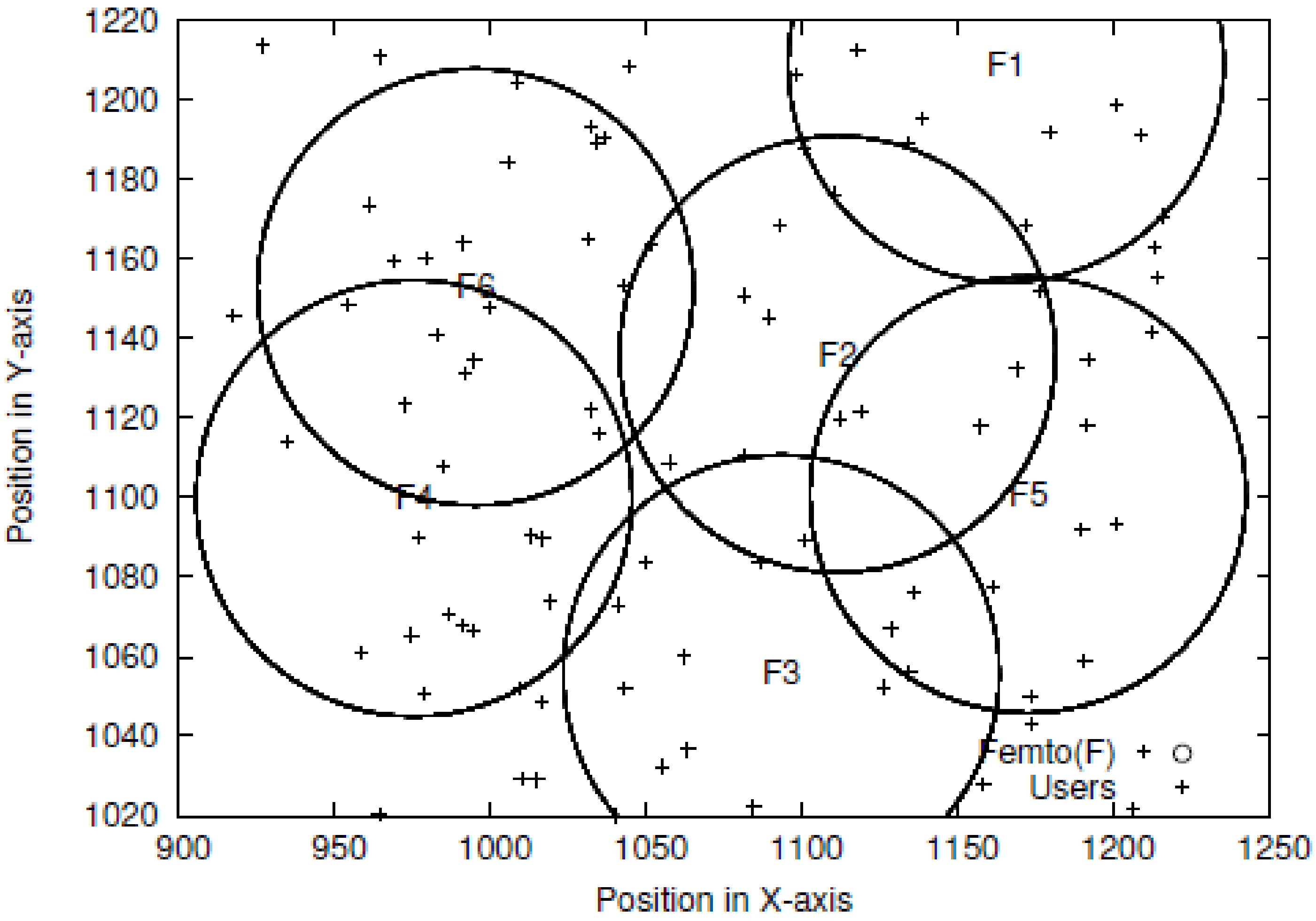
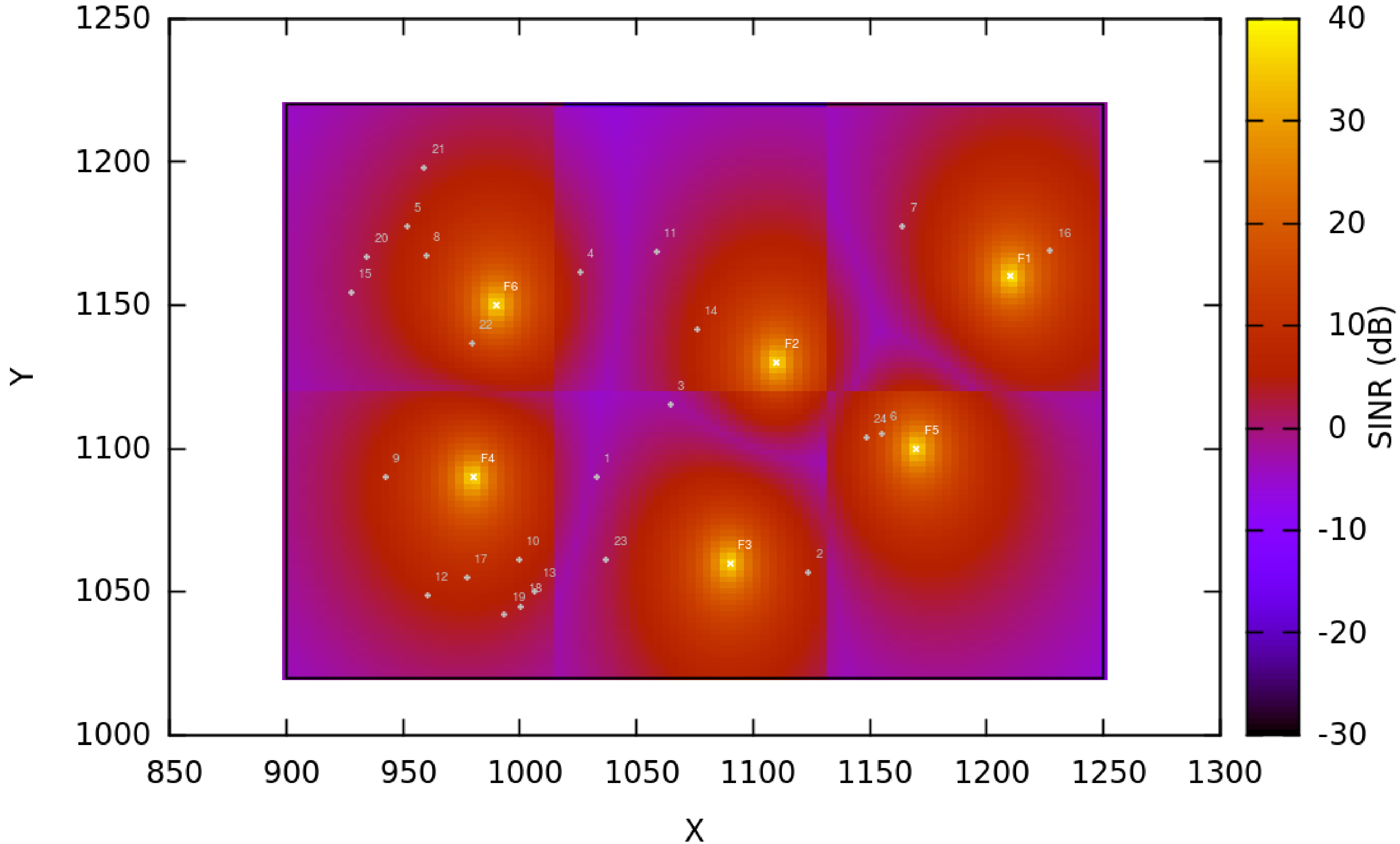
Parameters	Values
Number of Femto Cells	6
Number of UEs Per Femto	10, 15
UE Deployment	Random
Femto Coverage Range	70 m
Femto Bandwidth	5MHz (25 RBs)
Duplexing Mode	FDD
RB Allocation Algorithms	FFR, PF (Static ICIC), VR+PF
Simulated Traffic	Downlink (CBR Video)
Mobility of Mobile UEs	1m/s
Mobility of Static UEs	0.1m/s
Mobility Model	Building Mobility Model
Application Data Rate	4 Mbps
LTE Frame Duration	10 ms
Scheduling Interval (TTI)	1 ms

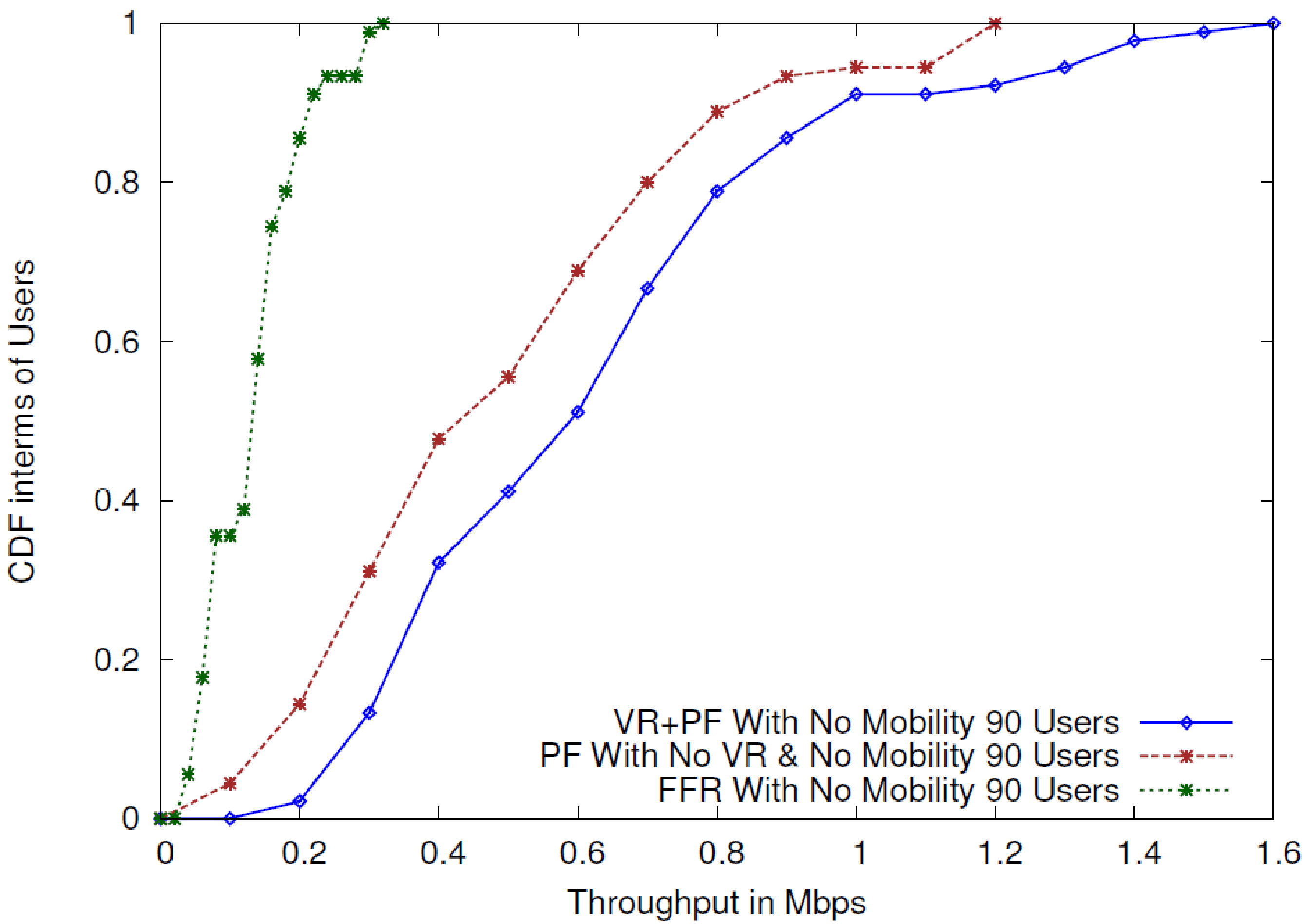
Positions of Six Femtos and 90 Users in Femto Net



SINR Heat Maps of Six Femtos in Femto Net

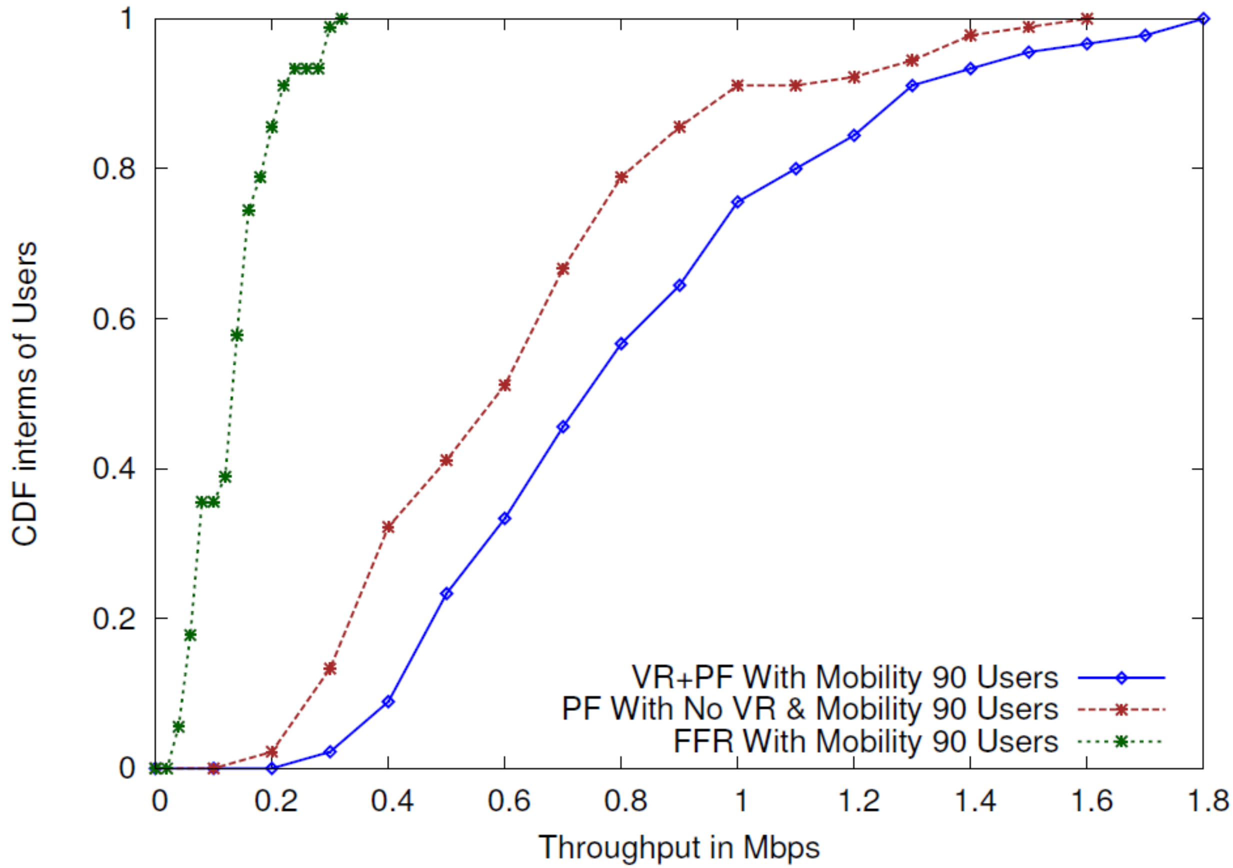


Throughput for 90 Static Flows



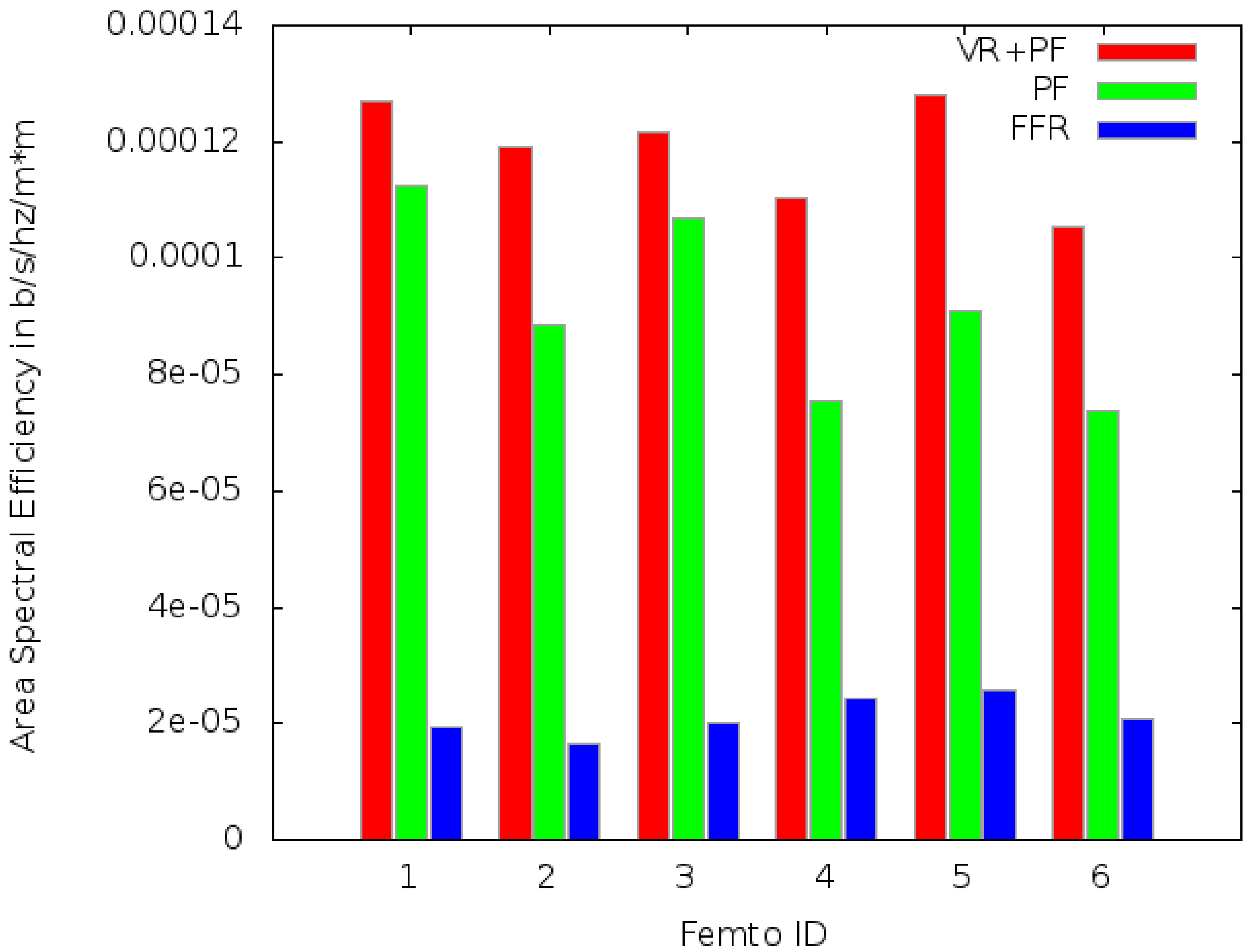
Average throughput for 90 static indoor users is increased by 29 % when VR algorithm is employed on top of PF scheduling.

Throughput For 90 Mobile Flows

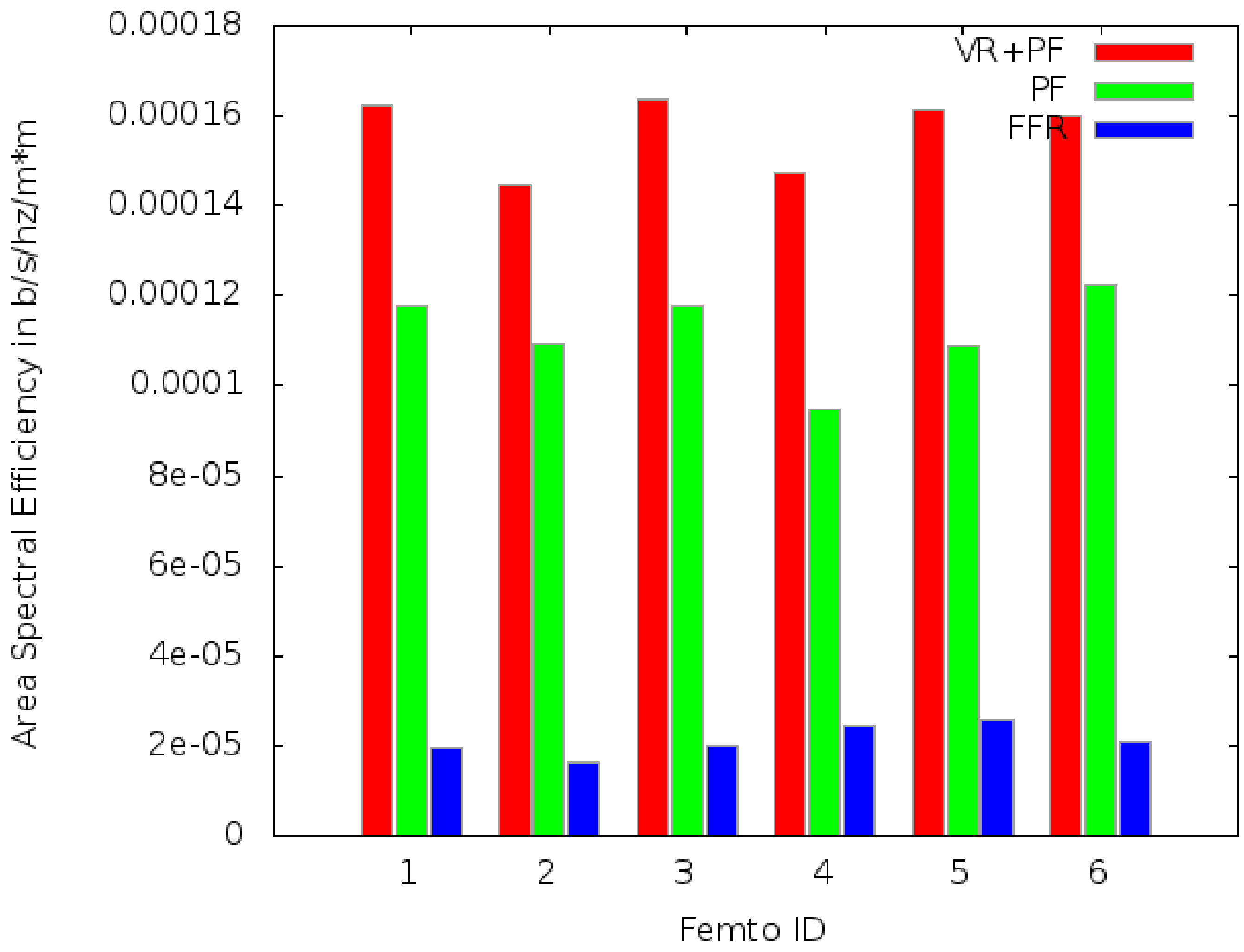


- ✓ Average throughput is increased by 37 % when VR algorithm is employed on PF.
- ✓ VR algorithm is good for mobile scenarios

Area Spectrum Efficiency for 90 Static Flows



Area Spectrum Efficiency for 90 Mobile Flows



Summary and Future Directions

- Proposed an efficient resource allocation algorithm by varying Inner (and hence Outer region) of Femtos dynamically
- Experimental results demonstrated superiority of proposed solution compared to existing solutions
- Studying energy efficiency of proposed solution
- Studying effect of traffic loads and communication delay over X2 interface on overall system throughput
- Applying proposed VR algorithm even for Macro BSs and studying performance in HetNets
- Extension to eICIC and so on …

Acknowledgments

- This work was funded by the Deity, Govt. of India (Grant No. 13(6)/2010CC&BT)
- IIT Hyderabad

THANK YOU!

Feedback ?

tbr@iith.ac.in