Institut für Kommunikations-Technik

Power control for interference management in LTE femto cell
An overview

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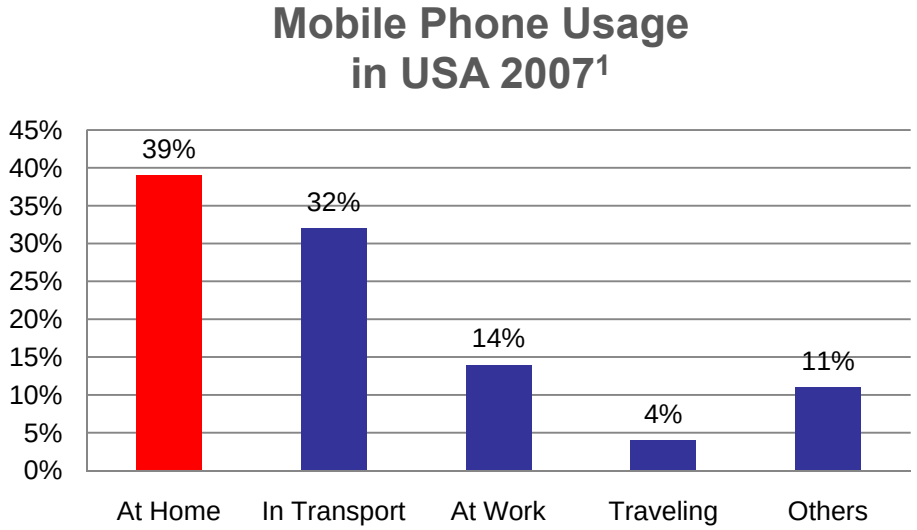
Presentation Outline

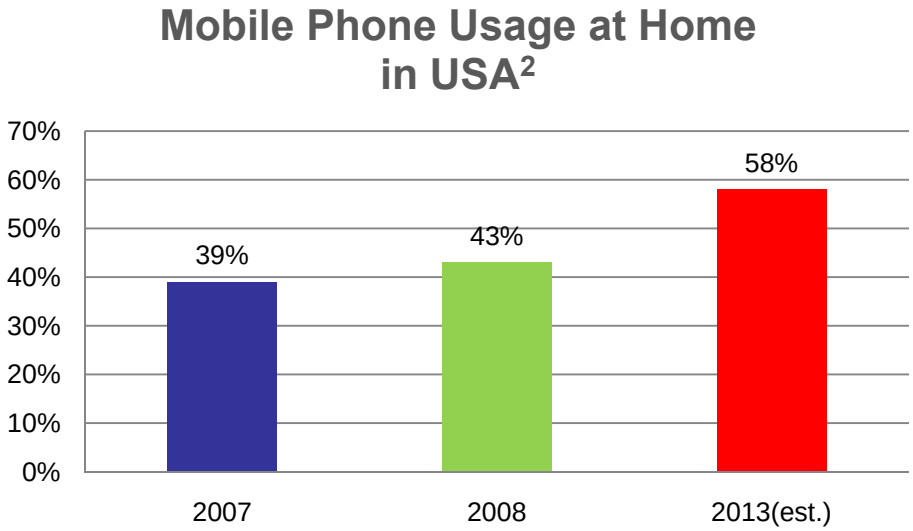
- Introduction to femto cell
- Interference problems in LTE femto cell
- Power control for interference management
  - downlink power controls
  - uplink power controls
  - advanced power controls
- Preliminary simulation results
- Concluding remarks

Why Femto at home?

- How many mobile phone calls are made at Home?



"Femto Cell Market to Reach $630 Million in 2010" [3]



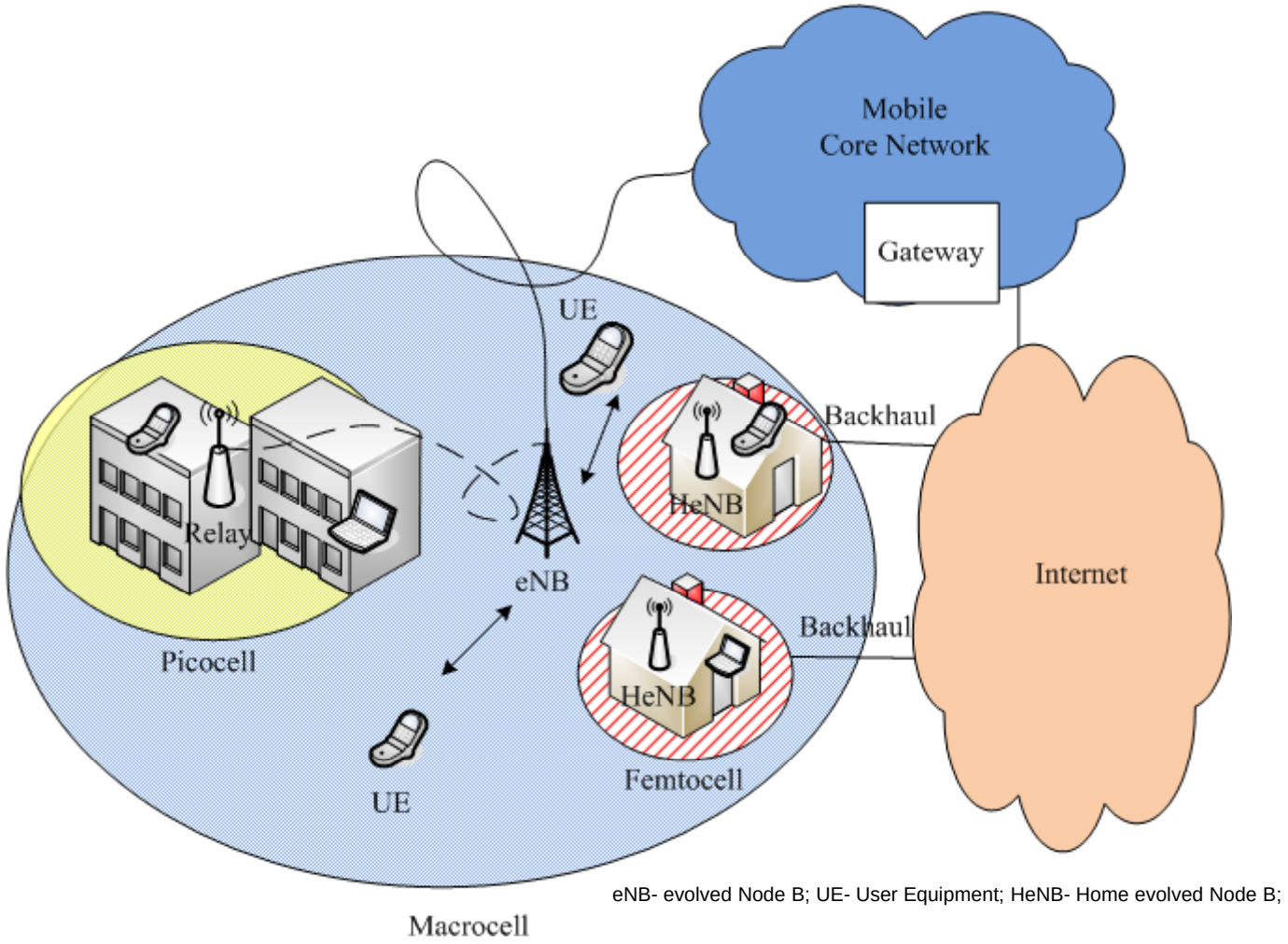
Femto cell is one promising solutions for mobile coverage at home:

- Reliable communication
- Easy install
- Low price and OPEX
- Seamless handover
- Network integration

1 – "The Case for Home Base Stations" tech. white paper by Femtoforum, Apr. 11, 2007
2 – "Mobile Phone Use in the Home is Growing" by David H. Deans, Sep. 29, 2008
3 – "Mobile market research report" by Infonetics Research, 2007

Femtocell for LTE

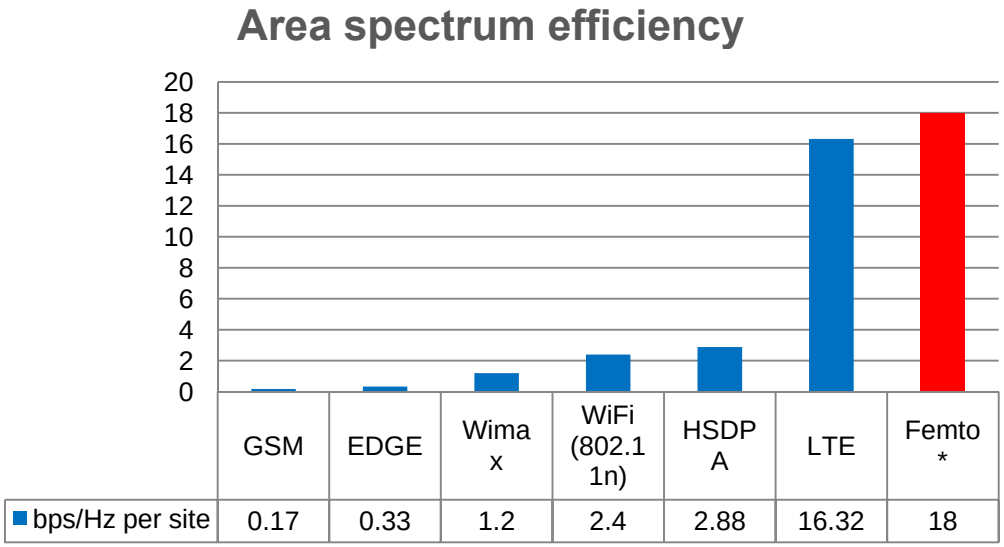
"Macro" "Pico" "Femto"



eNB- evolved Node B; UE- User Equipment; HeNB- Home evolved Node B;

Femto cell and spectrum efficiency

- We are running out of spectrum!



* - current industry goals

- Since 1957, the wireless capacity has an approximately million fold increase, 25x improvement from wider spectrum, 5x improvement from dividing spectrum into smaller slices, 5x improvement by designing better modulation schemes, and a whopping 1600x gain through reduced cell sizes and transmit distance."[2]

2 – "Area Spectral Efficiency of Cellular Mobile Radio Systems", by M. –S Alouini and Andrea Goldsmit, IEEE Trans. Vehic. Tech. Jul. 1999, pp. 1047-66

What challenges Femtocell will bring?

- Technical challenges
  - Interference problems
  - Low cost implementation
  - Network and integration
  - Seamless handover
- Non-technical challenges
  - Low operating expenditure
  - Security problems
  - Lawful issues
  - Health care problems

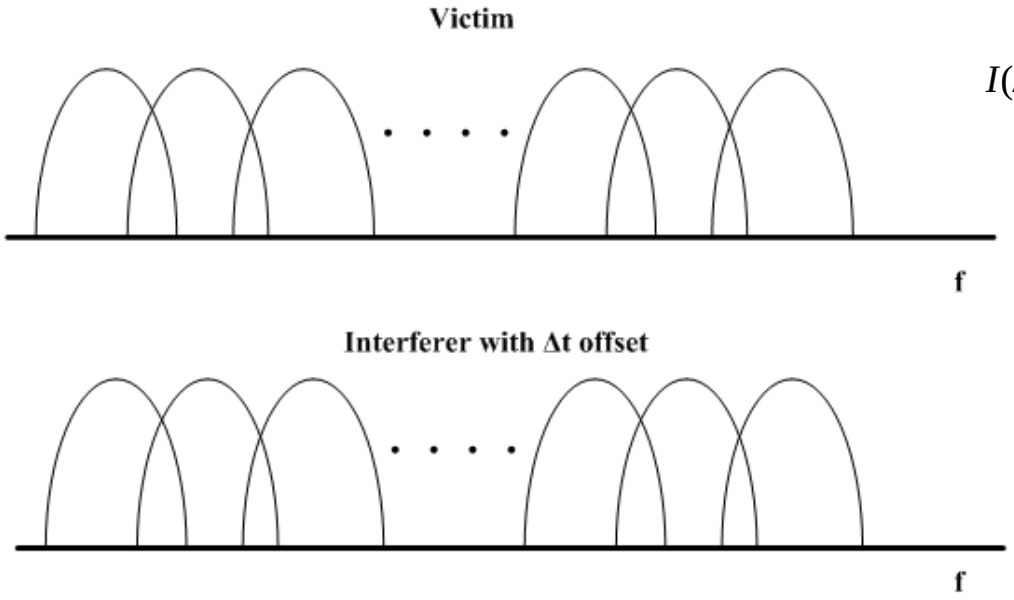
Interference problems in LTE Femtocell

- Femtocell number per macro cell is indefinite
- Femtocell location can be without planning
- Frequency reuse strategy for LTE is already aggressive
- LTE air interfaces: OFDMA in downlink and FC-FDMA in uplink
- Restrictions on the functionalities of Home eNB
- Imperfect synchronization for Femtocells
- Priority issues
- Close/Open Connectivity issues

- Efforts from both academy and industries: esp. 3gpp ran4, ff wg2

OFDMA interference pattern in Downlink

- No intra-cell interference – orthogonal resource blocks
- Inter-cell Interference with perfect synchronization
- Inter-cell Interference with timing offset[1]



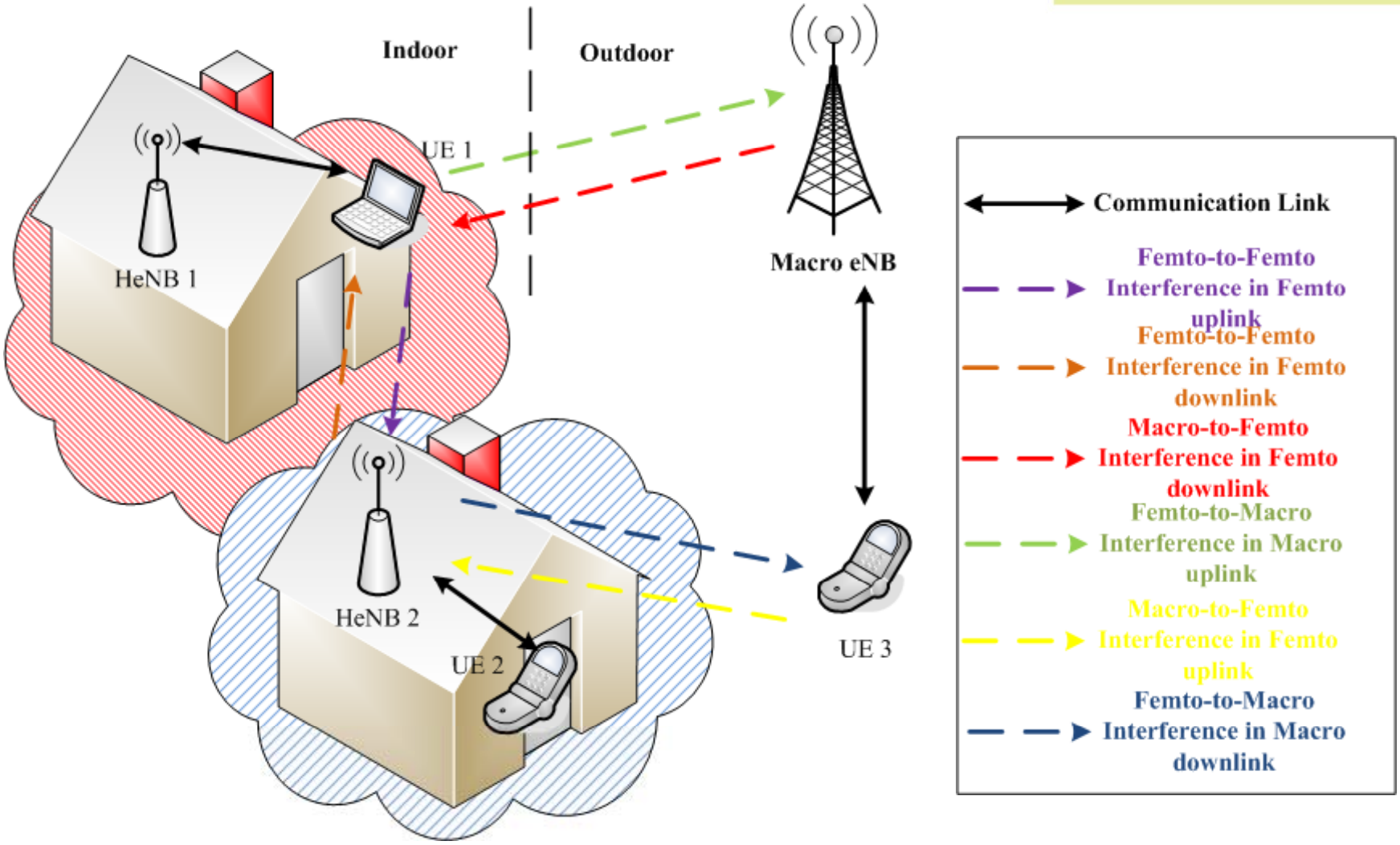
$$I(\Delta t, l) = \begin{cases} \delta(l) & 0 < \Delta t < t_{cp} \\ \left| \dfrac{\sin(\pi l (t_{cp} - \Delta t)/T)}{\pi l} \right|^2 & t_{cp} < \Delta t < T + t_{cp} \\ 0 & T + t_{cp} < \Delta t < T + 2t_{cp} \end{cases}$$

if Δt is uniformly distributed

$$\bar{I}(l) = \begin{cases} \dfrac{2T + 3t_{cp}}{6(T + t_{cp})} & l = 0 \\ \dfrac{T}{2(T + t_{cp})} \dfrac{1}{(\pi l)^2} & l \neq 0 \end{cases}$$

1 – J-W. Lee, "Other-Cell Interference Reducing Resource Allocation in OFDM-Based Asynchronous Cellular Systems", EURASIP Journal on Wireless Comm. and Networking, 2008

Interference Types



How serious are they?

- Evaluate the influence of different types of interferences
  - mainly on Link budget study
  - Computer simulations
  - Field measurements

Interference Types	Influence Level	Note
Femto-to-Femto Interference in Femto uplink	Moderate	Rare to occur Tx power limit for Femto UE
Femto-to-Femto Interference in Femto downlink	Moderate	Adaptive power control Prevent dead zones
Macro-to-Femto Interference in Femto downlink	Low	Num. of affected users small
Femto-to-Macro Interference in Macro uplink	Moderate, potentially high	Limit Femto UE power
Macro-to-Femto Interference in Femto uplink	Low	Near-far effect
Femto-to-Macro Interference in Macro downlink	High	Handover, adaptive Femto BS power control

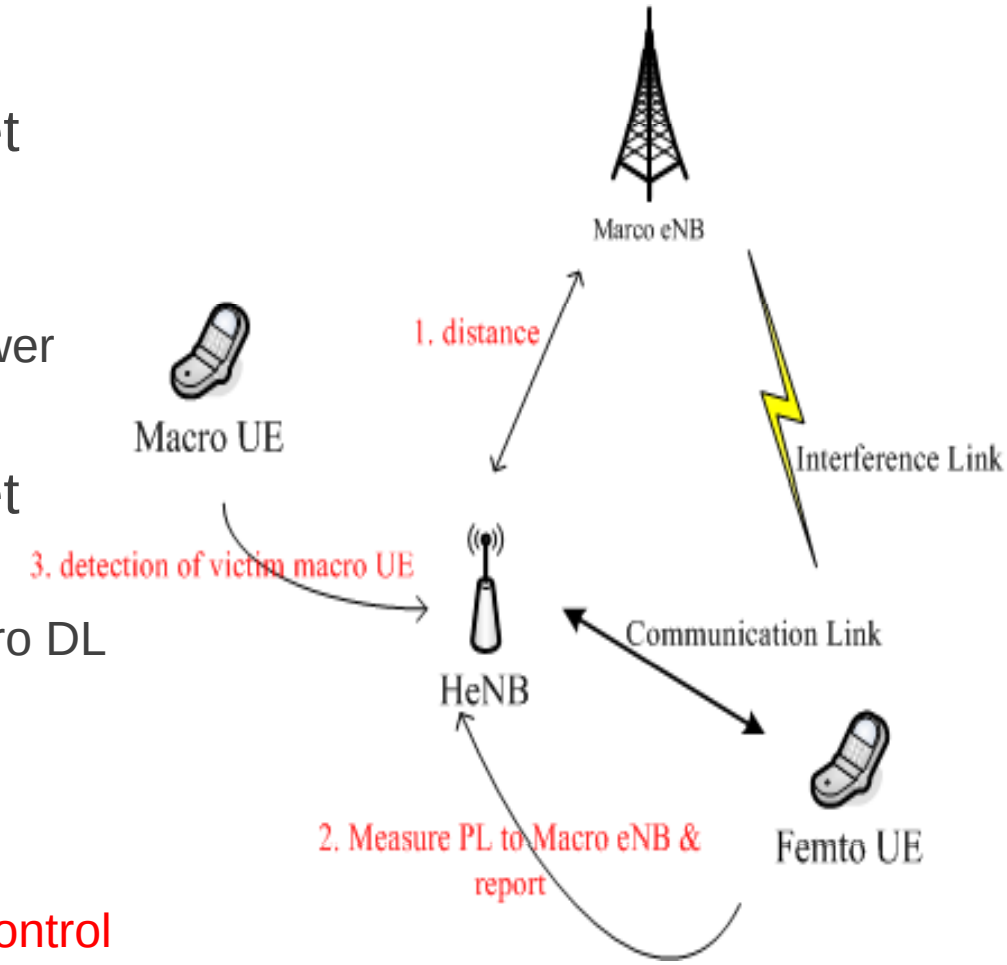
1 – “Interference Management in OFDMA Femtocells”, Femtoforum WG2 whiter paper, 2009

Power control algorithms

- PC algorithms existing in LTE macro cell
  - Downlink
    - basically constant
  - Uplink
    - Open loop – Fractional power control
    - Closed loop – link SINR measurement and control signaling via DL
- PC algorithms for LTE femto cell to develop
  - Downlink
    - non-constant transmit power
  - Uplink
    - Open loop – modified Fractional power control
    - Closed loop – may approach optimal power allocation
  - Advanced PC algorithms
    - Joint PC with sub-band allocation etc. – additional degrees of freedom
    - Cooperative PC

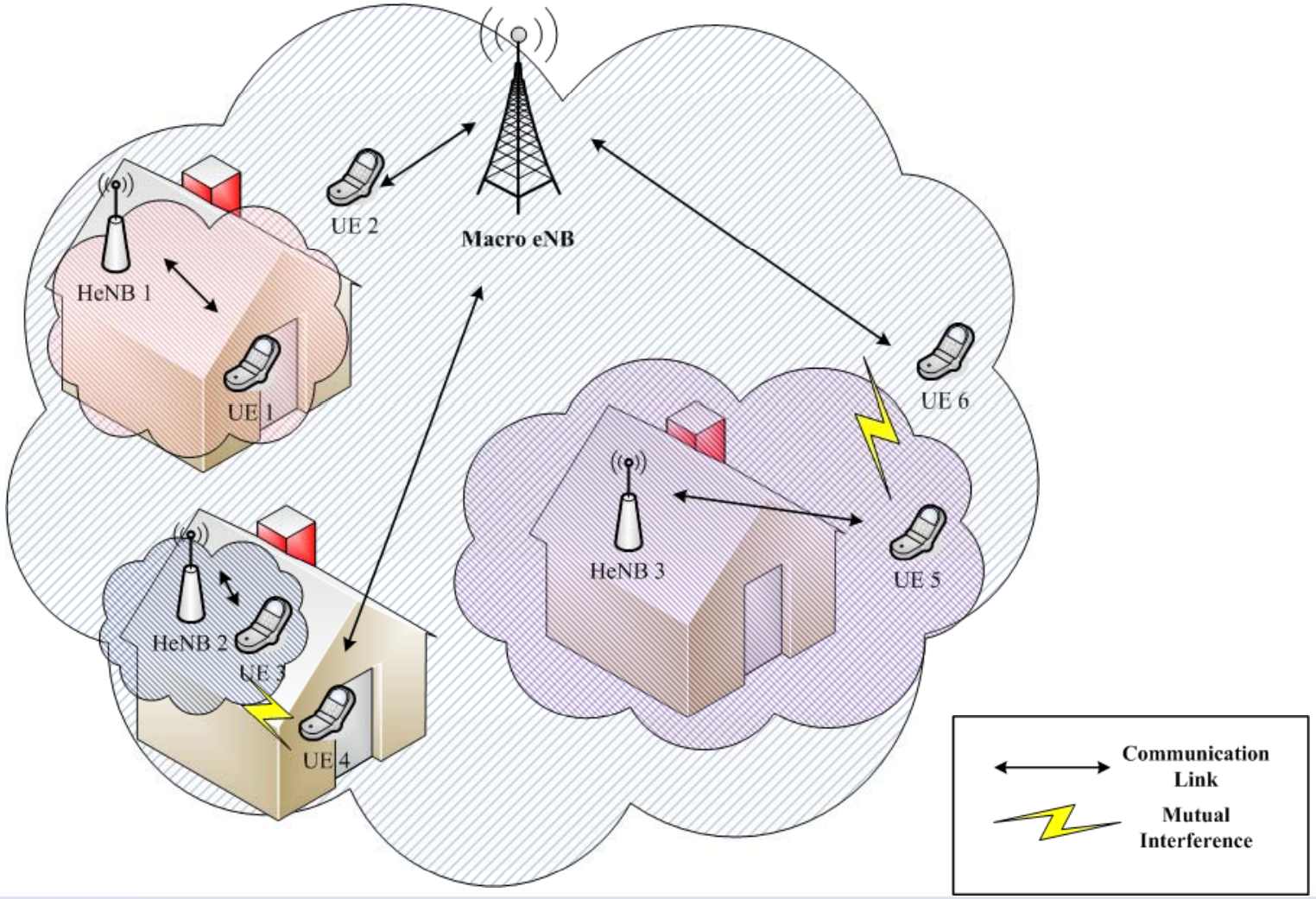
Algorithms for Downlink femto cell PC

- to mitigate the Femto-to-Macro interference in Downlink
- 1. Based on distance to closet Macro eNB
  - Femto eNB's location is known
  - far distance = reduce HeNB power
- 2. Based on pathloss to closet Macro eNB
  - measure signal strength of Macro DL
- 3. On detection of victim UEs
  - only protect when needed
  - if detected, strict HeNB power control
  - if not detected, soft power control



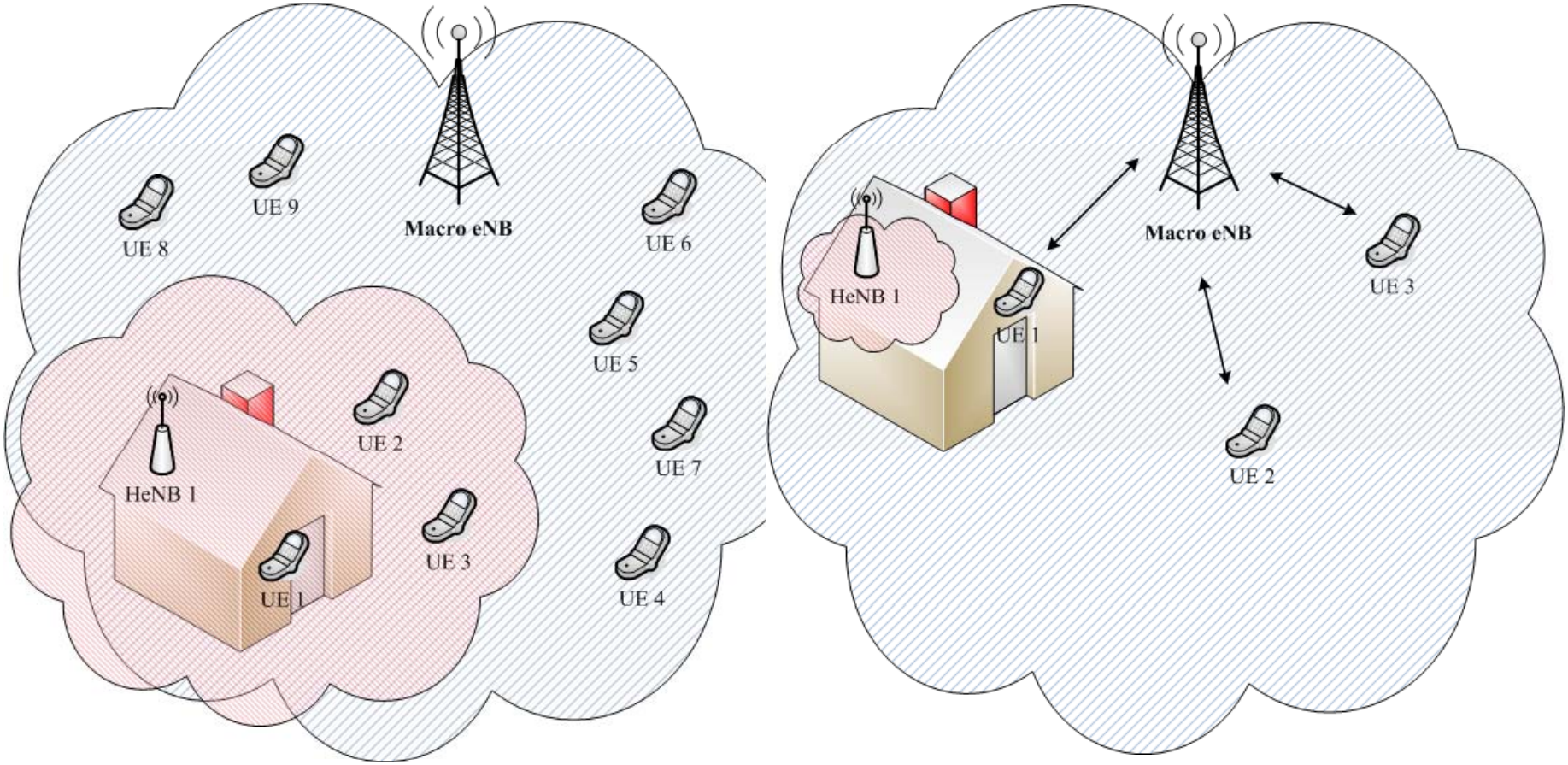
Downlink PC with Connectivity issues

- ill “cell breathing” raises interference



Further on “cell breathing”

- Femtocell expands to unburden “Hot Spot” load
- Femtocell shrinks in “Cold Spot”



Algorithms for Uplink femto cell PC – Open Loop

- Conventional Fractional power control

$$P_t = P_{\max} \times \min\left\{1, \max\left[R_{\min}, \left(\frac{PL}{PL_{x-ile}}\right)^{\gamma}\right]\right\}$$

  - $P_{\max}$ is the power cap (cell specific)
  - γ is the fractional factor
- Modifications on FPC
  - Macro eNBs adjust $P_{\max}$ of the Femtocells in their vicinity
    - higher UL interference -> reduce $P_{\max}$
  - Macro eNBs adjust γ or PL_{x-ile} of the Femtocells in their vicinity
    - γ is a balancing factor between throughput and system coexistence
- Parameter sets proposed by 3GPP RAN4[1]

Parameter set	Gamma (γ)	PLx-ile	
		10 MHz bandwidth	5 MHz bandwidth
Set 1	1	112	115
Set 2	0,8	129	133

1 – 3GPP R4-091796, May 2009

Algorithms for Uplink femto cell PC – Closed Loop

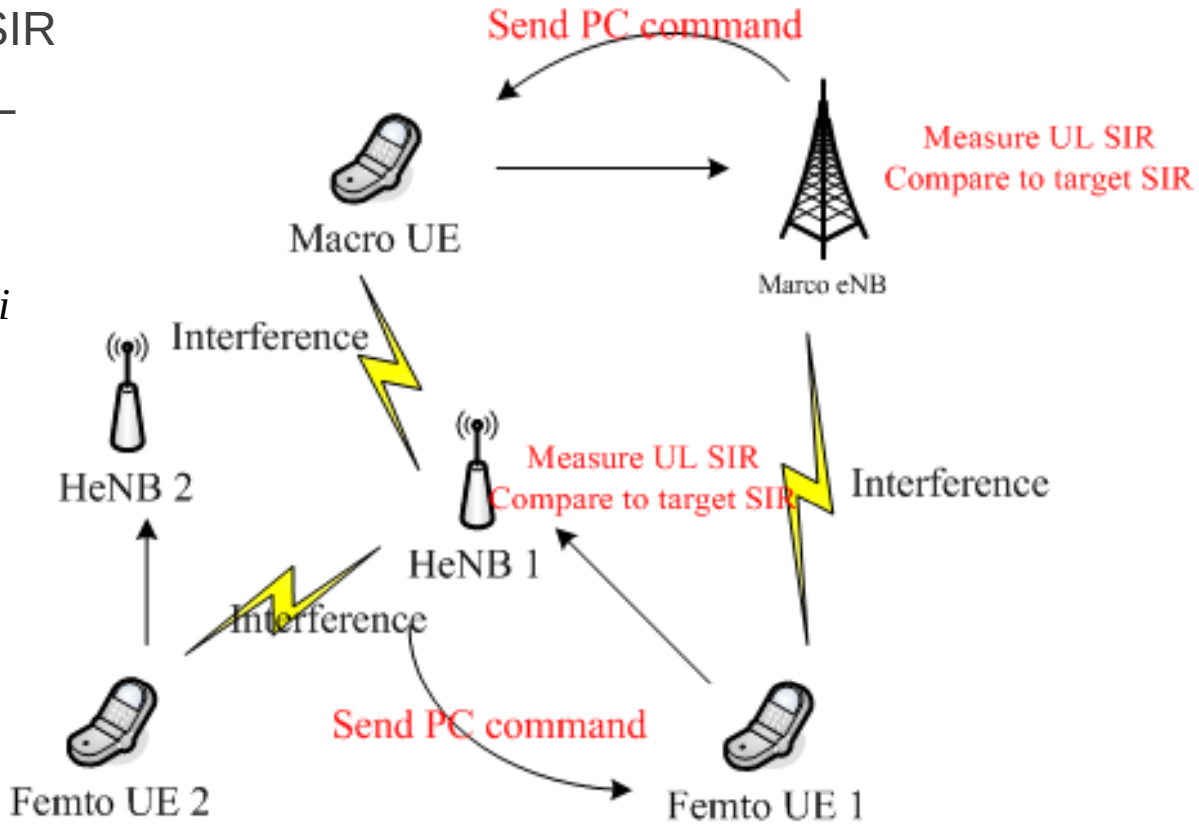
- optimal power controls
  - interference limited network, e.g. CDMA
  - assign target SIR
  - measure current UL SIR
  - feedback to UE via DL

$$\text{minimize} \sum_i p_i$$

$$\text{subject to } SIR_i(\mathbf{p}) \geq \gamma_i, \quad \text{for } \forall i$$

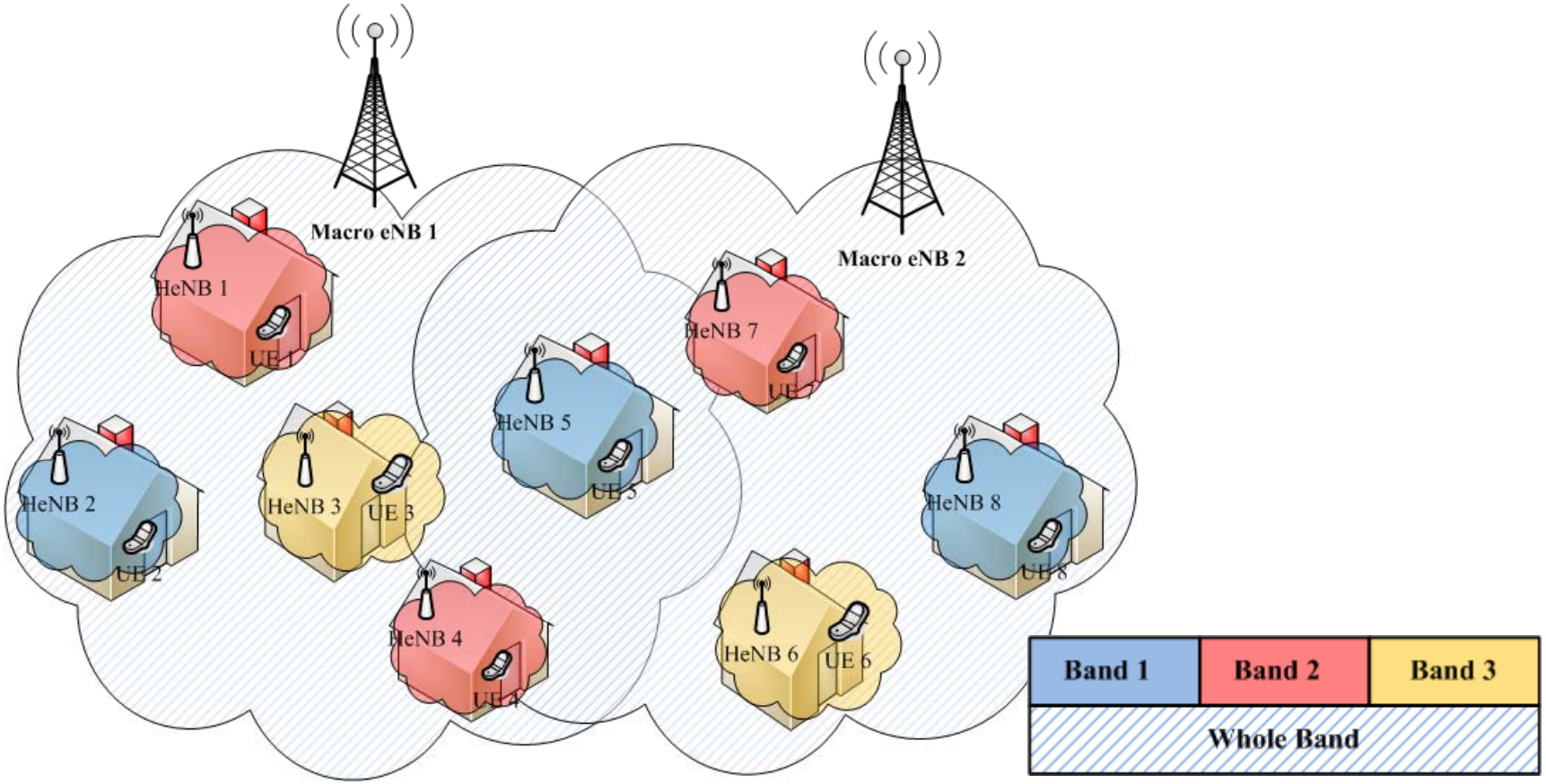
$$\text{variables } \mathbf{p}$$

$$p_i[t+1] = \frac{\gamma_i}{SIR_i[t]} p_i[t]$$



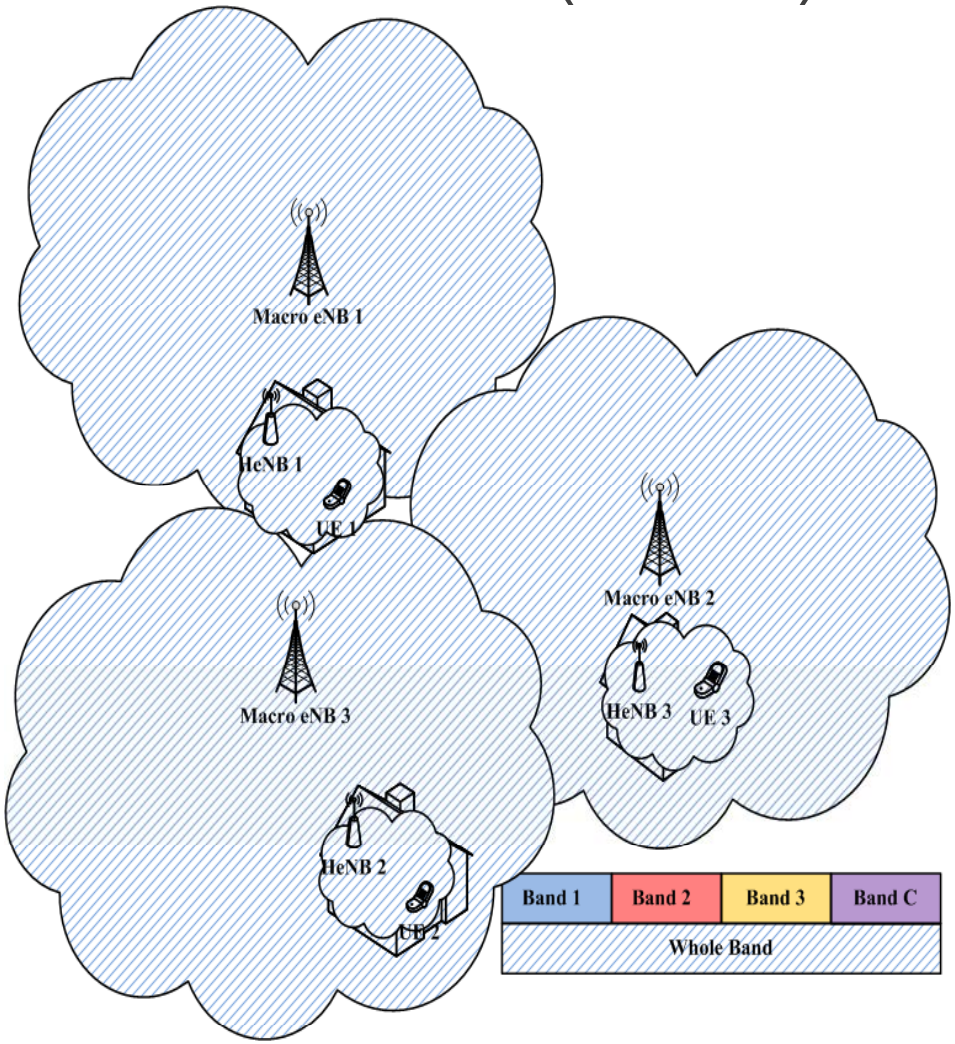
Fractional Frequency Reuse with PC

- Traffic demand on Femtocell is relatively low
- Optimal FFR allocation with joint power control
- Randomly FFR allocation

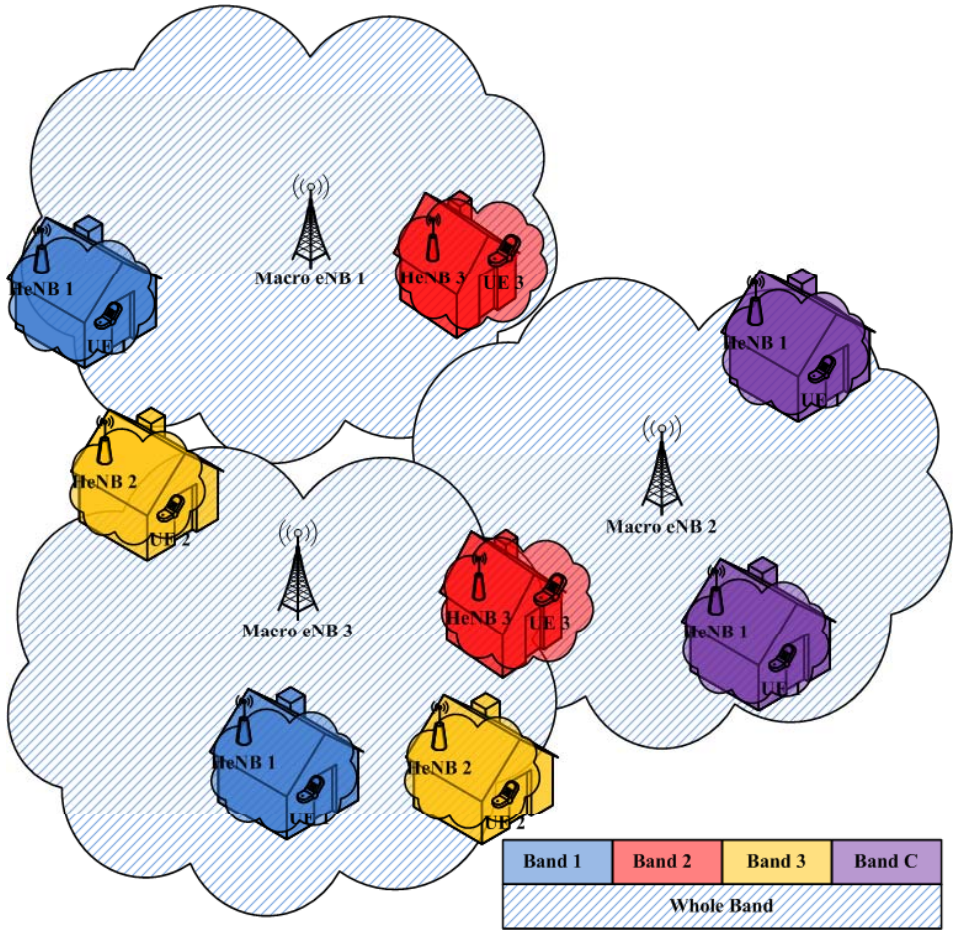


Joint PC and FFR

- FFR scheme 1 (baseline)

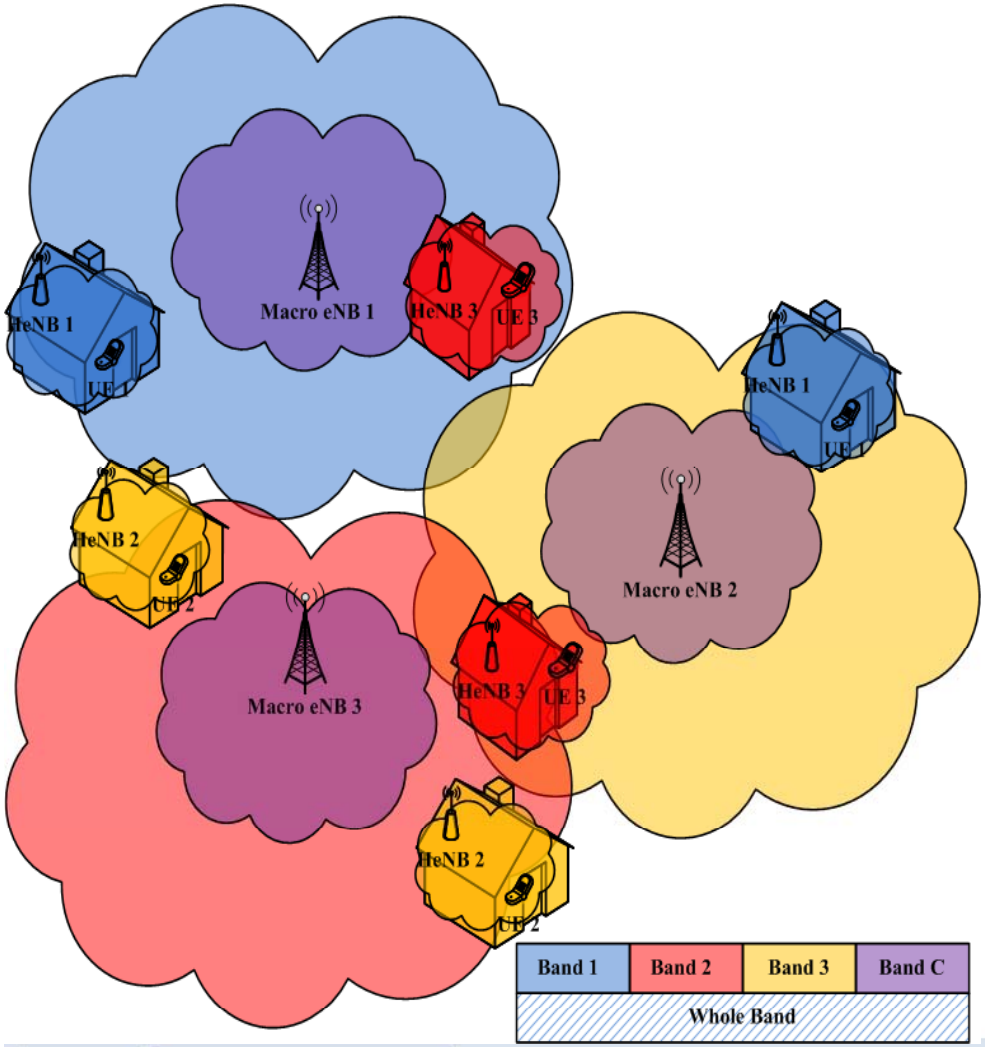


- FFR scheme 2

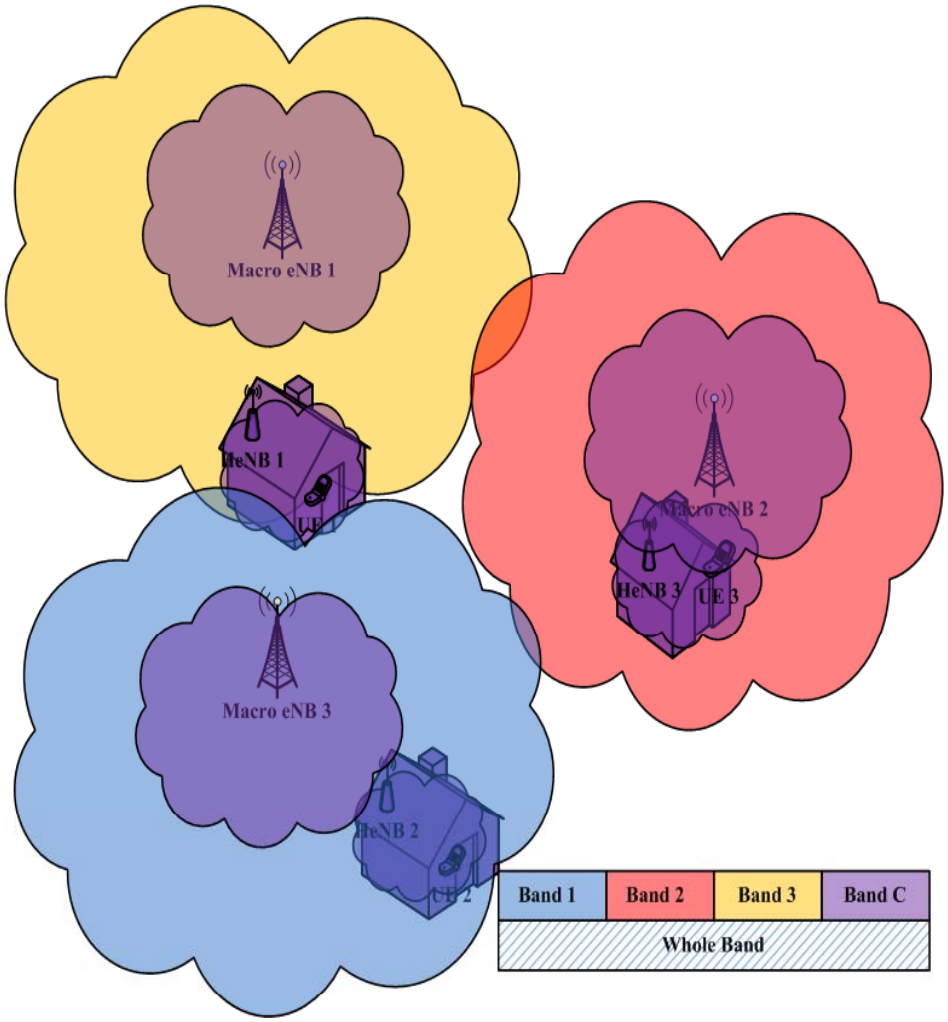


Joint PC and FFR

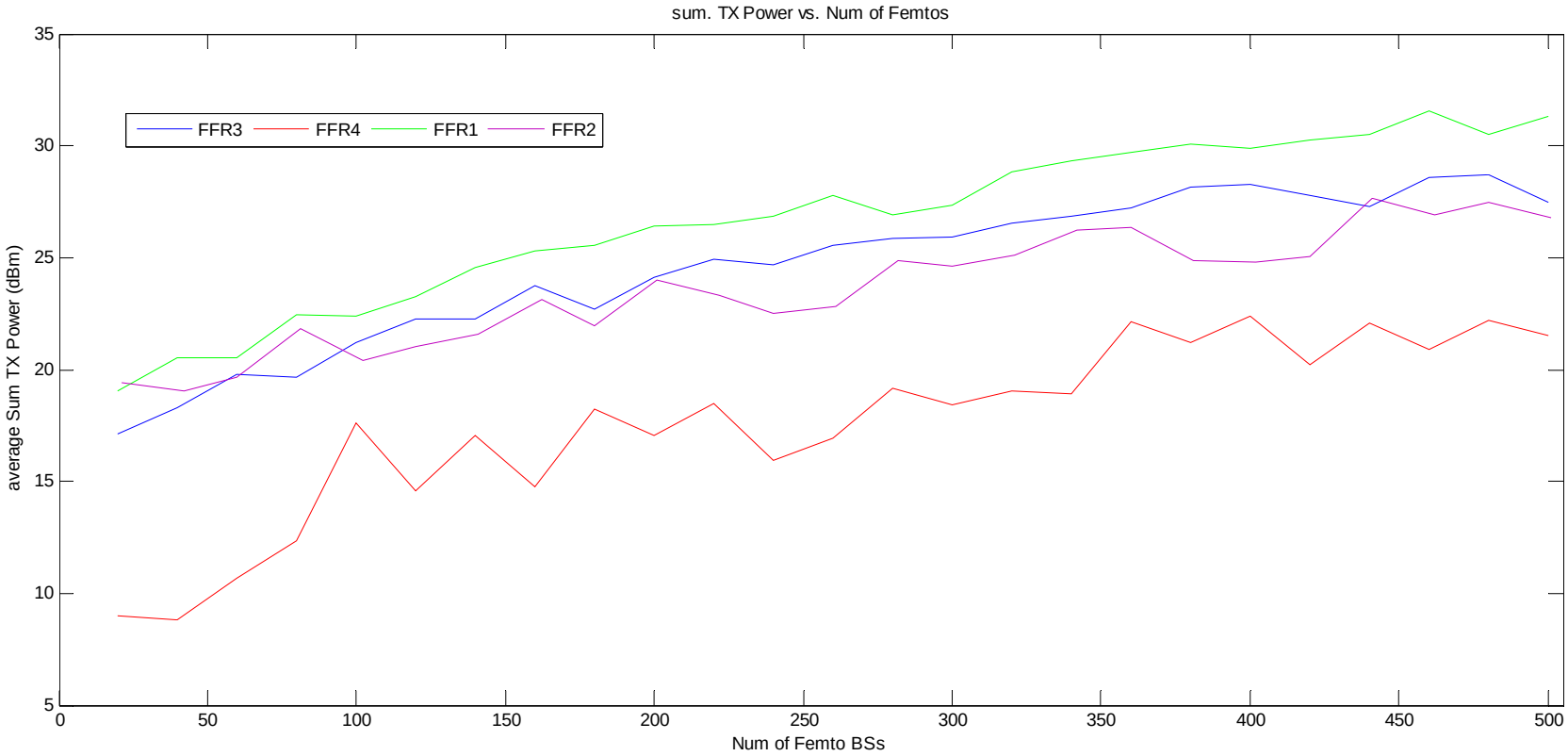
- FFR scheme 3



- FFR scheme 4



Preliminary results 500x Monto Carlo simulation



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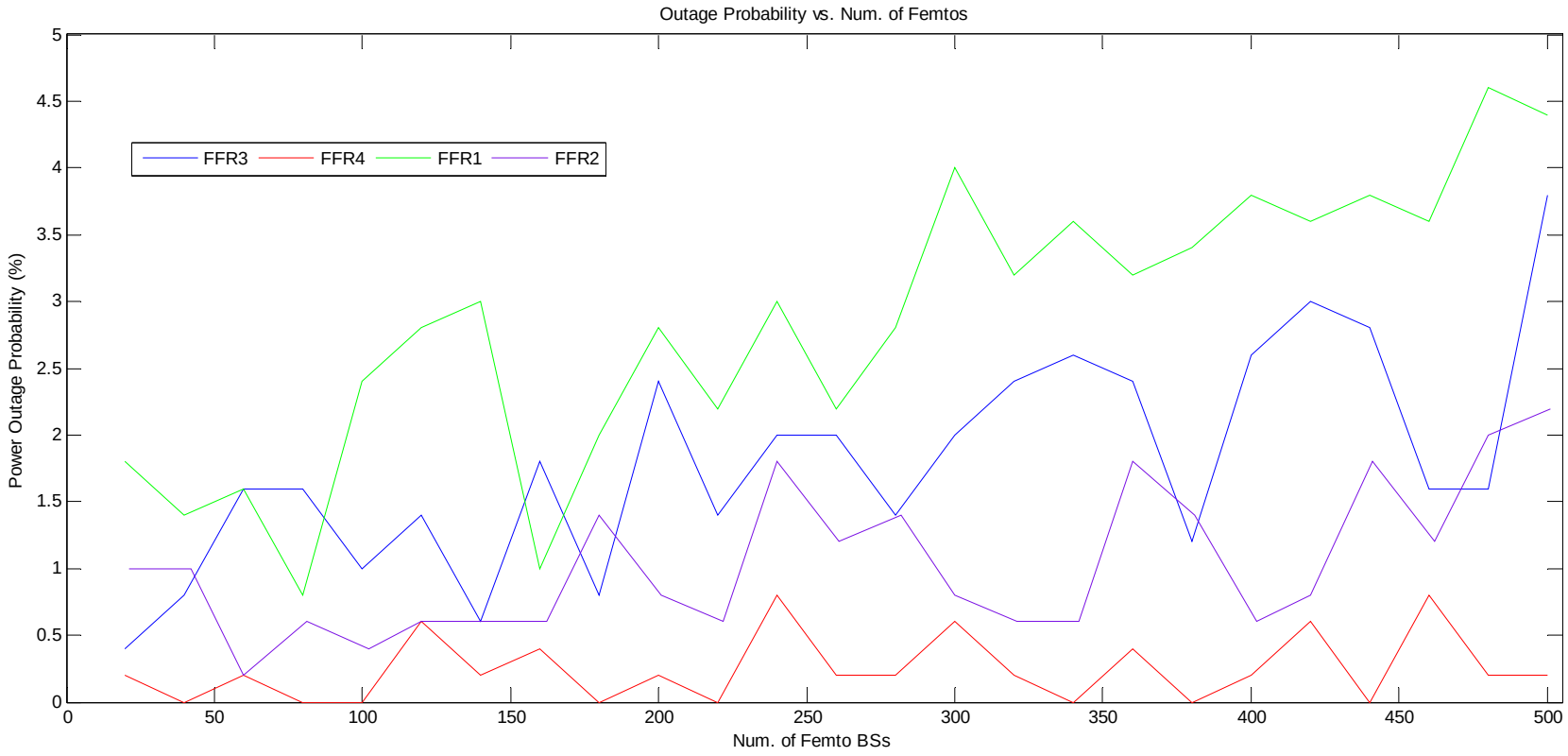

Besides FFR and power control

- Smart scheduling
  - Femtocell and Macrocell cooperative scheduling
  - Interference sensing and opportunistic scheduling
  - Time, frequency, antenna degrees of freedom
- Operators indoor band sharing
  - Win-win to all
- TDD at UL FDD
  - Uplink channel in FDD is not always crowded
  - TDD works well for indoor

Concluding remarks

- Femto cell is a promising technology
- Interference is one of the major problems for femto cell
- Power control can mitigate some interference but not all
- Advanced interference mitigations have to be developed
- Lots of works need to be done in experiment and measurement

Thank you for your attention