Interference study for cognitive LTE-Femtocell in TV White Spaces

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- Outline
  - Introduction
  - Models and scenarios
  - Antenna switching schemes
  - Simulation results
  - Conclusions and outlook

- Analog to digital TV switchover in the world
  - ATSC in North America
  - DVB-T/T2 in Europe
  - others
- TV UHF Spectrum re-planning
  - “dividends”
  - many frequency holes (or TV white spaces, TVWS)
  - for certain channel at certain location
- Why not license-exempt cognitive access these TVWS?

- Recent measures by regulation bodies
  - United States:
    - FCC 2nd memorandum and order in 2010
  - United Kingdom:
    - Ofcom cognitive access statement in 2009
  - EU:
    - CEPT-ECC draft report in 2010, still under consideration
    - many pioneering projects under EU FP7, such as: COGEU, etc.
- Possible License-exempt application
  - Hotspot technologies: WiFi, Femtocell
  - PMSE devices
  - others

4G LTE powered by Femtocell

1. residential use
2. extend to indoor
3. deployed by end-user
4. backhaul to Internet
5. reduce cost
6. increase bandwidth

Question:
potential interference problems for cognitive access LTE-Femtocells?

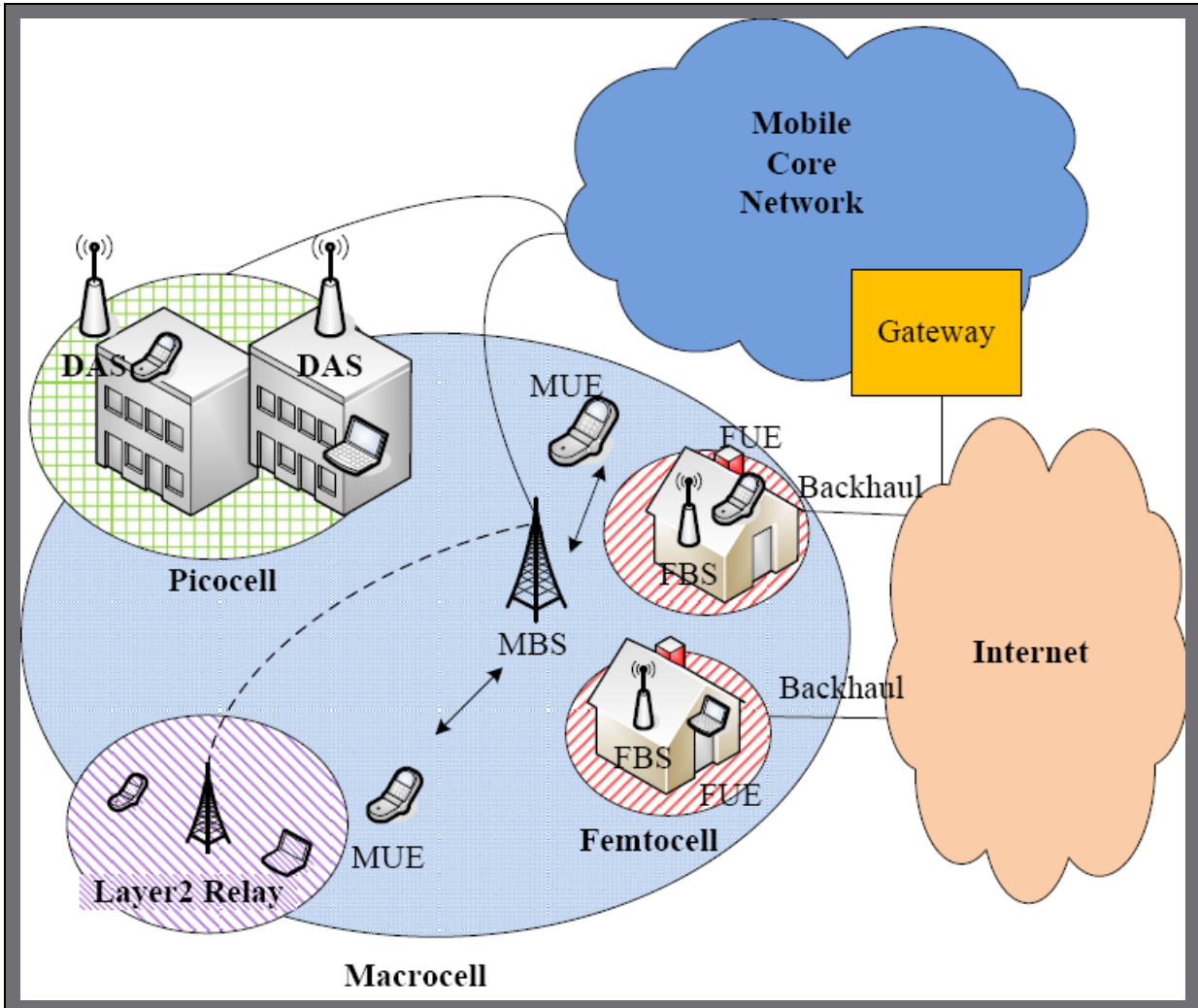


Figure: Future heterogeneous cellular system

What the regulation says (e.g. FCC):

1. separation from primary users
2. immediate back-off
3. spectrum sensing, or
4. geo-location database
5. co-channel
6. adjacent-channel
7. transmit power CAP (in terms of EIRP)
8. mandatory power control
9. "polite" to peer users (peer coexistence)

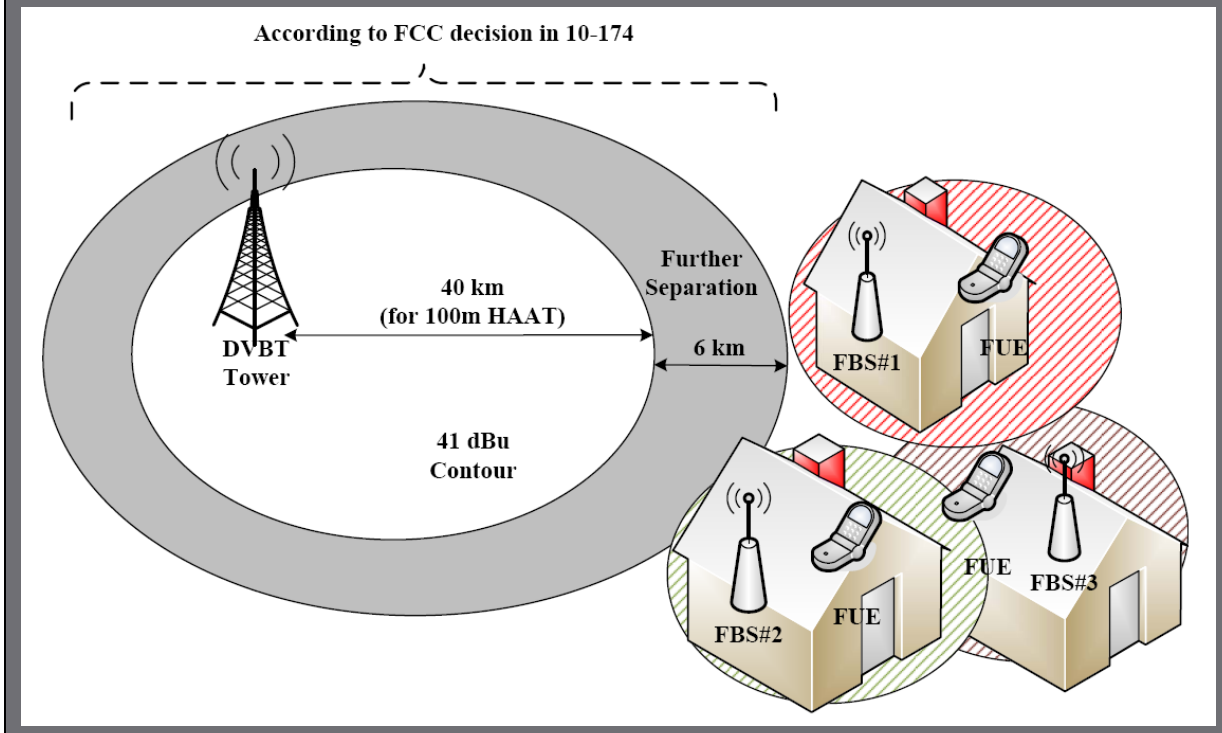


Figure: Exemplar FCC TVBD planning for Femtocell

How good is the coverage of the LTE cognitive Femtocell?

1. restricted by regulated EIRP 16dBm (by FCC)
2. European residential house model
3. random FBS placement

How bad is such radio emission out of the building?

1. main source of interference to primary users, and peer users

Figure: Model of study building in 3D

Figure: Model of study building in 2D and FBS placement

LTE R8 performance validation

1. 5 MHz LTE system
2. adaptive modulation and coding schemes
3. multi-path indoor wireless channel
4. channel emulated by Ray-tracing
5. Link-to-system Mapping
6. Effective Exponential SIR Metric (EESM)

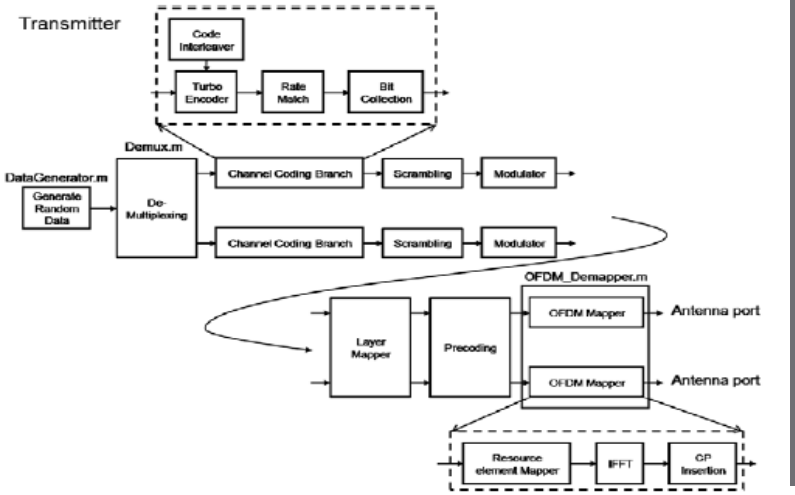


Figure: LTE PHY layer diagram

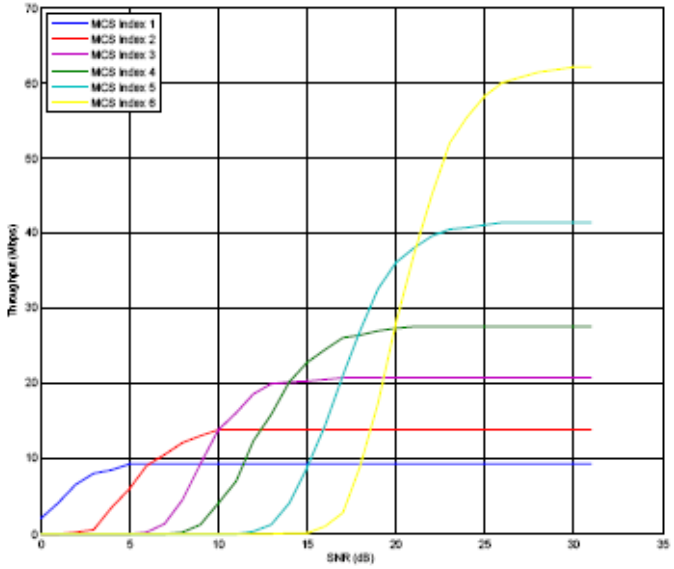


Figure: LTE SIR and throughput performance

LTE-Femtocell peer coexistence study

1. measure the out-of-building emission leakage
2. statistics profile (c.d.f.)
3. Poisson Point Process (PPP) distributed in spatial domain
4. intensity profile
5. measure the Interference over Thermal (IOT)
6. determine the outage rate

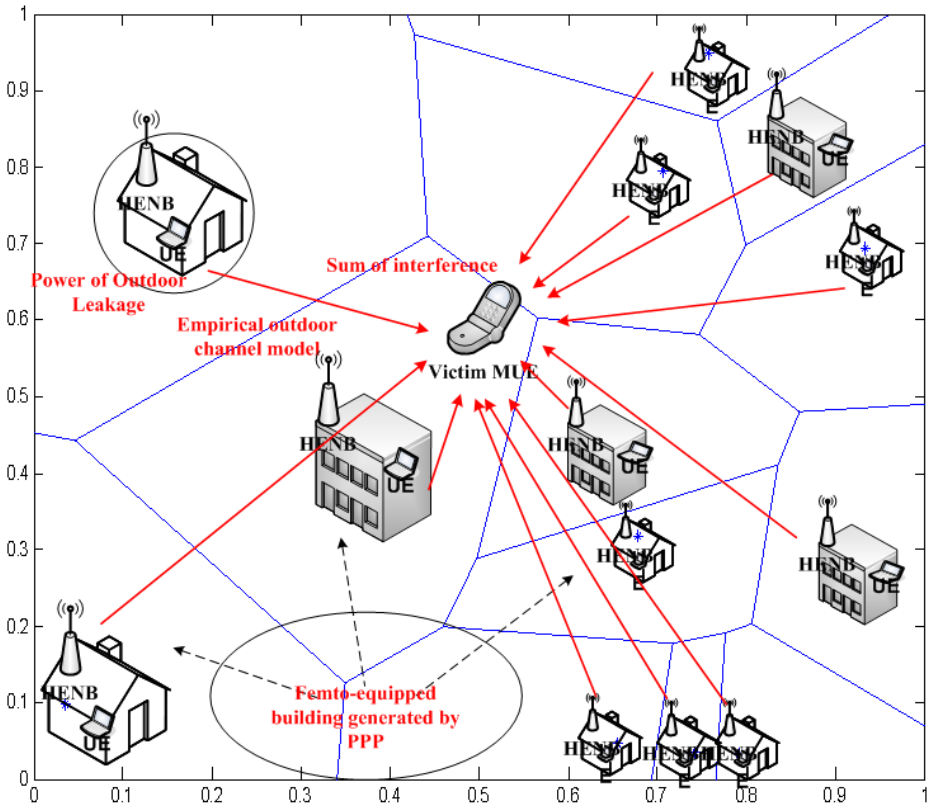


Figure: PPP distributed Femto and accumulated interference

Antenna for Femto base stations

common omni-directional approach

1. good for indoor
2. low cost
3. good coverage under EIRP restriction

directional-antenna approach

1. conventionally only good for outdoor
2. pattern-switch is low cost
3. beamforming is more complex

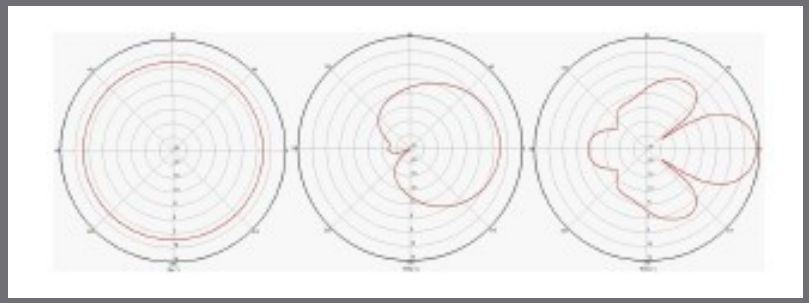


Figure: antenna pattern for omni-directional, switching-patch, and beamforming cases

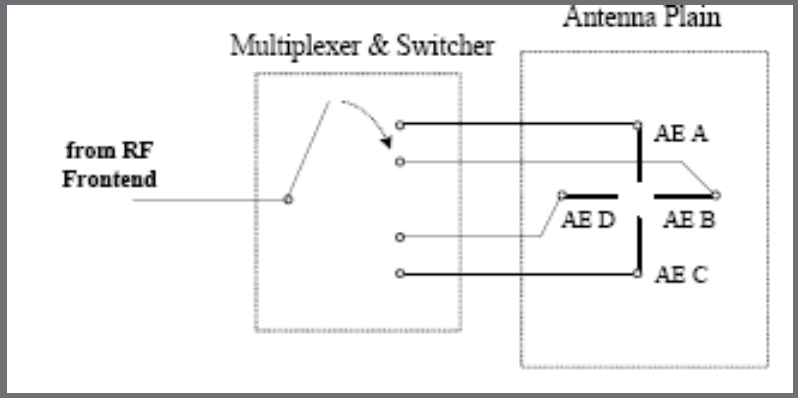


Figure: the pattern switching and combining scheme

– Preliminary results
  - Simulation setup:
    – Frequency:
    – Freq A: 580 MHz (low-end to TVWS)
    – Freq B: 760 MHz (high-end to TVWS)
    – Freq C: 2100 MHz (common for LTE in EU)
  - Antenna for Femto BS:
    – Omni-directional
    – Scheme I (pattern switching)
    – Scheme II (beamforming)

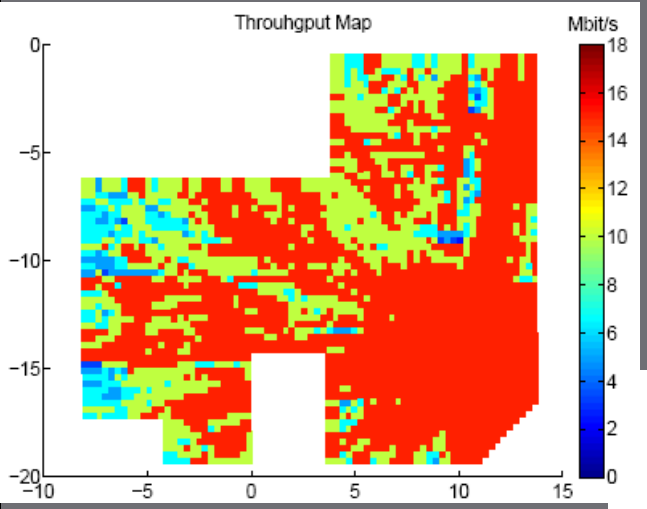
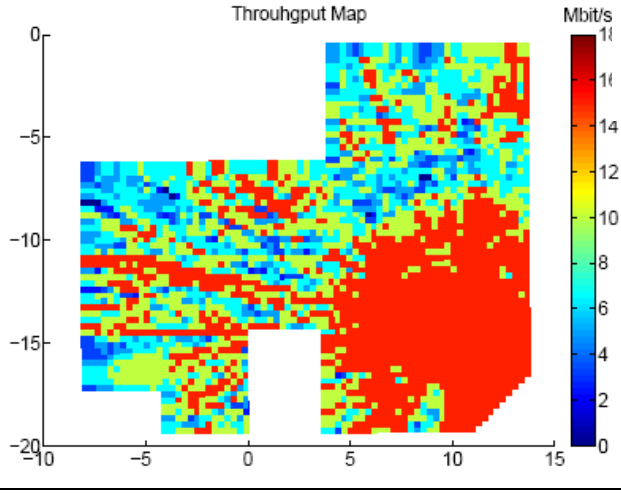


Figure: Freq A mean=12.7 Mb/s coverage=100%

Figure: Freq B mean=10.7 Mb/s coverage=99.8%



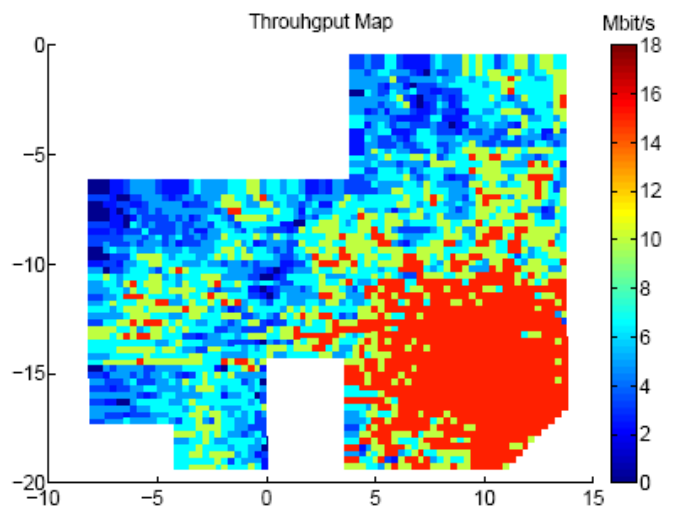


Figure: Freq C mean = 8.6 Mb/s coverage=98.9%

Throughput maps for one FBS equipped with omni-antenna

- Finding 1:
  - Direc-antenna has a penalty in indoor coverage, but not huge

	Freq A	Freq B	Freq C
Omni-antenna	99.2%	97.4%	90.6%
Scheme I	99.0%	95.2%	87.4%
Scheme II	98.4%	96.7%	88.3%

  - 1. lower frequency, better radio propagation
  - 2. regulated EIRP is enough for excellent Femto application coverage
  - 3. thanks to the fast adapting mechanism supported by LTE regular uplink sounding reference signal (SRS)

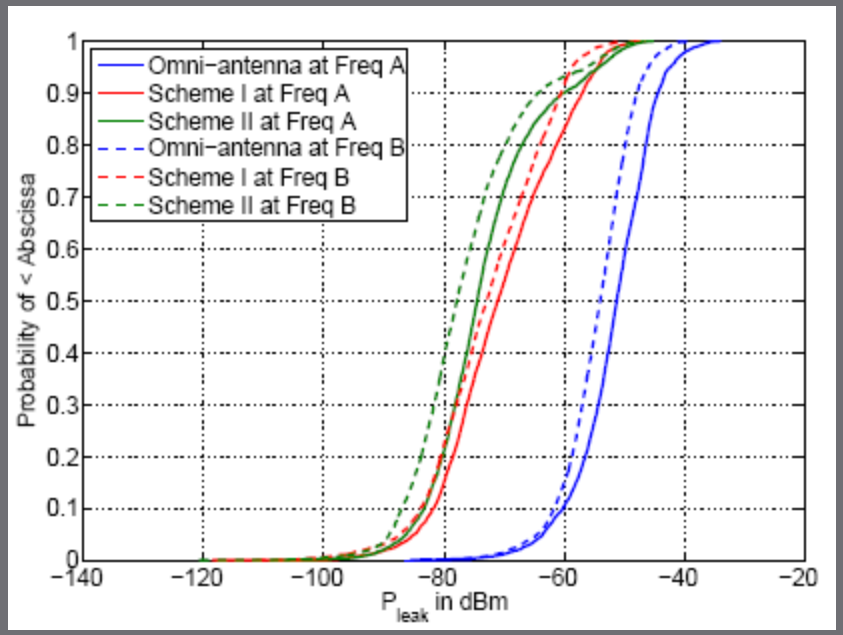


Figure: outage due to peer interference of Femtocell

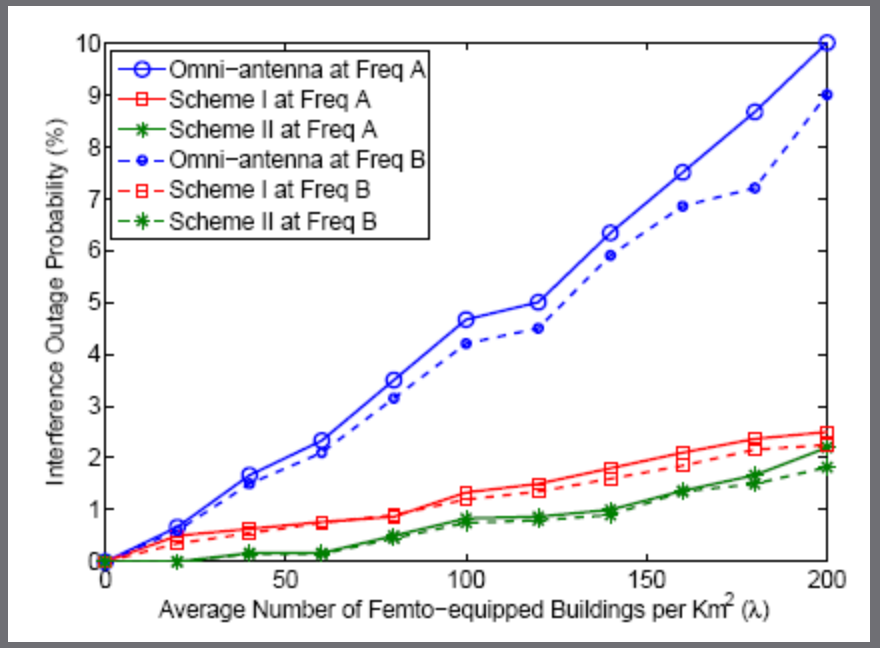


Figure: outage due to peer interference of Femtocell

Finding 2: Direc-antenna has a substantial better coexistence-performance

- Conclusion:
  - TVWS
    - next possible spectrum for Femtocell application
  - Cognitive-Femto
    - excellent LTE indoor coverage is demonstrated in simulation
  - Interference & Coexistence
    - directional antenna is effective of reducing it

- Further works:
  - other interference management schemes
  - research license from Bundesnetzagentur
  - online test-bed demonstration in progress

The End