Interference in Femtocell Networks

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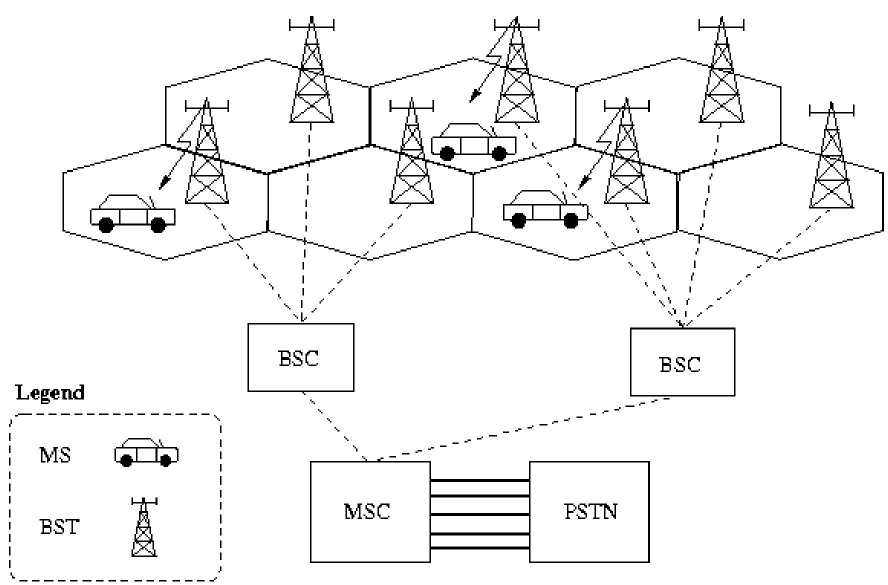
Overview

- Wireless cellular networks
  - Current challenges in cellular networks
- Femtocell networks
  - Network architecture
  - Technical aspects
  - Pros and cons in femtocell networks
- Interference in femtocell networks
  - Example: Interference in WiMAX femtocell networks
  - Challenges for interference cancellation/mitigation
- Current solutions

Wireless cellular networks (briefly…)

- Wireless access network made up of a number of cells
- Each cell served by a fixed transmitter (base station BS)
- Users usually access the network through a certain **dedicated resource** (carrier frequency, time-slot, code)
- Cells used to increase and improve coverage
- BSs connected to core network through Base Station Controllers (BSC)
- BSC perform Radio Resource Management operations such as access control, handover between cells, etc.

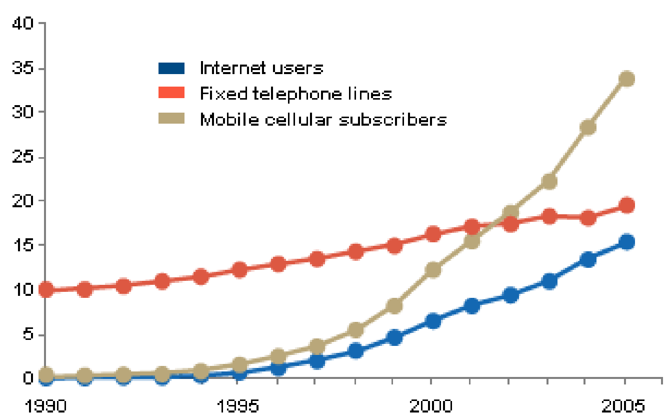


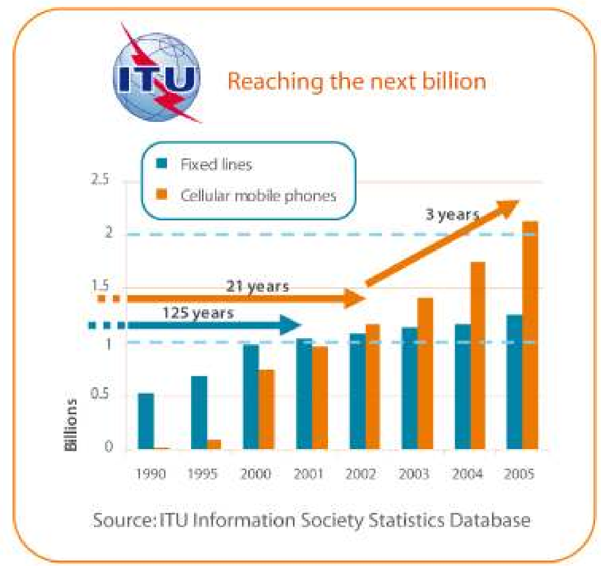
Wireless cellular networks (briefly…)

- Two “current” examples:
  - GSM (2G)
    - 900 and 1800MHz
    - FDMA(125 channels)/TDMA(8 time slots) and FDD
    - Enhancements (2.5G): GPRS, EDGE
  - UMTS (3G)
    - 1885–2025 MHz (uplink) and 2110–2200 MHz (downlink)
    - W-CDMA
- Widely deployed and used everywhere (each one of your cellphones)

Access to information and communication technologies grows fastest in the mobile sector

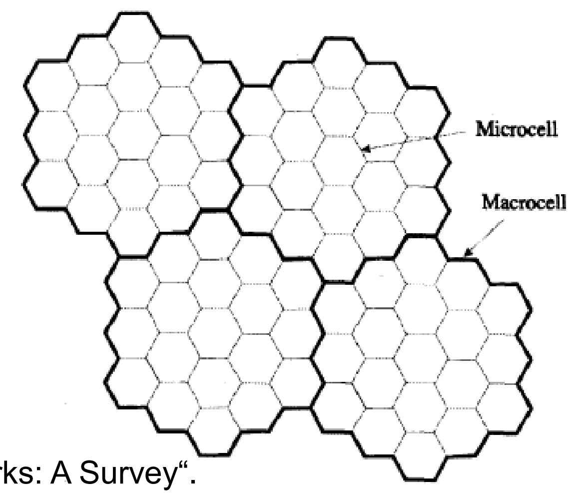
Number of telephone subscriptions and Internet connections per 100 population, 1990-2005 (Percentage)





Wireless cellular networks: current challenges

- New trends in cellular networks…
  - New “multimedia” services
    - Video streaming
    - Web 2.0 (MySpace, Facebook, Twitter…)
    - etc
  - Cellphones indispensable in everyday life
    - E-mail
    - Mobile Internet
    - Google maps to find that restaurant where I am supposed to be in 10 minutes
    - etc
- Demands for higher data rates and capacity!
- Wireless capacity has doubled every 30 months over the last 104 years [1]
- How to increase capacity?
  - 25x improvement from wider spectrum
  - 5x improvement by dividing the spectrum into smaller slices
  - 5x improvement by designing better modulation schemes
  - 1600x gain through reduced cell sizes and transmit distance

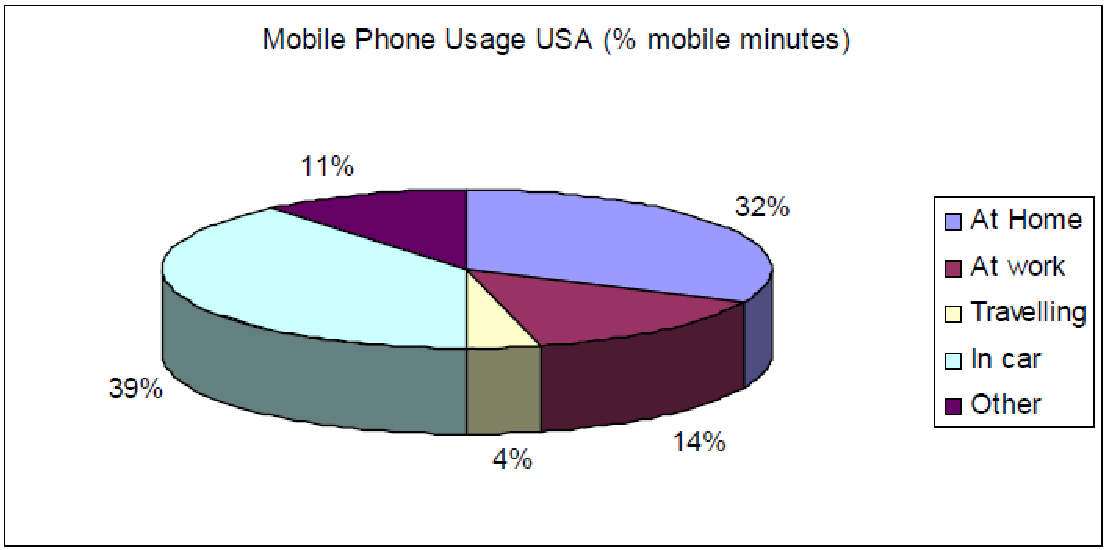


Macro-cell → Micro-cell → Pico-cell → …

[1] V. Chandrasekhar, J. Andrews, A. Gatherer, and T. Instruments, "Femtocell Networks: A Survey“.

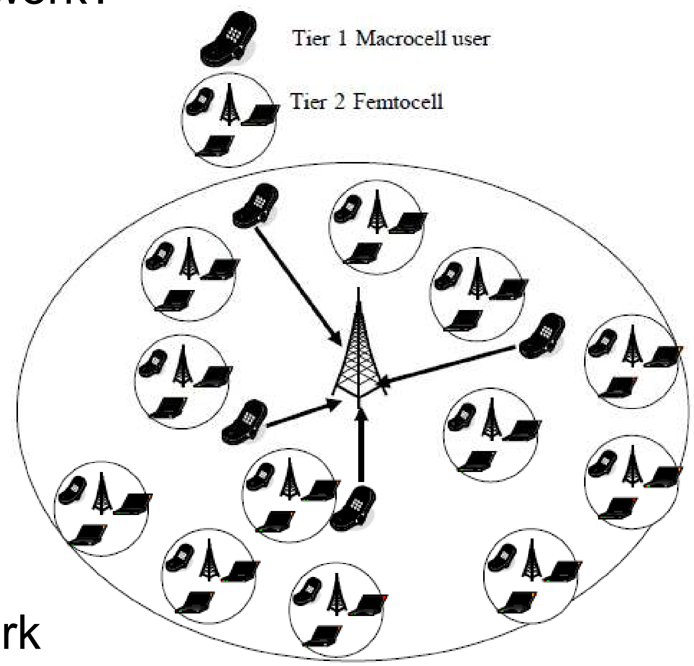
Femtocell networks

- Network infrastructure for micro-ization of cellular networks is very expensive
- Solution → user deployed base stations (femtocells)
- Users purchase and install themselves a small low-power BS at their apartment/office
- About 46% of the mobile users will be covered



Femtocell networks: network architecture

- How does this work?



- Two-tier network
  - Femtocell APs overlaying on top of the macrocell network
  - Hierarchical cell structure
  - Location of the FCs is “unknown” to the network operator
  - FCs connect to the core network through an IP backhaul (local broadband access: DSL, cable, etc)

Femtocell networks: technical aspects

- Femtocell AP:
  - Low transmitted power
  - Low range
  - Indoors
  - IP backhaul connection to the core network through the broadband access the user already has at home
  - Target cost 100$
    - To ensure widely deployment (users have to buy it)
    - Much simpler than a “regular” cellular BS
    - Not synchronized with the rest of the network
  - Average of 2 to 4 users per FC
- Already being manufatured by some vendors
  - 32 million FC base stations expected to be deployed by 2012 [1]

[1] V. Chandrasekhar, J. Andrews, A. Gatherer, and T. Instruments, "Femtocell Networks: A Survey“.

Femtocell networks: technical aspects

8000 Series
Motorola Femtocell Access Point

Specifications

STANDARDS/ COMPLIANCE	
3GPP Spec Version	3GPP Release 6 2006-06
3G Radio Interface	UMTS WCDMA FDD

USER	
Number of Users	Maximum of 20 users in Idle Mode
Cell Radius	200m Maximum (16m – 26m in a typical in-building deployment scenario)
UE Speed	<3.6 miles/hour

TRAFFIC CHANNELS	
Signaling	3.4 Kbps and 13.6 Kbps signaling SRBs; 12.2 Kbps AMR voice, bi-directional (four users); 64 Kbps circuit-switched multimedia, bi-directional (four users); 64 Kbps packet-switched data, bi-directional (four users); 128 Kbps downlink packet-switched data, 64 Kbps uplink (four users); 384 Kbps downlink packet-switched data, 128 Kbps uplink (two users)

HSDPA CHANNELS	
Maximum Number of Codes	10
Maximum number of HS-SCCH	2
HS-PDSCH modulation	QPSK, 16QAM
Supported UE categories	1 – 8, 11, 12
Peak Data Rate	3.6 Mbps (upgradeable to 7.2 Mbps; uplink 128 Kbps and 384 Kbps PS)
HSUPA Channels	Future Support for HSUPA (optional feature delivered by software upgrade)

RADIO ACCESS LAYER	
NAS (Non Access Stratum)	SS, SMS, CC, SM, MM, GMM
AS (Access Stratum)	PDCP, RRC, RLC, MAC
Transport Channels	BCH, PCH, RACH, FACH, DCH, HS-DSCH
Physical Channels	SCH, CPICH, P-CCPCH, S-CCPCH, PICH, AICH, DPCH, PRACH, DPDCH, DPCCH, HS-DPCCH, HS-PDSCH, HS-SCCH

PHYSICAL LAYER	
Frequency Band	Band 1; Receive 1920 MHz – 1980 MHz; Transmit 2110 MHz – 2170 MHz
Transmit Power	10dBm Maximum
Node B Performance	Compliant to TS25.141 Requirements for Local Area Node B (except max. TX power)
Dynamic Power Control	DPC Modes 0 and 1

NETWORKING LAYER	
Security	IPSec ESP, IKEv2 (with NAT traversal), EAP-AKA/SIM
Protocols	IPv4, IPv6, ARP, ICMP, TCP, UDP, SNTP
Voice Gateway	SIP, SDP, RTP, RTCP
Core Network Interface	SIP/SDP Pre-IMS and 3GPP Rel 6 IMS compliant

Logical Interfaces	
Radio Network Interface	3G UMA (variant), Iub over IP (optional)

EXTERNAL INTERFACES	
SIM card	Push-to-insert, push-to-release type SIM card holder
Number of antennas	1 (internal to the unit)

ENVIRONMENTAL	
Operating Temperature	0° C to 40° C (32° F to 104° F)
Storage Temperature	0° C to 70° C (32° F to 158° F)
Relative Humidity	20 – 80% Non-Condensing
External Power	12 VDC, 1000mA
Power	+6 VDC at 2.6A maximum from external power supply adaptor (100 – 240V 50 – 60Hz AC)
Acoustic noise	<25 dB

WEIGHT AND DIMENSIONS	
Weight	0.9 lb (408g)
Dimensions	7.9 in L x 4.6 in W x 3.9 in H (200 mm x 118 mm x 98 mm)
Horizontal desktop placement or vertical standing	

All features, functionality, and product specifications are subject to change without notice or obligation.

Femtocell networks: pros and cons

- Improvements:
  - Femtocells cover indoor area (50<R_FC<200 m) → high coverage and better signal reception for indoor users (better QoS)
  - Indoor FC users transmit much less power → great savings in battery life
  - Most indoor users connected through FCs → more "room" and capacity in the MC and better QoS in the MC.
    - In CDMA-based networks this is specially good because indoor users are the ones causing the highest amount of interference
  - "Zero cost" to the network operator
  - Network operator can offer cheaper services through the FCs
- New challenges:
  - FC BSs not synchronized → handoff MC↔FC?
  - How will the backhaul provide acceptable QoS?
  - Location tracking for emergency (911) phone calls?
  - Open or closed access? (Can a pedestrian next to your building transmit through your FC if there's no MC signal? Can this user do at least an emergency call through your FC?)
  - Interference
  - etc

Interference in femtocell networks

- Cross-tier interference!!!
- 3 extra degrees of complexity in the interference problem
  - MC user to FC BS (Figure 1)
  - FC user to MC BS (Figure 2)
  - FC to FC (Figure 3)

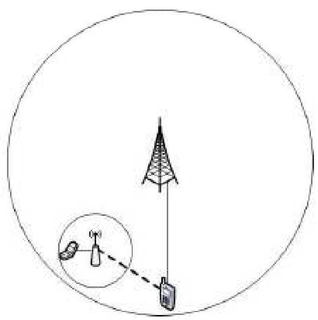


Figure 1: MC user to FC base station interference.

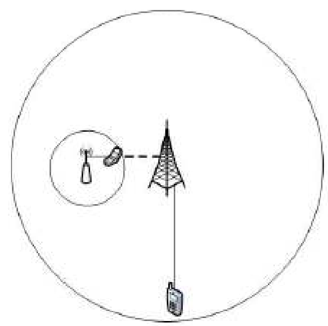


Figure 2: FC user to MC base station interference.

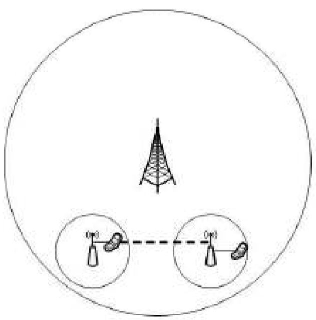
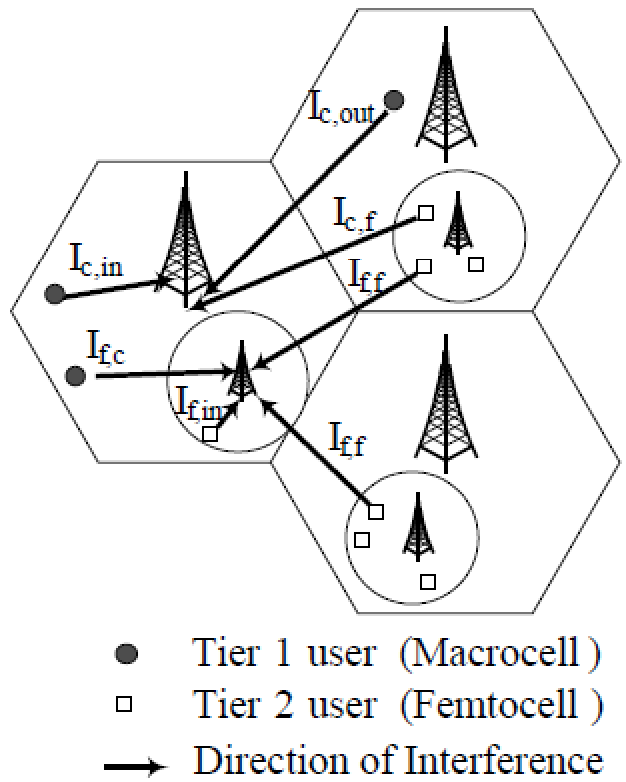


Figure 3: Femtocell to femtocell interference.

Interference in femtocell networks

- It gets even worse in a multi-cellular scenario… [2]



[2] Chandrasekhar, V., Andrews, J.G., "Uplink Capacity and Interference Avoidance for Two-Tier Cellular Networks", IEEE Global Telecommunications Conference, 2007. GLOBECOM '07.

Example: interference in WiMAX femtocell networks

- What happens if FCs are deployed and nothing is done? [3]

Coverage (%)			Large cell scenario				Small cell scenario			
			Sparse deployment		Dense deployment		Sparse deployment		Dense deployment	
			Public	Private	Public	Private	Public	Private	Public	Private
FS transmit power	0 dBm	Indoor	99.7992	99.7992	98.3728	93.787	97.9310	93.7931	89.8050	70.0355
		Outdoor	75.4035	75.2498	72.9183	68.5603	71.3465	69.1297	67.8608	55.4464
	10 dBm	Indoor	100	100	98.8116	94.0828	99.0038	94.3295	91.3121	70.3901
		Outdoor	75.3267	73.1745	71.4397	57.4319	71.0181	64.1215	64.9468	33.4971
	20 dBm	Indoor	100	100	99.0385	94.1568	99.387	94.4061	91.1348	69.9468
		Outdoor	74.6349	68.6395	67.2374	37.7432	59.4581	51.6420	65.7658	13.5954
Coverage (%) without Femto-AP		Indoor	70.48		70.86		80.15		79.34	
		Outdoor	76.10		74.32		72.33		73.55	

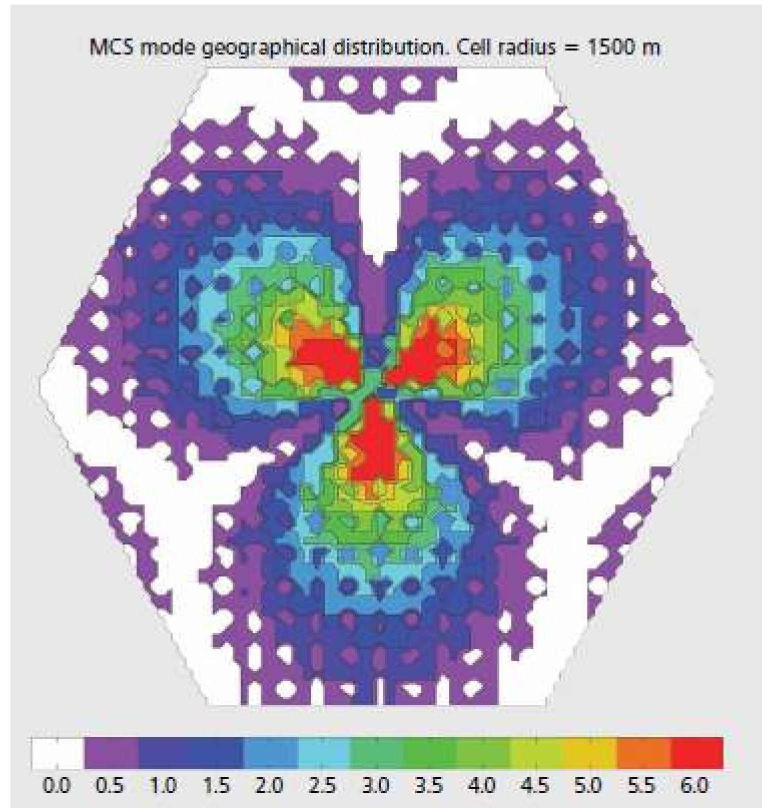
■ **Table 1.** *Indoor/outdoor coverage in different simulation scenarios.*

Interference very problematic for MC (outdoor) users in small cell (urban) scenarios, specially if FCs are "private".

[3] S. Yeh, S. Talwar, S. Lee, and H. Kim, "WiMAX femtocells: a perspective on network architecture, capacity, and coverage," Communications Magazine, IEEE, vol. 46, no. 10, pp. 58-65, 2008.

Current solutions

- Not much work done about interfence in femtocell networks
- Work mostly focusing in 4G femtocells
  - OFDMA
  - WiMAX (WiBro in Korea)
- Distributed algorithms (FCs not synchronized with the rest of the network)
- Some analytical works
  - Channel models
  - Interference model
  - → Per tier outage probability
  - → Coverage



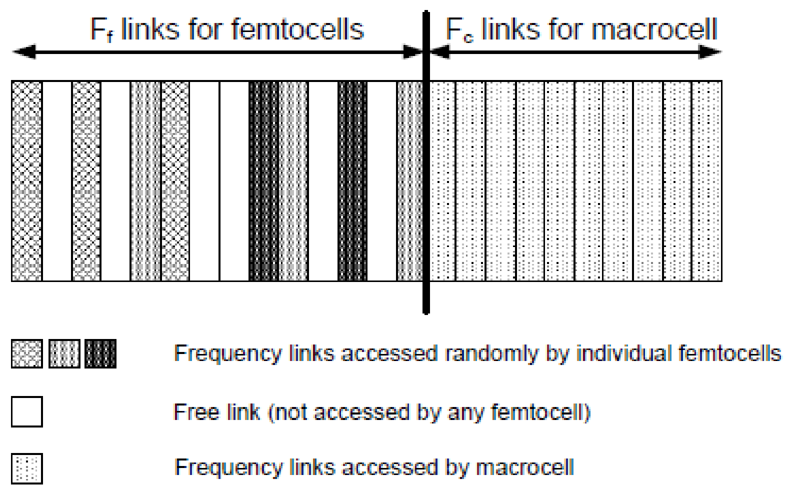
■ Figure 4. *Geographical distribution of spectral efficiency in cells.*

[3]

[3] S. Yeh, S. Talwar, S. Lee, and H. Kim, "WiMAX femtocells: a perspective on network architecture, capacity, and coverage," Communications Magazine, IEEE, vol. 46, no. 10, pp. 58-65, 2008.

Current solutions

- All the proposed solutions use a spectrum division
  - Cross-tier interference → Interference avoidance strategy better than Interference supression (in a randomly deployed femtocell network)
- Reserve a section of the available spectrum for the FCs and the rest for the MCs [4]
  - Femtocells only use a portion of the reserved spectrum
    - Randomly selected
    - Frequency-ALOHA (a number of femtocells "competing" for a shared medium)
  - Maximize Area Spectral Efficiency (ASE) [bps/Hz/m^2] as a function of ρ (ratio spectrum for FCs to total available spectrum)



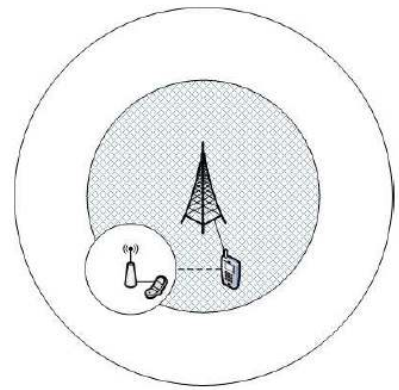
[4] Chandrasekhar, V., Andrews, J.G., "Spectrum Allocation in Two-Tier Newtorks", 2008.

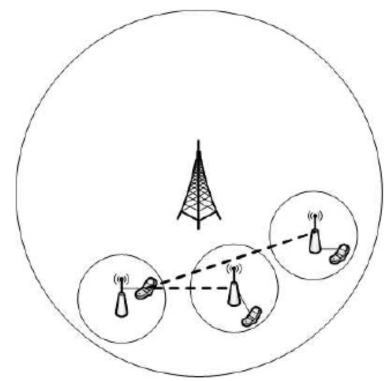
Current solutions

- Problems with a spectrum division:
  - Femtocells are by definition indoors (apartment, offices, etc)
  - Estimated an average of 2 to 4 users per FC.
  - Users spend most of the time either at work or at home, plus some other time outdoors.
  - Subcarriers reserved for FCs are idle most of the time

Waste of bandwidth!!!

- New ideas (final project)
  - Interference caused by a MC user depends on the tx power.
  - Tx power depends on the distance (path loss) to the BS
  - Classify users depending on distance (path loss)
  - Allocate frequencies according to the MC kind of user → **cross-tier interference cancellation/mitigation**
  - FC users only interfere with users within neighboring FCs
  - FCs are not synchronized with the rest of the network → **distributed approach**
  - **Game theoretical approach** for the frequency allocation in the FCs
  - **Directive antennas**





References

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