quasar Assessing **real life** benefits of Cognitive Radio

Use of TV white space for mobile broadband access - Analysis of business opportunities of secondary use of spectrum

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Business opportunity

- Business opportunity depends on the specific scenario / use case
  - The type of service
  - The user density, demand and willingness to pay
  - The type of radio network deployment
  - If the spectrum is used as the ”only” resource or as a complement
  - The business cases of competiting solutions

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A Multitude of Multitudes - QUASAR Service Scenarios

- Cellular Use of White Spaces
  - MBBA in rural areas – macrocell deployment
  - MBBA in urban areas – macrocell deployment
- WiFi-like Use of White Spaces
  - MBBA in urban areas - femtocell deployment
- Secondary Wireless Backhaul
- Secondary Spectrum Commons in Radar Band
- Indoor Broadband in Aeronautical Spectrum
- Cognitive Machine-to-Machine (Infrastructured)
- Cognitive Machine-to-Machine (Ad hoc)

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Scope and motivation

- Research question:
  How to evaluate the business opportunities of technical solutions and mechanisms that support the secondary use of spectrum allocated to a primary user?
- Project challenge:
  To connect the technical and business analysis

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Agenda items

- Note on Methodology for cost & capacity analysis
- What can we observe if we look into wide area MBB access for capacity enhancement in urban areas
- What can we observe if we look into indoor MBB access services in offices and hot spot areas
- Summary

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General about the methodology

- The analysis is done for specific sub scenarios
- Links are established between the technical performance and the business case
- Key characteristics of the cost structure are identified and included in the analysis
- We can do the analysis without knowledge about **the exact** availability of spectrum, bandwidth, distribution in time and space
  - We start to do a ”what IF” analysis (sensitivity analysis)
  - When detailed technical data (spectrum availability and performance) are available we can include this

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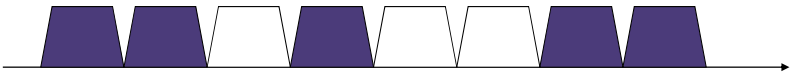
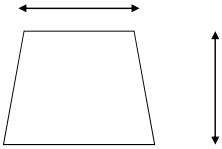
Bandwitdh and spectral efficiency



The available frequency ”channel” has a bandwidth
In the general case some average width and some variation in time and space



The frequency ”channel” has a spectral efficiency (SE)
In the general case some average SE and some variation in time and space

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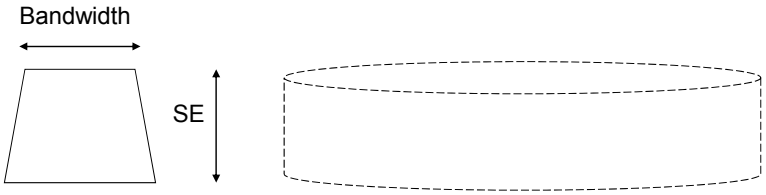
Spectral efficiency

- We will assume an equivalent ”usable” bandwidth and an ”average” spectral efficiency
- This will be used as the ”resource” used for dimensioning of the wireless capacity



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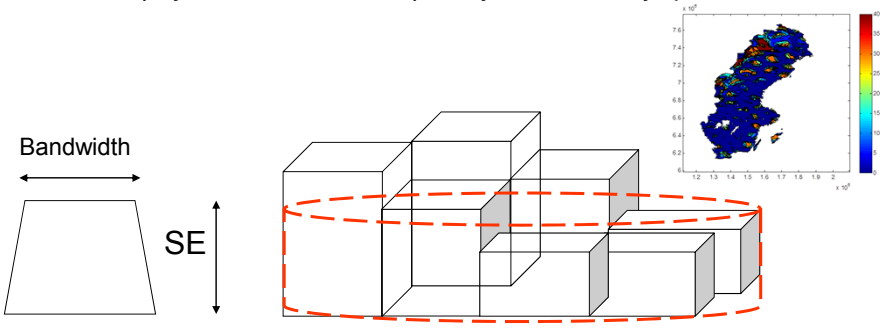
- **The spectral efficiency depends on**
  - The type of system used for secondary usage
  - The deployment and location of primary and secondary system



Availability data - squares

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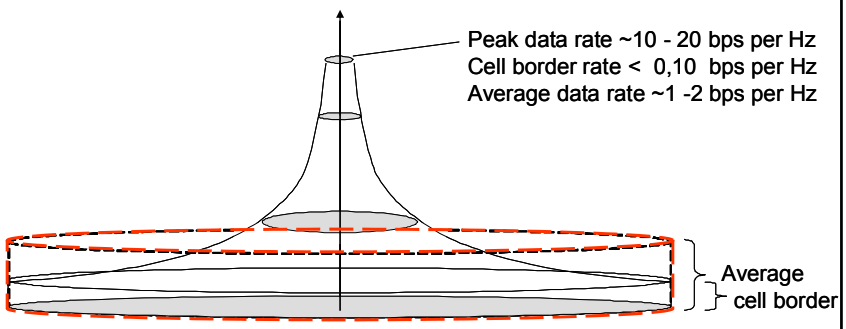
Compare
Spectral efficiency for cellullar systems



As a first step approximation this average value representative for the whole usage area is used
Sensitivity analysis can be made with higher/lower values of spectral efficiency

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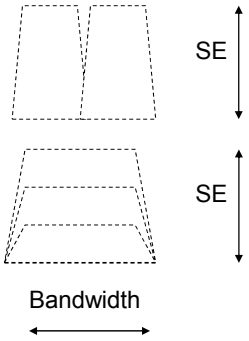
First approximation model

- **With this description we can model**
  - Sharing of bands between multiple actors
  - Variations in availability, interference levels or signal quality



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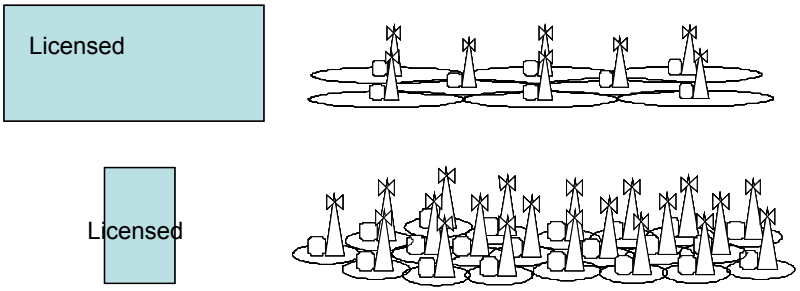
Network capacity, amount of spectrum and site density

- High bandwidth means high capacity per site, i.e fewer sites and the other way around



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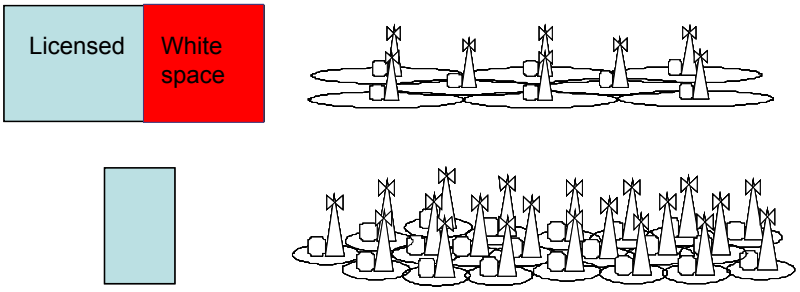

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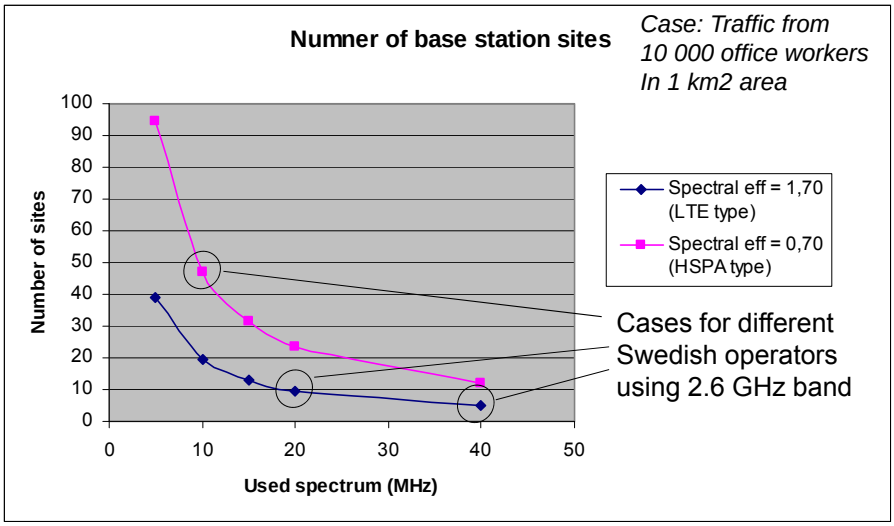
Impact of amount of spectrum
Case: New urban office area with many users



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Peak data rate is very important

- Marketing by swedish mobile operators

'The fastest Mobile broadband in Sweden - according to information retrieved from Bredbandskollen.se, November 25, 2010' (Telenor)[49]

'Today the best Mobile broadband in Sweden was nominated and the winner is Tele2. This means that you can do web surfing at higher speeds with Tele2 compared to any other operator.' [50] *'We have the fastest 4G network in Stockholm.'*(Tele2)[51]

'For the fourth year in a row the magazine 'Mobil' did nominate our mobile broad band to be the best in Sweden'[52] (HI3G)

'4G. The fastest mobile broadband in the world for just 15€ per month until the Easter holiday, ordinary price 60€ per month.' (Telia)

Compare
3G and 4G

- Telenors löften helt orealistiska

KTH-professor dömer ut kampanj om nya mobilnätet
Av: Helen Ahlbom 93 kommentarer
Publicerad 20 maj 2009 00:00

Telenor lovar hastigheter på 150 megabit/s till nästan hela svenska folket i sin senaste reklamkampanj. Det är fullständigt orealistiskt om man inte bygger 100 000-tals nya basstationer, anser Jens Zander, professor i radioteknik på KTH.

"Leve Allemansrätten!" utropar Telenor i reklamfilmer och stora affischer över hela landet. "Nu bygger vi Sveriges modernaste mobilnät. Det ger mer än 99 procent av svenska folket 150 Mbps via luften", utlovar bolaget på reklamplats.

Markendahl, Mäkitalo Mölleryd COST-TERRA meeting, Brussels

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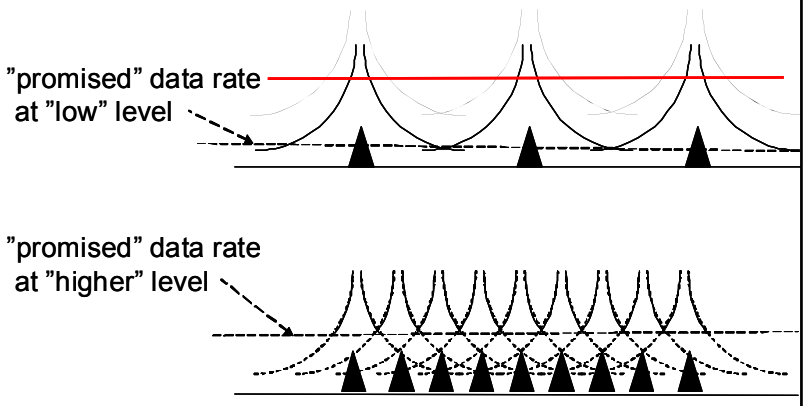
”Offered” bit rate vs coverage & load



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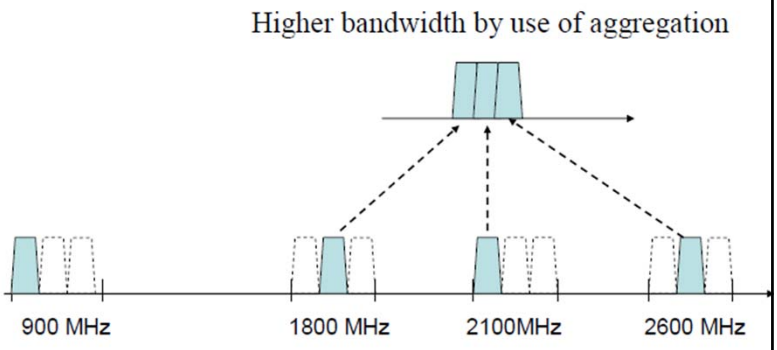
Data rate, bandwidth and aggregation of carriers or bands

- **The higher bandwidth the higher the data rate**



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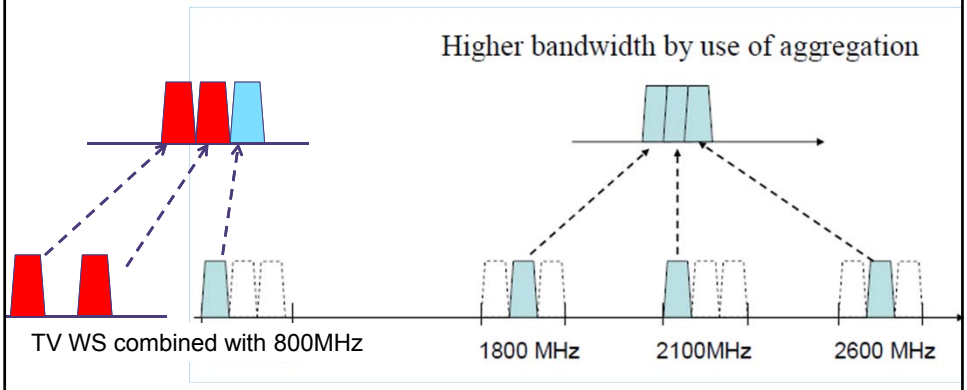

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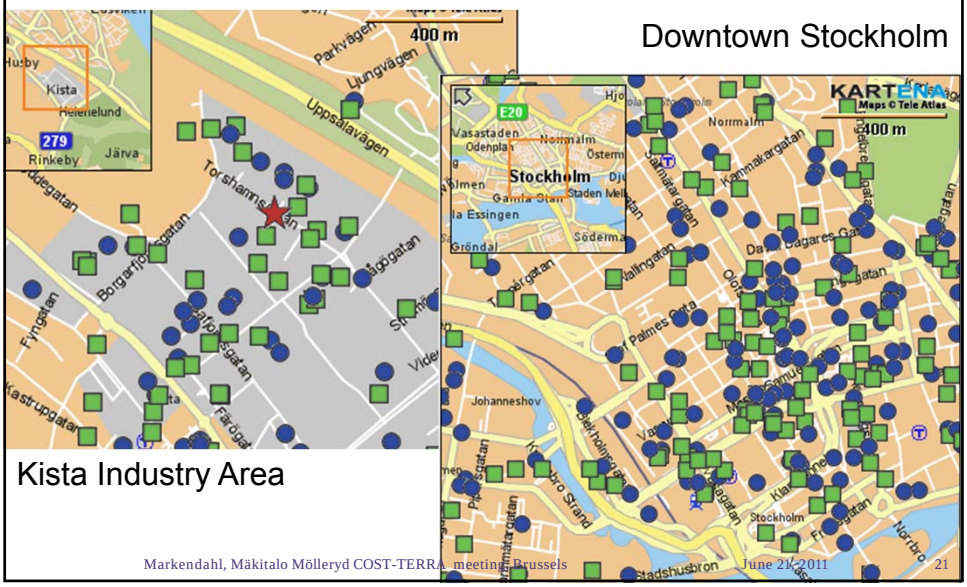
Base station site locations in urban areas

from PTS "Transmitter map" web page,



Downtown Stockholm

Kista Industry Area

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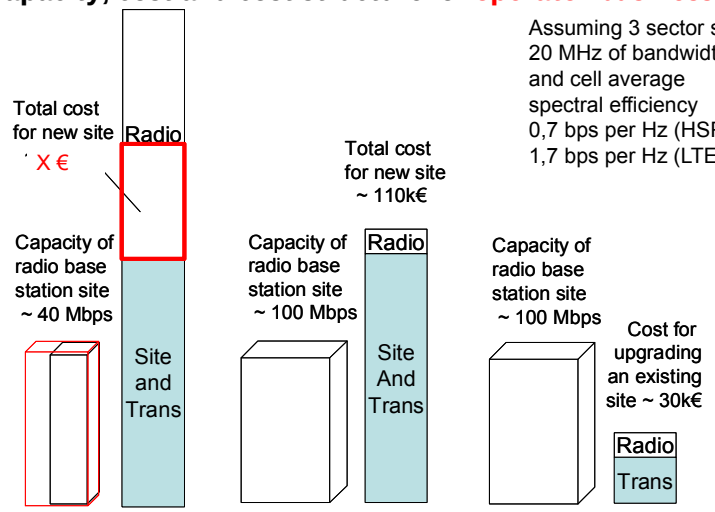
Capacity, cost and cost structure of operator business cases

Assuming 3 sector site
20 MHz of bandwidth
and cell average
spectral efficiency
0,7 bps per Hz (HSPA)
1,7 bps per Hz (LTE)



New TV WS operator **Greenfield MNO** **Existing MNO**

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Femtocells

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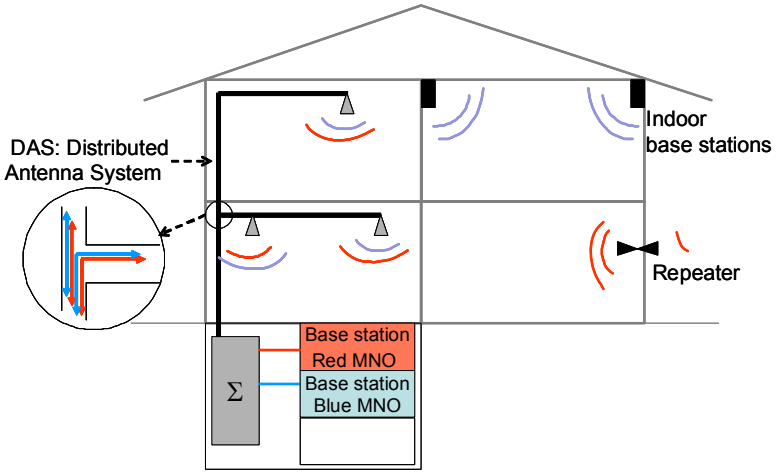
Different solutions for indoor coverage



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Wireless indoor solutions

- Indoor solutions are not only used in order to compensate for wall penetration losses
- Other reasons may be:
  - Companies want ensured and dedicated capacity
  - Companies use mobile phones as office phone
  - Mobile operators want to increase customer loyalty
  - Mobile operators want to offload data traffic from outdoor (more expensive?) macro networks

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Indoor wireless solutions are used in two different business settings

B2B2C 1. To ensure public access in shopping malls, subways, sport arenas

- The users are subscribers of the operators that visit the shopping mall, etc
- The operators have agreements with the owners of the mall, the arena, etc
- The service IS the ensured indoor coverage

B2B 2. To provide indoor ”private” access at company offices etc as part of a complete offer

- The users are the employees of the ”company”, etc
- The indoor coverage is just one part of the offer
- Other components can be outdoor coverage, handsets, IT support and services, call centers

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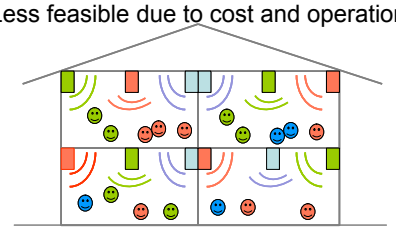
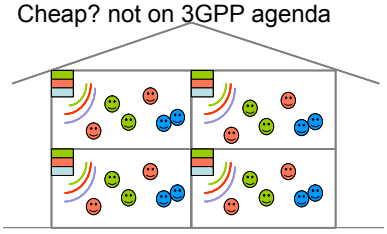
Options for femtocell deployment

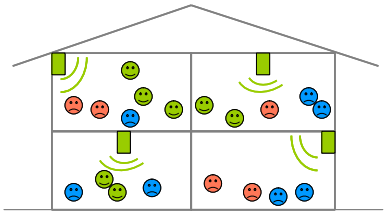
Parallell single-operator networks
Less feasible due to cost and operation



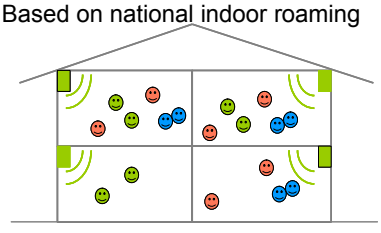
Multi-operator access points
Cheap? not on 3GPP agenda



Single operator femtocell network



One multi-operator network
Based on national indoor roaming



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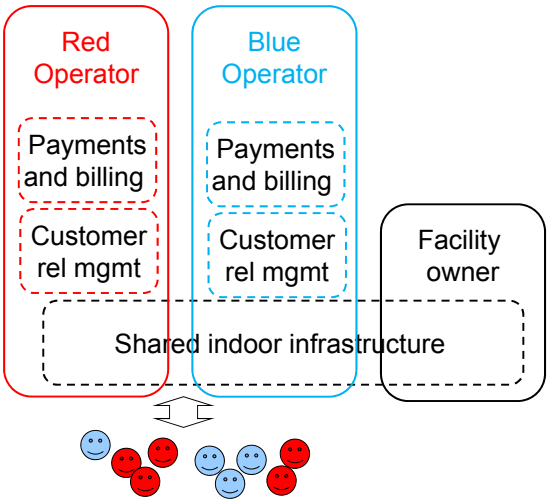
Shared indoor infrastructure



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Business feasibility of femtocells

- Femtocells are feasible for deployment at offices
  - Scalable solution, access for a specific user group
- Open issues for femtocells deployed for public access
  - Difficult with multiple femtocell networks
  - Cost benefits compared to macro networks is unclear
  - Interference problems and spectrum allocation issues

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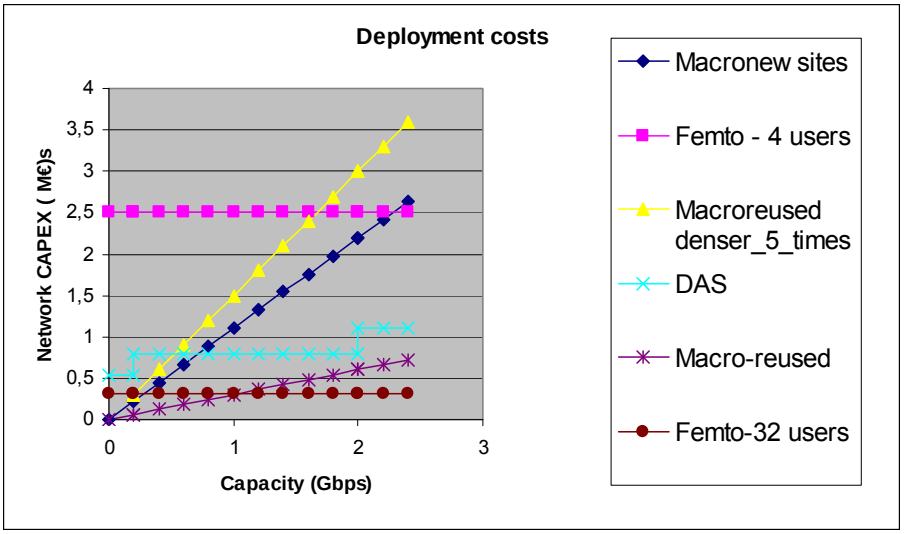
Example of deployment costs for indoor demand



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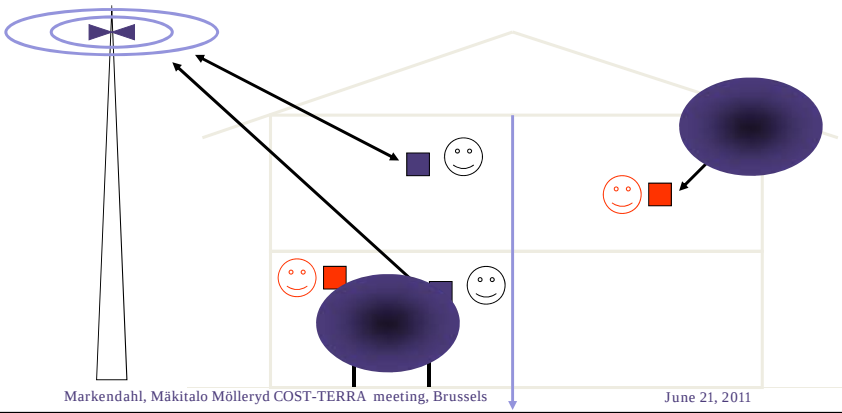
The dead zone problem

- Femtocell base station cause interference in the downlink for UEs connected to macro base stations, i.e. for closed access
- Areas without any coverage (dead zones, coverage holes) appear in the vicinity of the femto base stations



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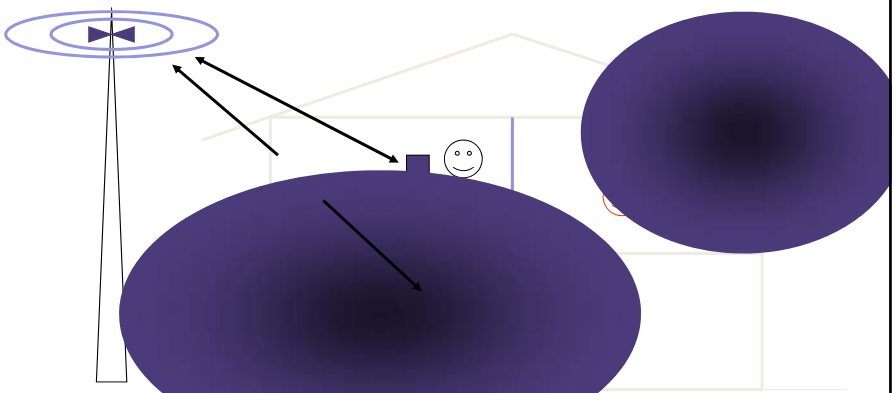
The dead zone problem

Occurs for closed acess femtocells
Dead zones are largest at cell borders
~ 20 m for co-channel operation (WCDMA)
1- 2 m for adjacent channels (WCDMA)



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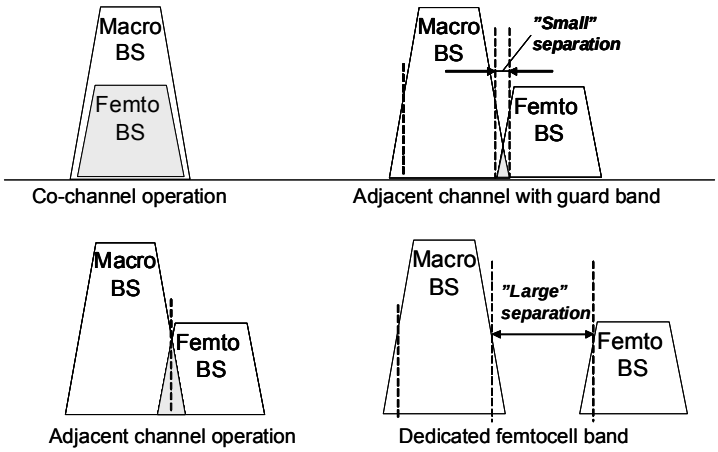
Macrocell-femtocell interference



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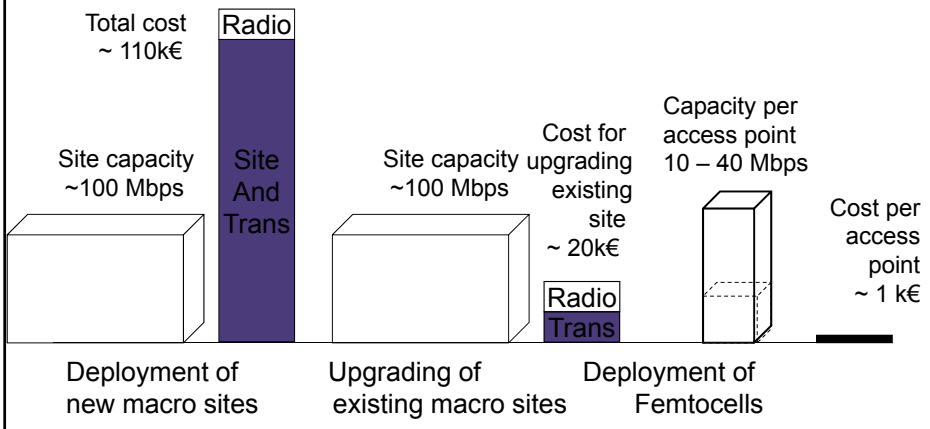
Cost and capacity for macrocellular and femtocell deployment



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Local operator using TV WS to offer ”indoor capacity”

- A local operator can deploy a femtocell network where only a fraction of the femtocell capacity is used
  - A ”few” available MHz can satisfy even very high demand levels
    - Example 1:
      One 5 MHz femtocell with Spectral eff = 8 bps/Hz
      can ”capacity wize” serve 400 ”10 GB per month users”
    - Example 2:
      1 MHz is enough to serve 40 users (with spectral effiency =4 bps/Hz)
      => One 8 MHz channel can be used for several 1 MHz femtocells
- This makes all bands and also ”a few MHz” of white space interesting

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Conclusions

- You need to compare solutions using TV WS with existing solutions and business cases ; i.e. the offers and cost structure of competitors
- Example mobile using TV WS for Mobile broadband

BUT!
Also consider other solutions
- WLAN
- Licensed > 3 GHz

  - New actors with "TV WS spectrum only" offering wide area mobile broad band access services will have problems
  - Local operators can use TV (or radar) WS to offer indoor access

- Exploit benefits of TV WS for existing solutions and actors

Capacity => delay or reduce need for deployment of new sites
Data rate=> with aggregation higher data rates can be offered

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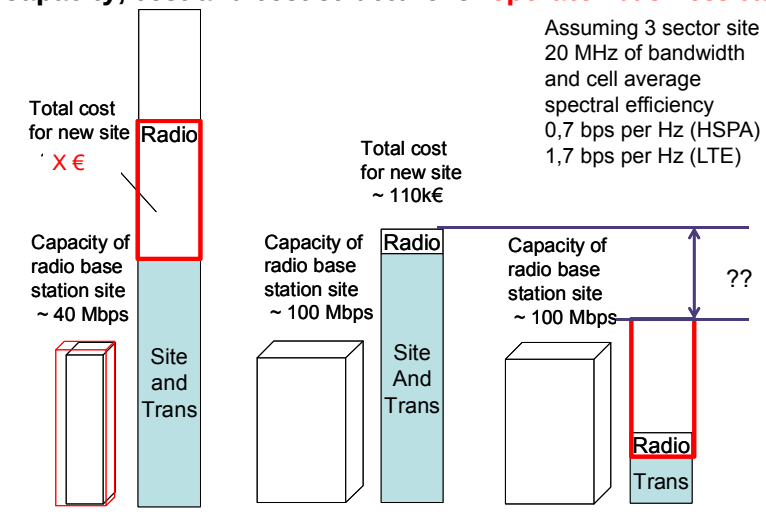
Capacity, cost and cost structure of operator business cases



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Thanks for your attention

- My e-mail: janmar@kth.se

- Link to my PhD Thesis, February 2011

  Mobile Network operators and cooperation
  – A tele-economic study of infrastructure sharing and mobile payment services

  http://www.impgroup.org/dissertations.php