# Network dimensioning and cost structure analysis + Introduction to HW3

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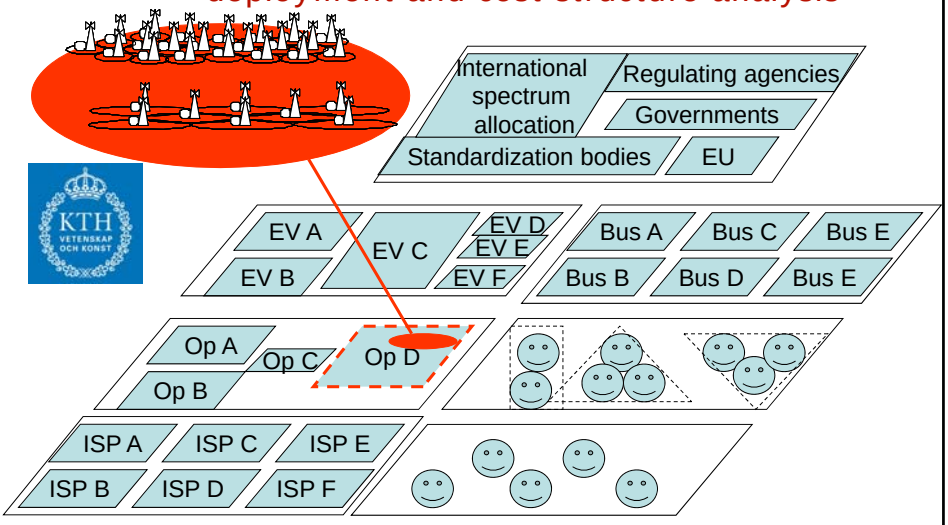
December 3, 2013



## Topics today

- The network dimensioning part of the course
- How to estimate user demand
- Network dimensioning
- Cost structure analysis
- About HW3

## About network dimensioning, deployment and cost structure analysis

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## About network dimensioning, deployment and cost structure analysis

- Economics of wireless infrastructure, scalability cost-capacity trade-offs, spectrum allocation
- Network dimensioning, deployment and configuration strategies, impact of user demand
- Cost structure modeling & analysis of network, to calculate CAPEX, OPEX, Net present value
- Homework 3: Dimensioning and high level design of a wireless network incl. cost structure analysis

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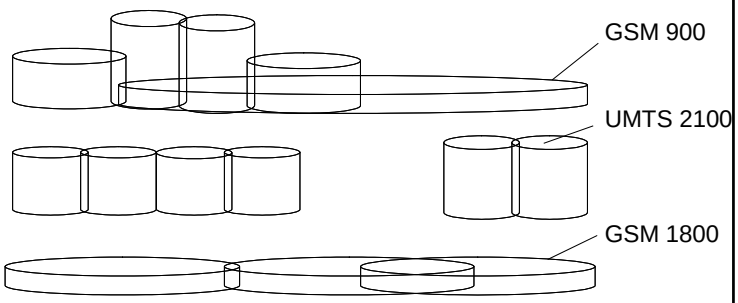
## Homework 3

- For a specific user and traffic scenario you will
  - Make the dimensioning of a radio access network
  - Analyze the cost structure for different options

Transmission

Buildout & Site costs

Radio Equipment

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## Agenda items

- To estimate demand
- Dimensioning of radio access network
- Capacity, data rates and spectral efficiency of radio access technologies (RAT)
- Trade offs using
  - Number of base station sites
  - Spectrum
  - Cell structure
- What to do when the demand increases?
- Cost structure analysis

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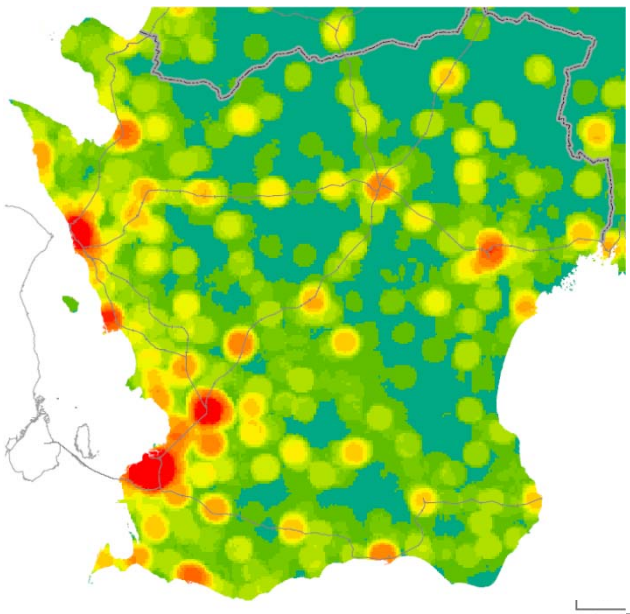
## Estimation of user demand

- How to describe demand
  - Location of users
  - Number of users
  - Service mix
  - Traffic per user
- How to estimate demand for dimensioning



## Population density in Skåne



## Population density (persons per sqkm )

- Sweden average: 20

- Sweden rural araes: 1 – 10
- Sweden suburban areas: 100-1000
- Sweden urban areas: 1000 -10 000

- EU region rural areas: 100-200

- Malmö average: 2000
- Stockholm average: 4000
- Stockholm city: 25 000

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## Geografical data for Sweden

| | Km² | Inabitants | Inh./km2 | Share of area | Share of population |
|---|---|---|---|---|---|
| Urban | 2 109 | 5 197 620 | 2 464 | 0,5% | 57% |
| Suburban | 23 780 | 3 249 652 | 137 | 5,2% | 35% |
| Rural | 431 473 | 732 206 | 1,7 | 94,3% | 8% |
| | **457 362** | **9 179 478** | **20,1** | **100%** | **100%** |

92% of the population is living at 6 % of the total area

8% of the population is living at 95% of the total area

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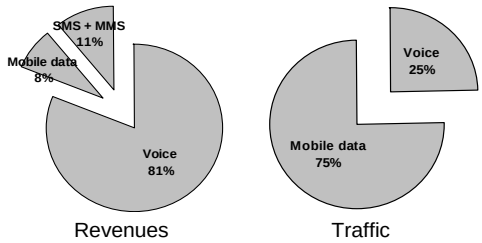
# Estimation of user demand

- The network dimensioning part of the course
- How to describe demand
  - Location of users
  - Number of users
  - Service mix
  - Traffic per user
- How to estimate demand for dimensioning



# Traffic, prices and revenues




**Traffic and revenue for different services at the Swedish market Q4 2008**

| EUR per MB | 2007 | 2008 |
|---|---|---|
| Voice | 1,46 | 1,36 |
| SMS | 439,5 | 351,6 |
| Mobile data (laptop) | 0,014 | 0,011 |

**Estimated price per MByte for voice, SMS and data for one Swedish operator**

## Amounts of data – orders of magnitude
(GB per month and person, 2010 Northern Europe)

- Voice traffic 0,01-0,02 GB
- Smartphones 0,10-0,20 GB
- Laptop MBB as complement 1 – 5 GB
- Laptop MBB as substitute 2 – 20GB
- Fiber to the home (house hold) 100-200GB

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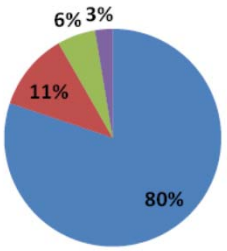
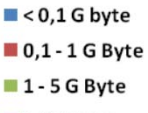
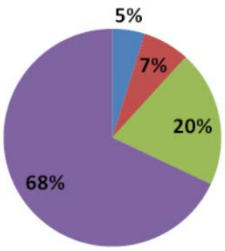
## Distribution of mobile broadband usage and subscriptions in Sweden Q4 2099




Share of subscriptions

Share of data usage

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## Estimation of user demand

- The network dimensioning part of the course
- How to describe demand
  - Location of users
  - Number of users
  - Service mix
  - Traffic per user

How to estimate demand for dimensioning

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## Demand estimates as input for dimensioning of network capacity

- Amount of data
  - per user, per time unit, per area unit
- Usage:
  - Amount of data per user and time unit
  - Example 1: 100MB per day
  - Example 2: 5 GB per month

  - needs to be expressed as kbps/Mbps per user

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## Demand estimates as input for dimensioning of network capacity

- Traffic
  - Amount of data per time unit per area unit
  - Depends on user density and usage per user
  - Example 1: 10 Mbps per sqkm
  - Example 2: 100 GB per day in a 2* 2 km area

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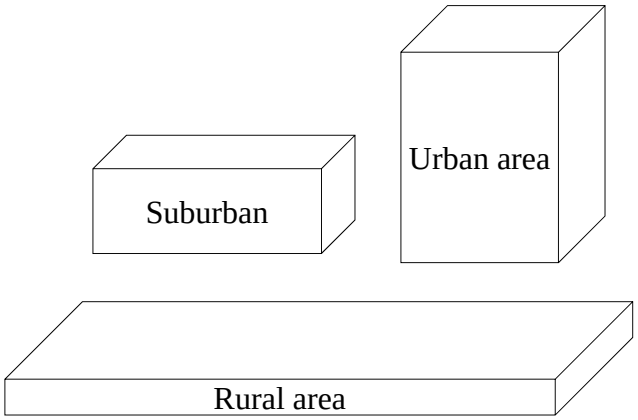
## Traffic density

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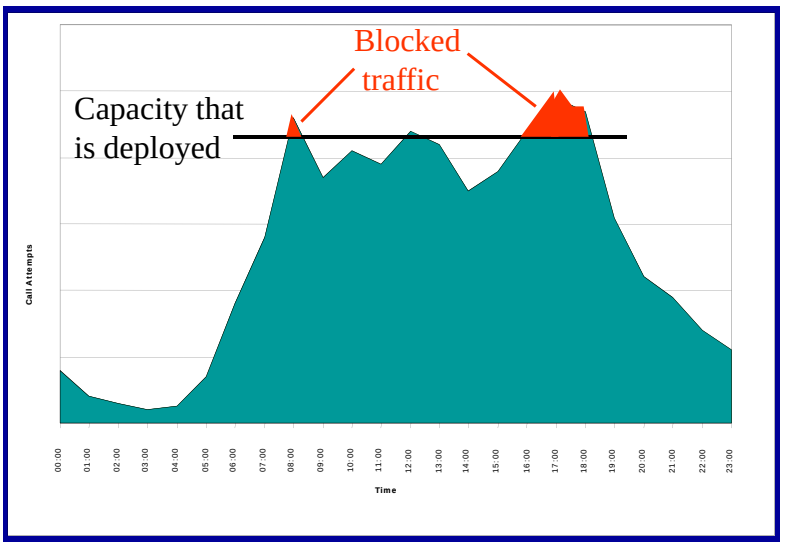
# Dimensioning Real time services

- For voice and RT data you need to estimate the maximum number of ongoing calls or session
  - Is based on the traffic during the ”busiest hour”



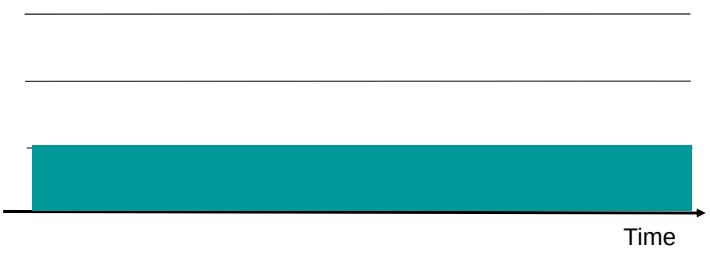
# Capacity dimensioning – The busy hour





## Capacity dimensioning – Mobile broadband

Montly demand of MBB spread out
- all days of the month
- all 24 hours of the day




For data NRT data traffic the approach with ”average data rate” per user can be used
X GB per user and month -> Y kbps per user

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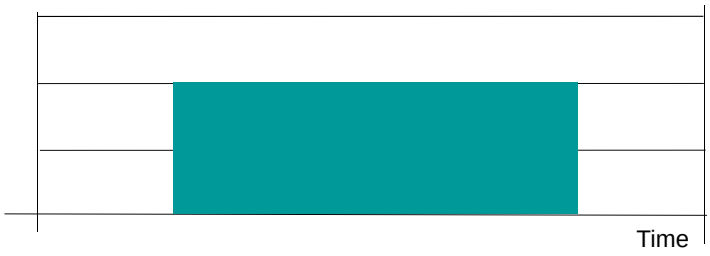
## Capacity dimensioning – Mobile broadband

Montly demand of MBB spread out
- all days of the month
- 12 out of 24 hours of the day

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## Capacity dimensioning – Mobile broadband

Montly demand of MBB spread out
- all days of the month
- 8 out of 24 hours of the day




## Short exercise

- What is the average data rate per user?
  - Example A.
    - Monthly usage 5.4 GB per user
    - Assume 30 days per month
    - Assume data used during 8 hours per day
  - Example B.
    - Monthly usage 14.4 GB per user
    - Assume 20 (office) days per month
    - Assume data used during 4 hours per day
- What is the average data consumption per month for these cases?
  - Example C.
    - The operator promises at least 1 Mbps
    - Assuming data usage 1 hour per day
  - Example D.
    - The operator promises at least 8 Mbps
    - Assuming data usage 4 hours per day

## Example of User demand – Mbps per sqkm

| | Average data rate per user (Mbps) | | | |
|---|---|---|---|---|
| Number of active users per sqkm | 0,01 | 0,1 | 1 | 10 |
| 10 | 0,1 | 1,0 | 10 | 100 |
| 100 | 1 | 10 | 100 | 1000 |

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## Are these numbers realistic?

- Population density
  - Stockholm average: 4000/ sqkm
  - Malmö average: 2000/ sqkm
  - Stockholm city: ~25 000/ sqkm
- Penetration of mobile dongles
  - 20 % 2010 (may be 50% in the future)
- Market share of operator ~ 40 %
  - Share of all users in an area: 0.2 * 0.4 = 8%
- Check Mbps per sqkm!! - With 8% of all users
  - In area with 25 000 / sqkm => 2000 / sqkm
  - In area with 2 500 / sqkm => 200 / sqkm
  - In area with 250 / sqkm => 20 / sqkm

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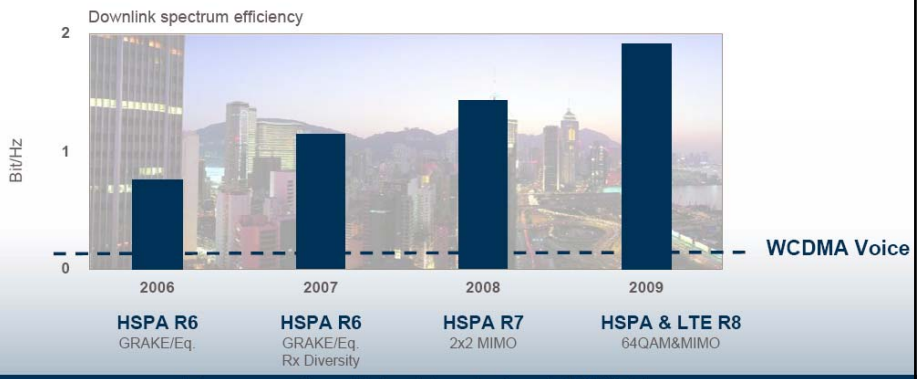
From Ericsson:
Capital markets day, May 2008

## HSPA and LTE capacity evolution




The capacity will double – but not 100 fold

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## Capacity of a base station?

I. Bandwidth * spectral efficiency * No sectors/ spectrum reuse

II. Bandwidth * No sectors/(spectrum reuse *spectral efficiency)

III. Bandwidth * No sectors *spectrum reuse /spectral efficiency

IV. Bandwidth * No sectors * Spectral efficiency

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## Capacity of a base station – type?

- Bandwidth * No sectors * Spectral efficiency

A. 5 MHz * 1 * 1 = 5 Mbps

B. 10 MHz * 3 * 1 = 30 Mbps

C. 20 MHz * 3 * 2 = 120 Mbps

D. 20 MHz * 1 * 10 = 200 Mbps

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## Implications for network deployment

- 1000 active users/sqkm, 50% market share
  => deploy capacity for 500 users /sqkm
- 5 GB usage per month per user
  ~ 15 kbps per user 24 hours all days for one month
  ~ 50 kbps per user during ”daytime” for one month
- Capacity estimates for 500 users
  - 5 GB users: ~ 25 Mbps/sqkm
- Compare with throughput for one ”cell”
  - ”3G” using 5 MHz ~ 3,5 Mbps
  - ”4G” using 20 MHz ~ 35 Mbps

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## Agenda items

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  - Number of base station sites
  - Spectrum
  - Cell structure
- What to do when the demand increases?
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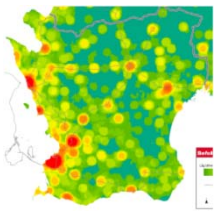
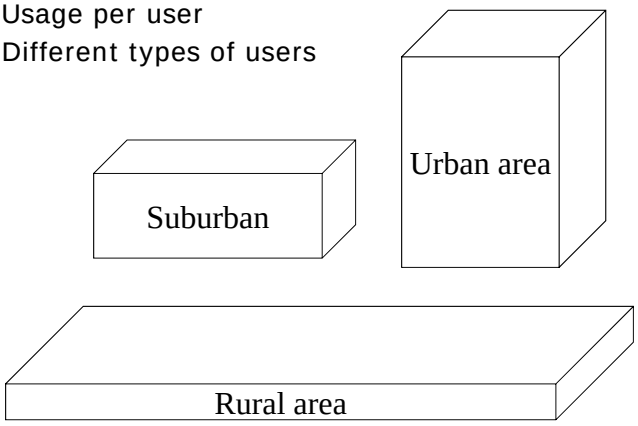
## Traffic density

- Estimate the demand
  - Number of users per area unit
  - Usage per user
  - Different types of users



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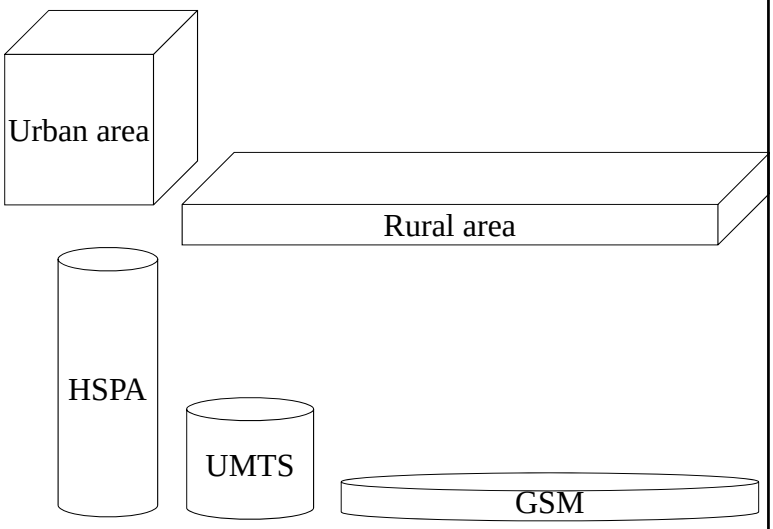
## The dimensioning problem

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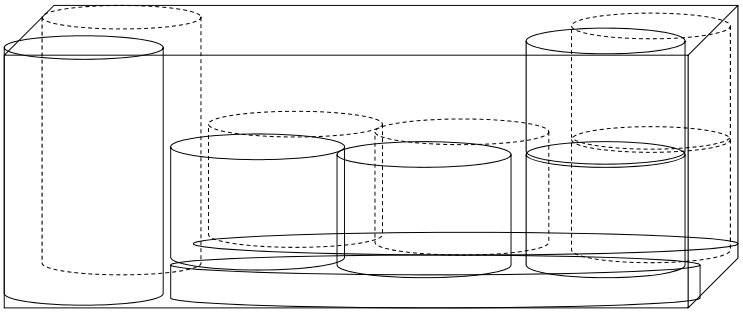
## The dimensioning problem

- To satisfy the demand
  - To ”fill the demand box” with ”resource cylinders”





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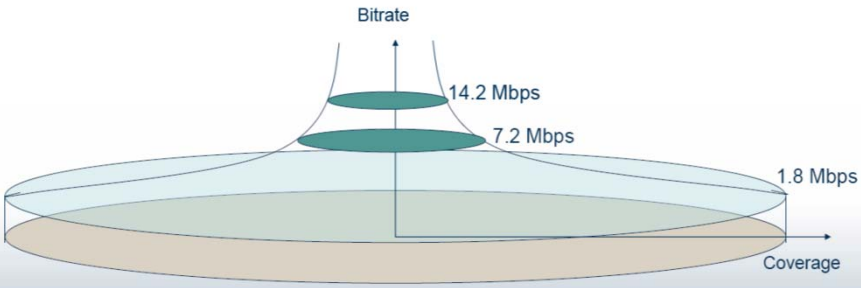
From Ericsson:
Capital markets day, May 2008

## Coverage vs. bitrate




Double peak rate does not correspond to double capacity

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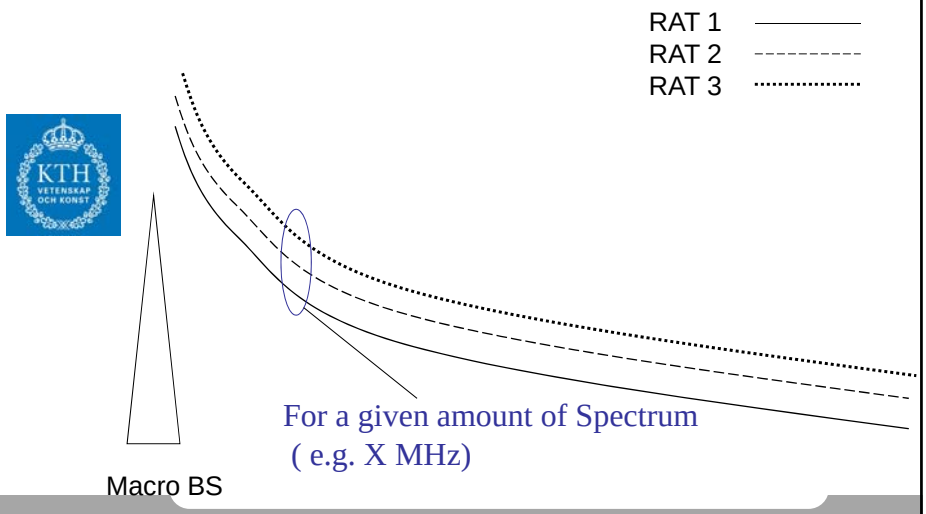
## Bit rate and range – Bandwidth and Radio Access Technology (RAT)

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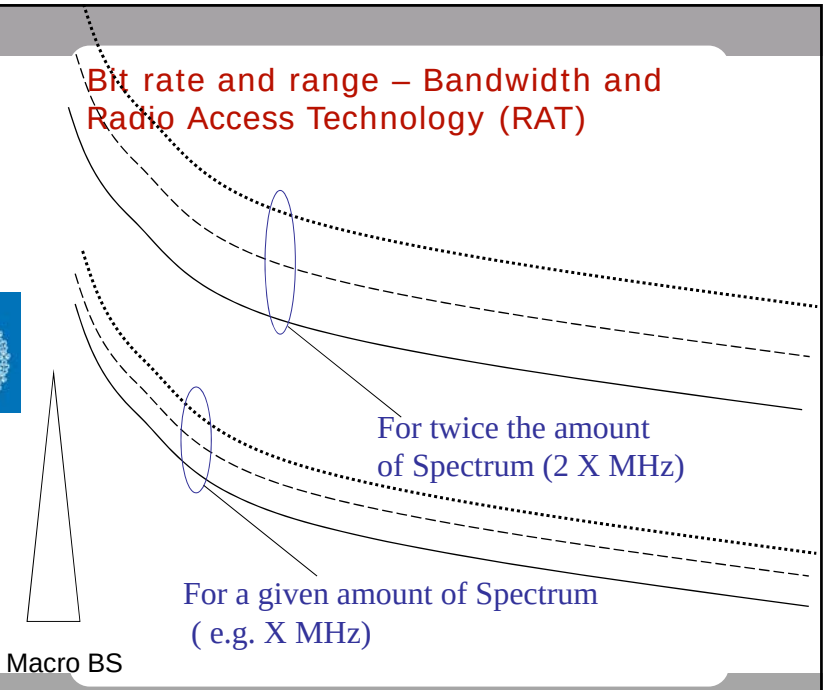
## Bit rate and range – Bandwidth and Radio Access Technology (RAT)

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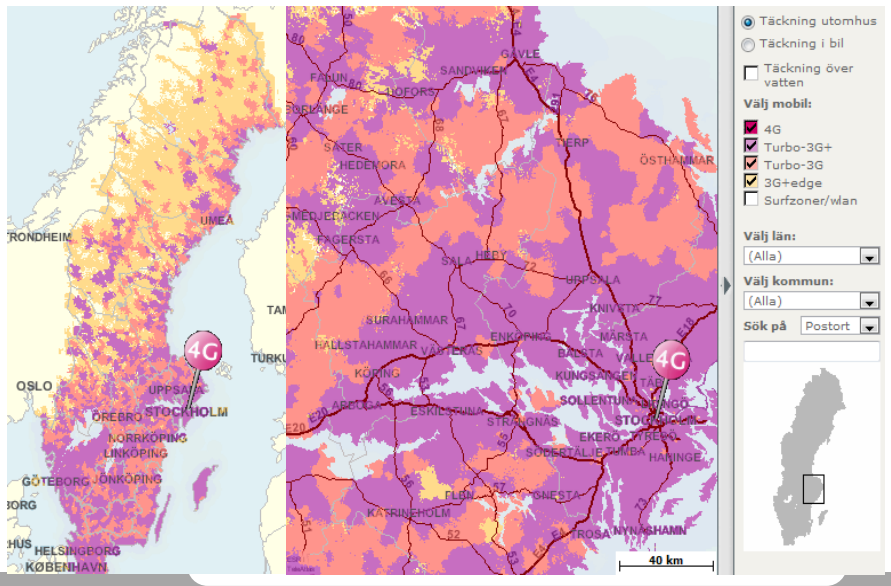


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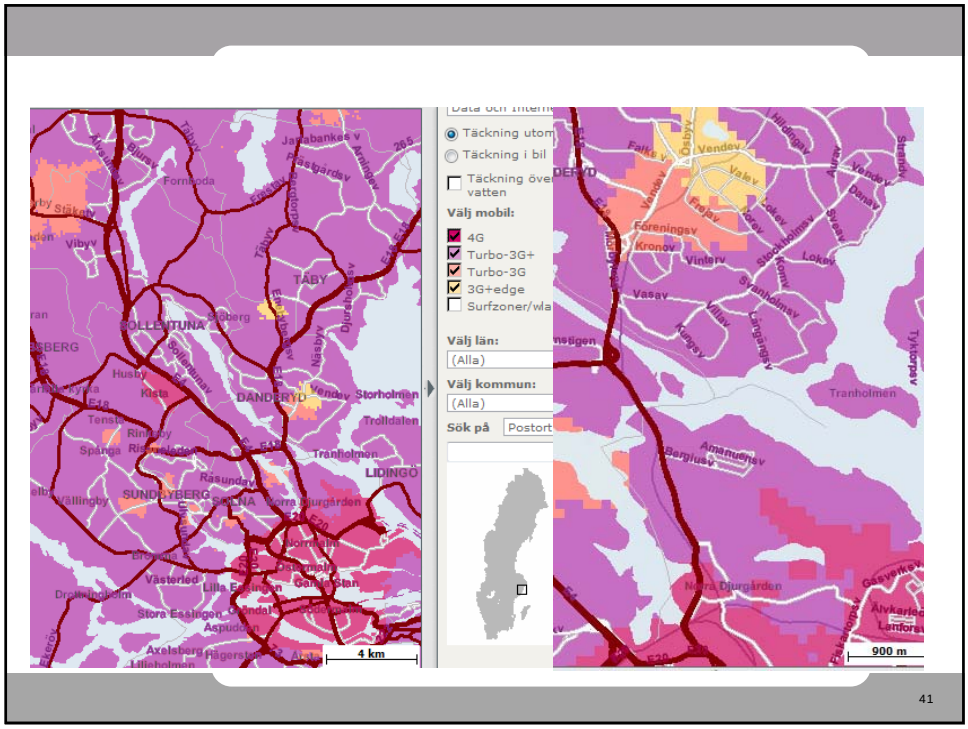
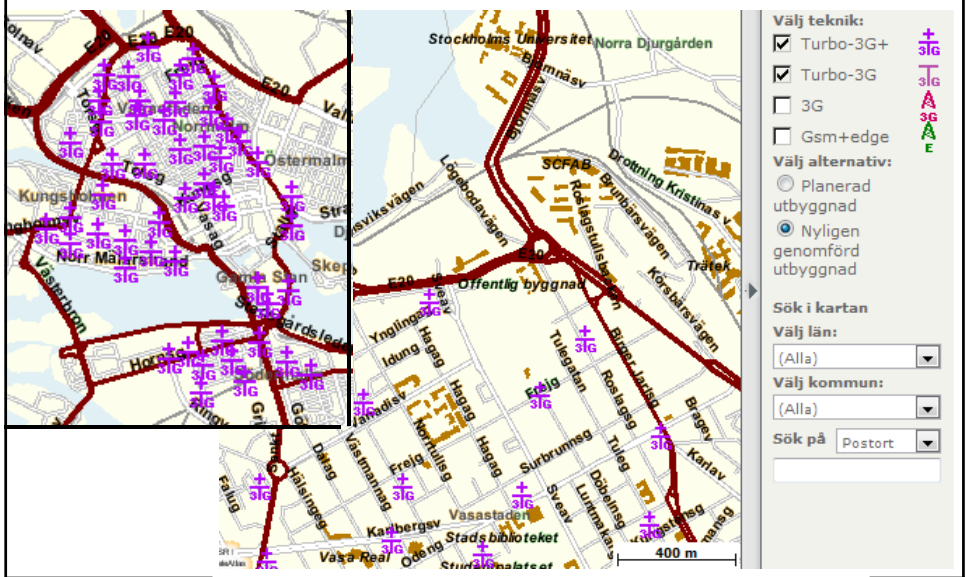
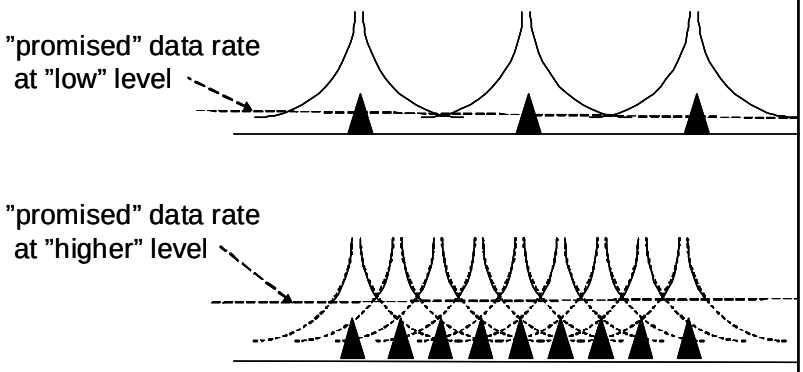



## Deployment Dowmtown Stockholm



## About promised data rates



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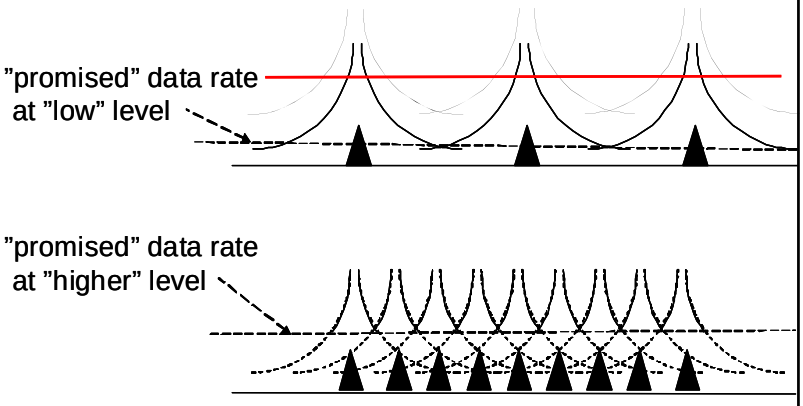

# - Telenors löften helt orealistiska

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.

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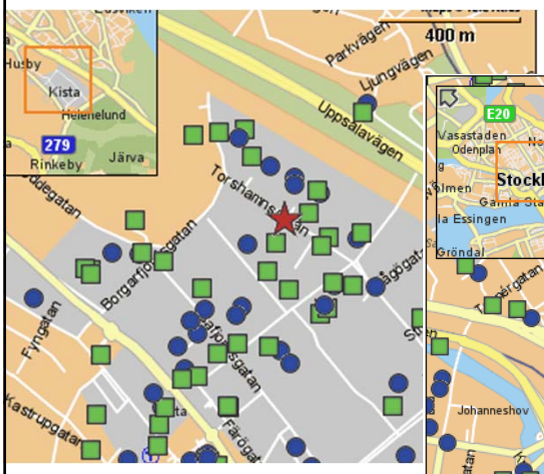
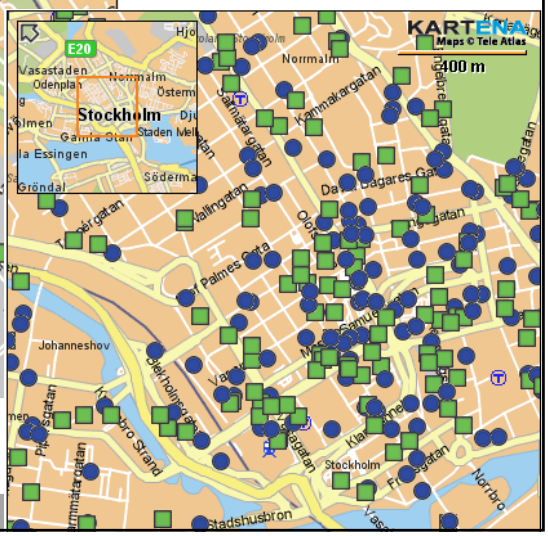
## Base station site locations in urban areas

from PTS "Transmitter map" web page, December 2009

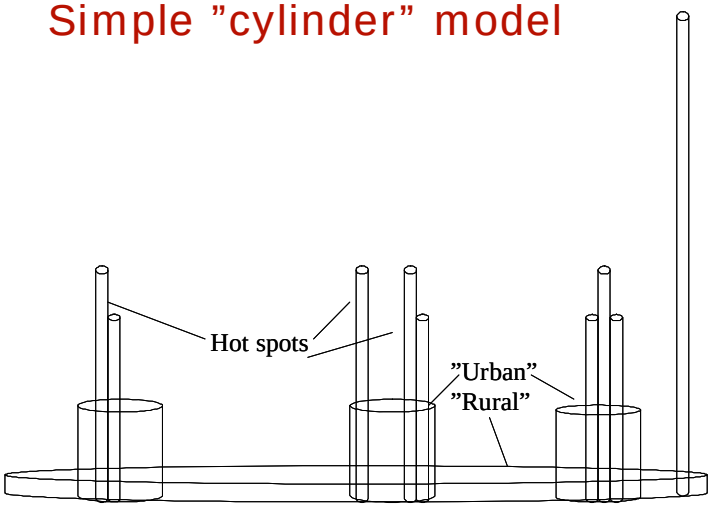



Kista Industry Area

Downtown Stockholm



## Simple ”cylinder” model

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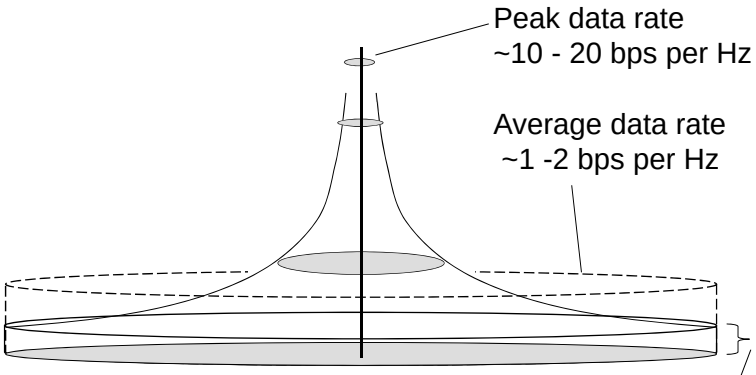
## Spectral effiency

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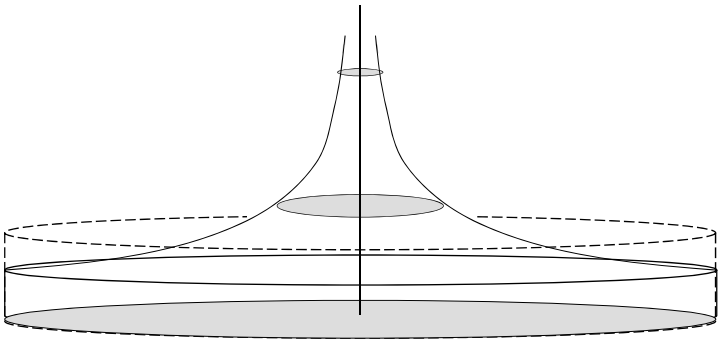
## Spectral effiency and cylinder model



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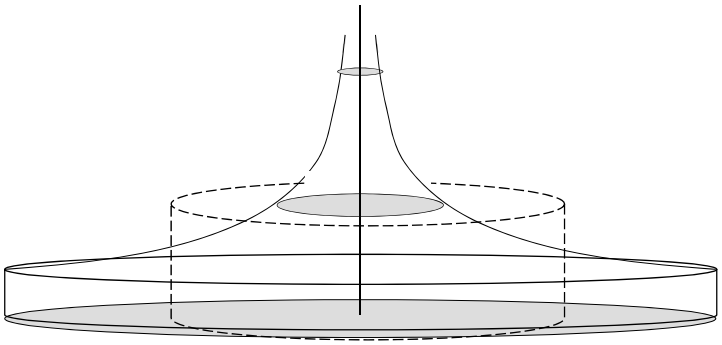
## Spectral effiency and cylinder model



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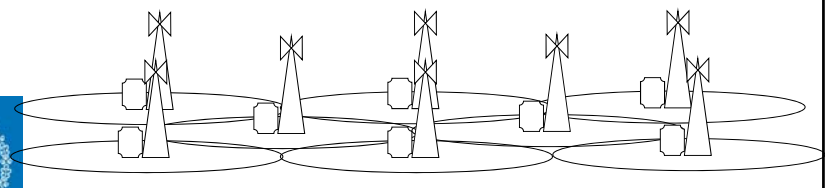
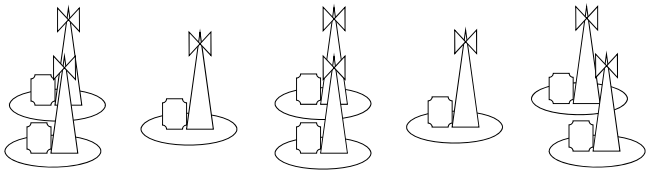


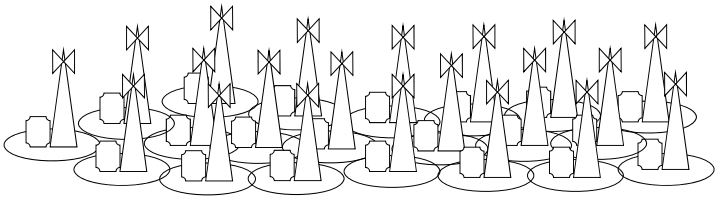
Cellular systems - low data rates



Cellular systems – higher data rates, the same sites



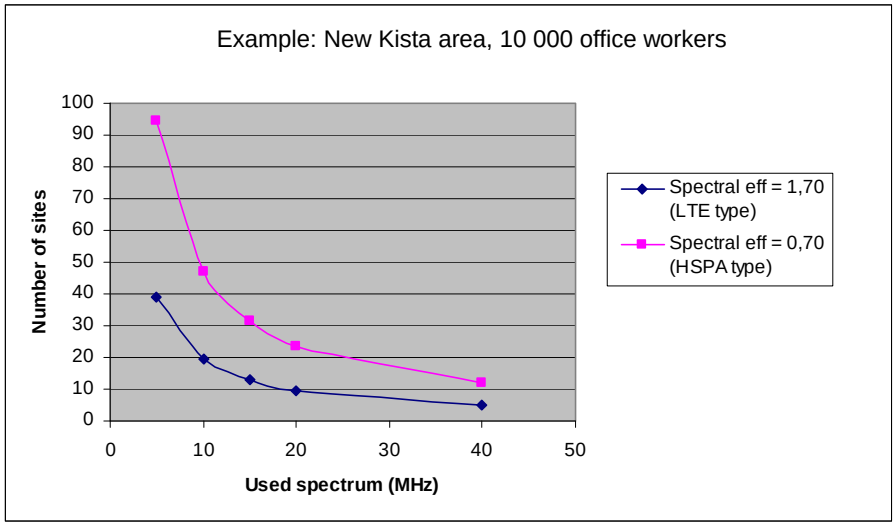
## Zander formula



$$C_{system} \approx c_{AP} N_{AP} \approx c' N_{user} B_{user} A_{service} f(Q)$$

$N_{AP}$ the number of access points (base stations)
$N_{user}$ the number of users
$B_{user}$ the average data rate of the users
$A_{service}$ the service area covered (volume indoors)
f(Q) is a function of the required Quality of Service.

## Amount of spectrum and number of sites



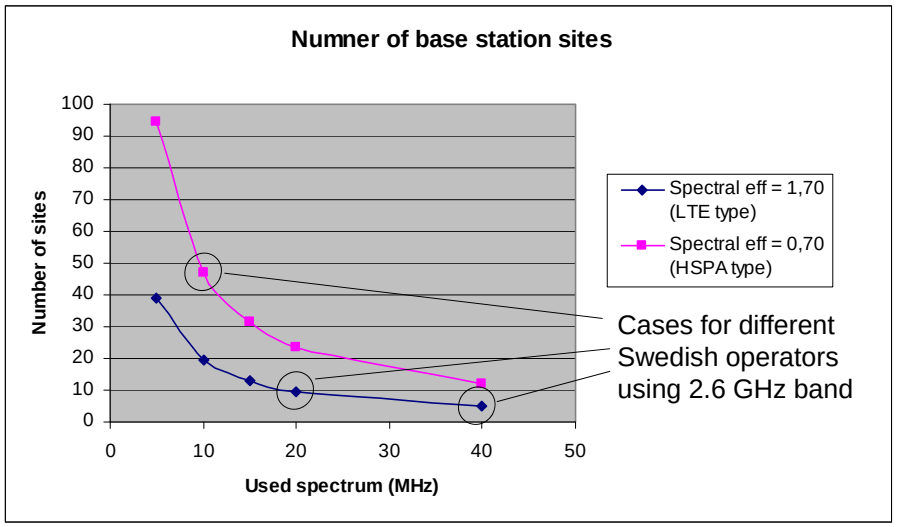



## Short exercise – work in 4 groups

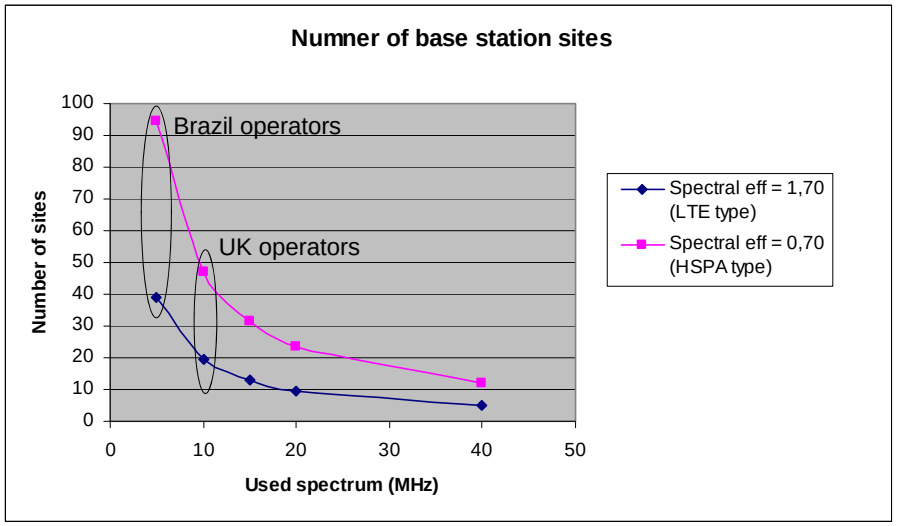
- How many base station sites need to be deployed in the following cases?

- Operator A, LTE in the 2.6 GHz
- Operator B, HSPA in the 2.6 GHz
- Operator C+D, LTE in the 2.6 GHz band and share network
- Operator E, LTE using unlicensed 1800 MHz band

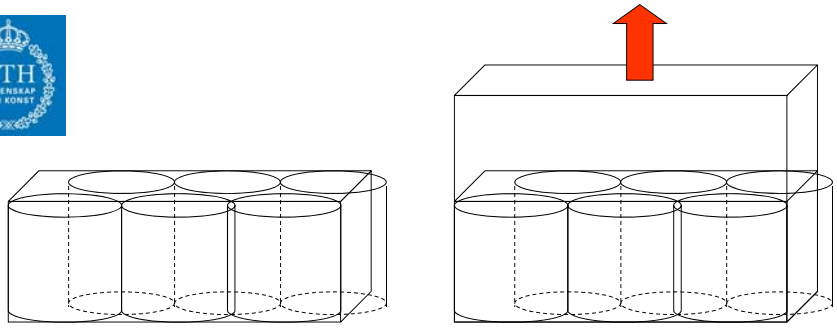
- You are allowed to ask me one question per group


Numner of base station sites
Number of sites
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
Used spectrum (MHz)
Spectral eff = 1,70 (LTE type)
Spectral eff = 0,70 (HSPA type)
Cases for different Swedish operators using 2.6 GHz band




Numner of base station sites
Number of sites
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
Used spectrum (MHz)
Brazil operators
UK operators
Spectral eff = 1,70 (LTE type)
Spectral eff = 0,70 (HSPA type)

## What to do when the demand increases?

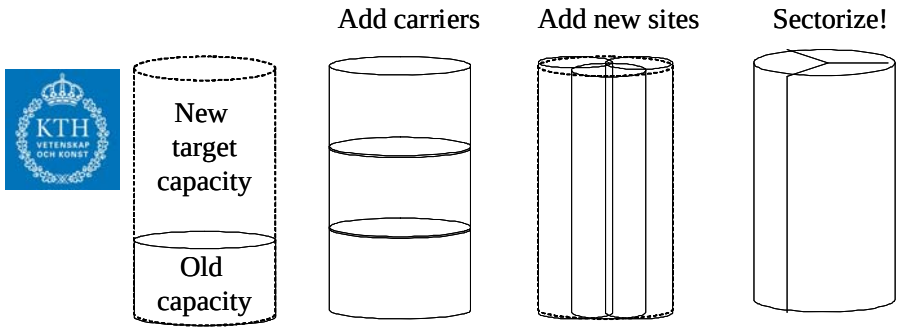




## What to do when the demand increases?

- Deploy a denser network
  - Add more sites (number of AP´s)
- Increase the bandwidth
  - Add more carriers
- Add sectors at existing sites
  - Add antennas and radio equipment

## What to do when the demand increases?

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## Capacity of a a cell as function of Spectral Efficiency and amount of spectrum

| Spectral efficiency | 5 MHz of Spectrum | 10 MHz of Spectrum | 20 MHz of Spectrum |
|---|---|---|---|
| 0,7 bps/Hz | 3,5 Mbps | 7,0 Mbps | 14 Mbps |
| 2,0 bps/Hz | 10 Mbps | 20 Mbps | 40 Mbps |

- Using a base station site with 3 sectors (cells) will result in a site capacity 3 times higher
- Example:
  - With a radio access technology with spectral efficiency = 2 bps/Hz and 20 MHz of spectrum
  - the site capacity = 120 Mbps

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## A short exercise: how many users can be served, - in a cell with capacities as below ?

| Spectral efficiency | 5 MHz of Spectrum | 10 MHz of Spectrum | 20 MHz of Spectrum |
|---|---|---|---|
| 0,7 bps/Hz | 3,5 Mbps | 7,0 Mbps | 14 Mbps |
| 2,0 bps/Hz | 10 Mbps | 20 Mbps | 40 Mbps |

- Use the “user demand” A, B C or D from before

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## Agenda items

- To estimate demand
- Dimensioning of radio access network
- Capacity, data rates and spectral efficiency of radio access technologies (RAT)
- Trade offs using
  - Number of base station sites
  - Spectrum
  - Cell structure
- What to do when the demand increases?

→ Cost structure analysis

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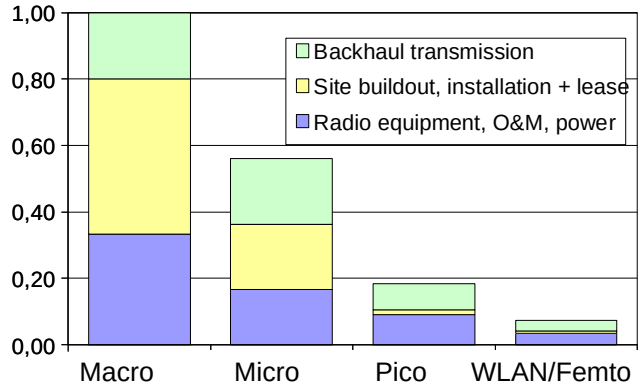
## Cost structure of radio access networks

- It is not only costs for the base station equipment (the radio) but also for the transmission & sites

From
Klas Johansson
PhD thesis 2007

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## Cost and capacity - examples

| Equipment | Cost [kEuro] | Capacity [Mbps] |
|---|---|---|
| EDGE Macro BTS, 3 TDMA carriers | 10 | 0,7 |
| EDGE Macro BTS, additional sector | 5 | 0,7 |
| EDGE upgrade for existing GSM Macro | 5 | 0,7 |
| WLAN AP (1 AP per site) | 1 | 10 |
| UMTS Macro BTS, first cell at site | 20 | 1 |
| UMTS Macro BTS, additional cells (sectors or carriers) | 10 | 1 |
| UMTS Micro BTS, one cell only (i.e. no build out) | 10 | 1 |
| HSDPA Macro BTS, first cell at site | 25 | 3 |
| HSDPA Macro BTS, additional cells (sectors or carriers) | 15 | 3 |
| HSDPA Micro BTS, one cell only (i.e. no build out) | 15 | 3 |

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## Financial aspects

- Price erosion
- Discounted cost model
  - We need to consider the time and how the value of changes over time
  - Net Present Value calculation

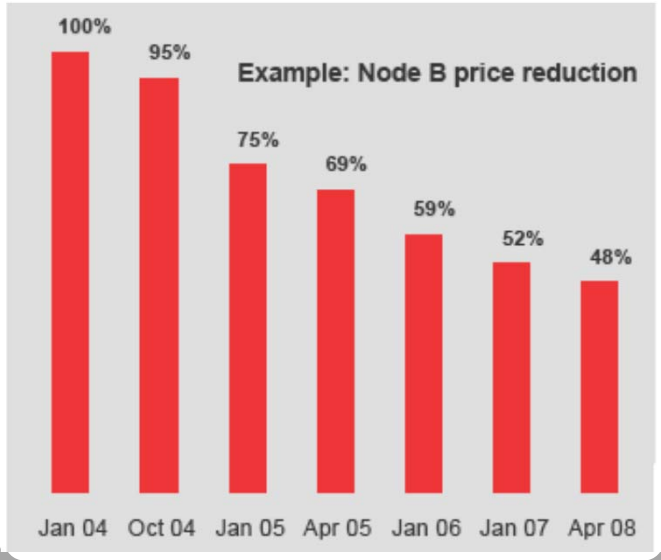


## Price erosion

- All costs; equipment, leases, labour etc have an associated ”cost trend”
- One example is Moore law for electronics
  - The performance/cost ratio is doubled every 18th month
- For price erosion 5 % you get

| | | | | | | |
|---|---|---|---|---|---|---|
| 100 | 95 | 90,25 | 85,7375 | 81,45063 | 77,37809 | 73,50919 |

## From Vodafone, March 2008

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## NPV calculation

- We need to consider the time and how the value of changes over time
- Net Present Value calculation (NPV in Excel)

| Year | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Value | V1 | V2 | V3 | V4 |

V1_1
V2_1
V3_1
V4_1

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## Good luck with HW3



## Homework 3

- For a specific user and traffic scenario you will
  - Make the dimensioning of a radio access network
  - Analyze the cost structure for different options

| Transmission |
| --- |
| Buildout & Site costs |
| Radio Equipment |