Case: Spectrum and network economics

Scope

- Analyze drivers, benefits and obstacles for operators to build and operate efficient mobile networks
- Each of you will get a country to analyze

Your tasks

1. Describe the overall situation and main challenges in your country for spectrum and mobile networks
2. Compare the network strategy, deployment status and offred services for two operators in your country

What to do in order to pass

- Prepare a draft report and send for review
  Max 4 pages in total
- Review reports of others in the review group
- Present review comments in group session
- Make a oral presentation of results
  Max 6 minutes and 3 slides
- Attend the presentation seminar
- Revise report according to the review comments and submit a final version

Schedule for the Case: Spectrum and network economics

- March 2,
  - Lecture: Introduction to tele-economic modelling and analysis and the student case to analyse
  - Each student gets individual asssigment
- March 9
  - Lectures on operator challenges and spectrum
  - Q&A session for your assignment
- March 18
  - Oral presentation of your case
- March 2- 20
  - You will work with your case, report and presentation and review work of others, see details next slide

Activity	Deadlines
Home work is assigned to each student	15-03-02 ; 12.00
Draft report sent to teacher & reviewers filename: "country"_v1.doc	15-03-10; 16.00
Review comments sent to teacher and authors filename: "country"_review_by"name"	15-03-12; 10:59
Review session and discussions in review groups (no teacher present)	Anytime before 15-03-13; 16:00
Do your presentation slides, put together all slides in the review group and send to teacher filename: "countryA, countryB, countryC".ppt	15-03-16; 11:59
Oral presentation, Each review group will present together	15-03-18; 09:00-12:00 Max 6 min per student
Send final report version to teacher filename: "country"_v2.doc	15-03-20; 11:59
Feedback and grading send to student	15-03-27; 12.00 latest

Introduction to Wireless Infrastructure Economics

Jan Markendahl, Associate Professor,
Wireless Infrastructure Deployment and Economics
Communication Systems , KTH
March 2, 2015

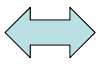
WHAT IS Wireless Infrastructure Economics?

Costs, Prices, Revenues, Profits

Money related to capabilities and resources
Distribution of costs, cost structure models and analysis

Trade-offs between

Capacity
Performance



Network Costs
Amount of spectrum

TODAY, two main parts

- First part is about overall picture, problems and challenges
- Second part is about network dimensioning, trade-offs, relationships and different solutions
- Cost
- Capacity
- Spectrum

TODAY, the first part

- First part is about overall picture, problems and challenges
- **Where are the costs?**
- In the fixed/Broadband networks?
- In the Mobile Networks?
- In the Radio Access Network of the Mobile networks?
- In the Core Network of the Mobile Networks?
- For a Mobile Operator in general?

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- **Where are the revenues? What kind of services?**
- Voice
- Messages
- Data
- Music
- Other services

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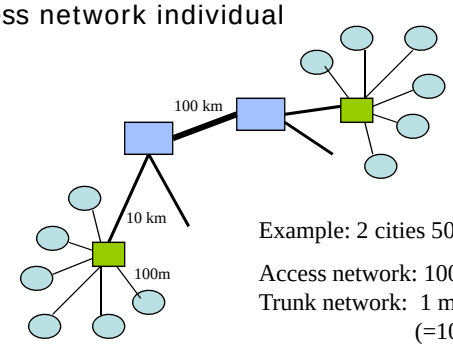
The “last mile” problem: Most investments in Access Networks

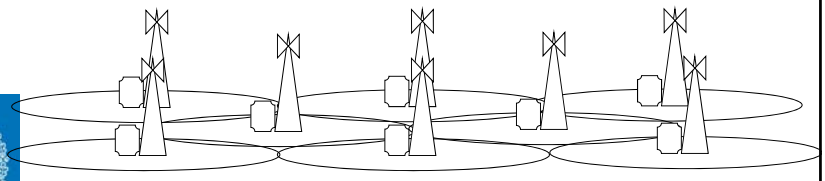
- Backbone network shared by many
- Access network individual



Example: 2 cities 50.000 user each

Access network: 100 m/user
Trunk network: 1 m/user
(=100 km/100.000 users)

Cellular networks in rural areas – large coverage areas per base station - few base stations per area unit



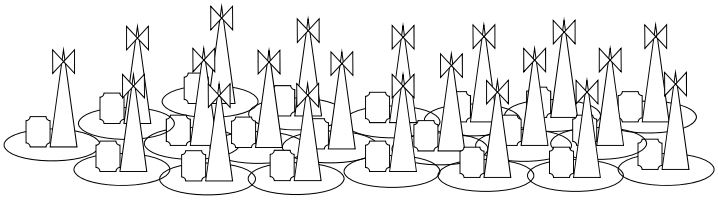
Range limitations

- Typical ranges (NLOS):
  - 10 kbit/s (GSM) 25+ km
  - 500 kbit/s (EDGE) 5-10 km
  - 2 Mbit/s (UMTS/) 2-3 km
  - 10 Mbit/s (HSPA) 500 m
  - 100 Mbit/s (LTE/WLAN) 50-150 m

- Coverage limited system

$$N_{BS} = \frac{A_{tot}}{A_{cell}} \propto \frac{1}{R^2}$$

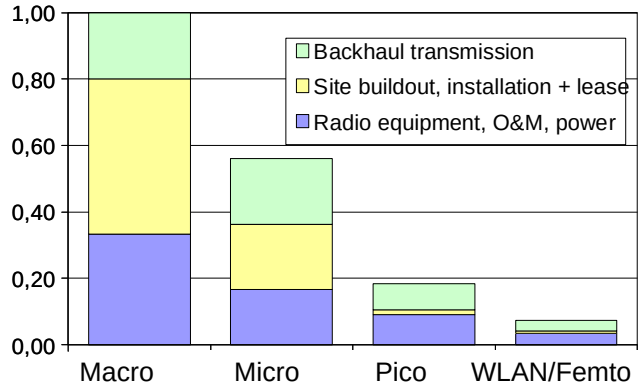
Cellular networks in urban areas – many base stations per area unit



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



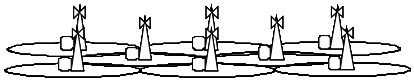
The infrastructure cost for capacity limited systems

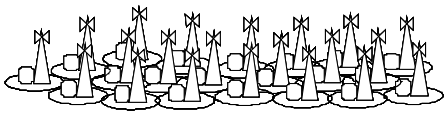
- Spectrum limitation
  - Btot available bandwidth
  - Spectral /reuse efficiency K

$$Cost \propto N_{BS} \propto \frac{N_{user} B_{user} K}{B_{tot}} A_{tot}$$

Spectrum, capacity and cost

- High bandwidth means high capacity per site, i.e less number of base station sites





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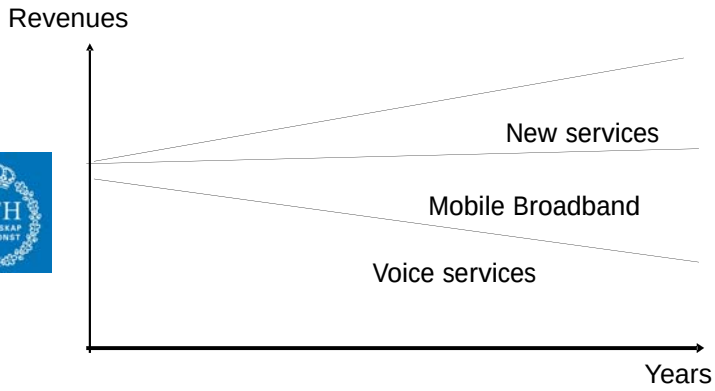
One motivation for our research
New services require new solutions



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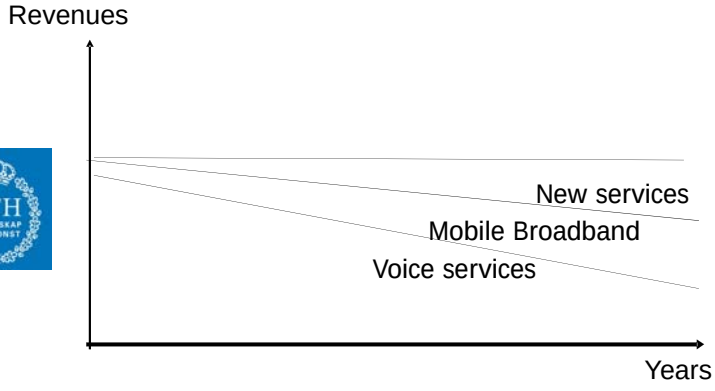
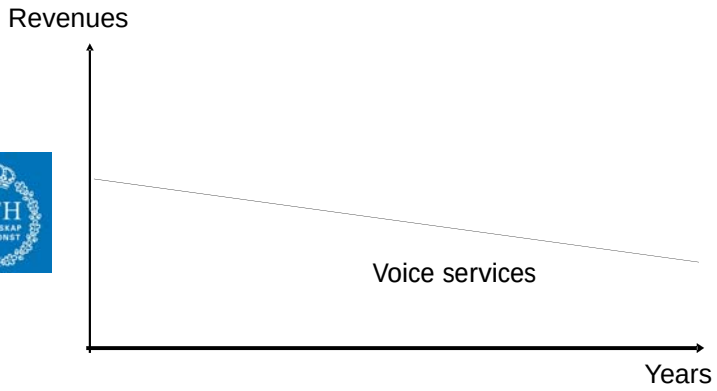
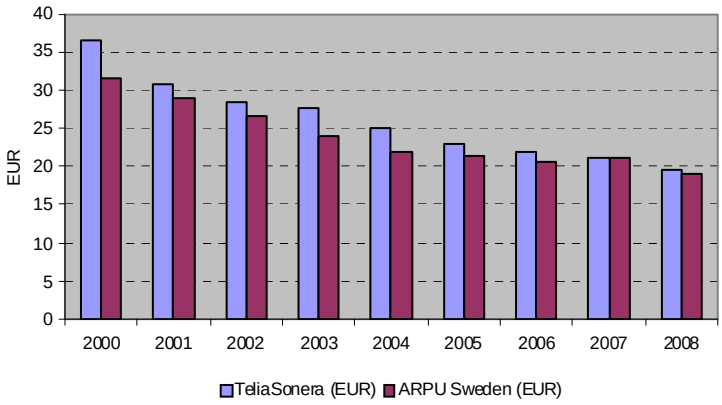


Declining voice revenues



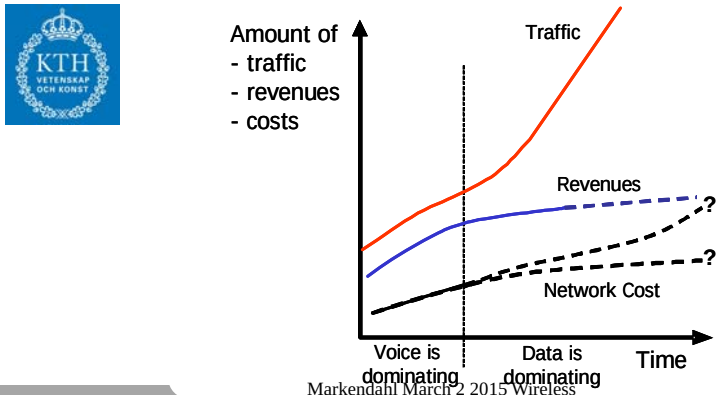
Revenues for mobile voice services in Sweden 2000-2008



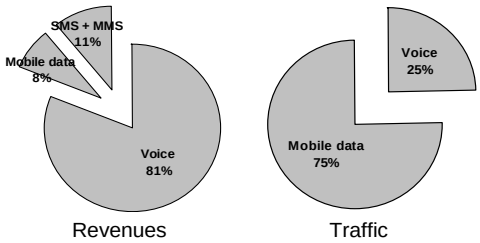
From Mölleryd, Markendahl, Werding and Mäkitalo conference paper presented at CTTE 2010, May 2010

The revenue gap
”de-coupling” of traffic and revenues”

- Flat rate tariffs create large increase of data traffic
  - –Many GB per user per month
  - –Data traffic up >100 % per year
  - –Revenues do not follow



Traffic, prices and revenues



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

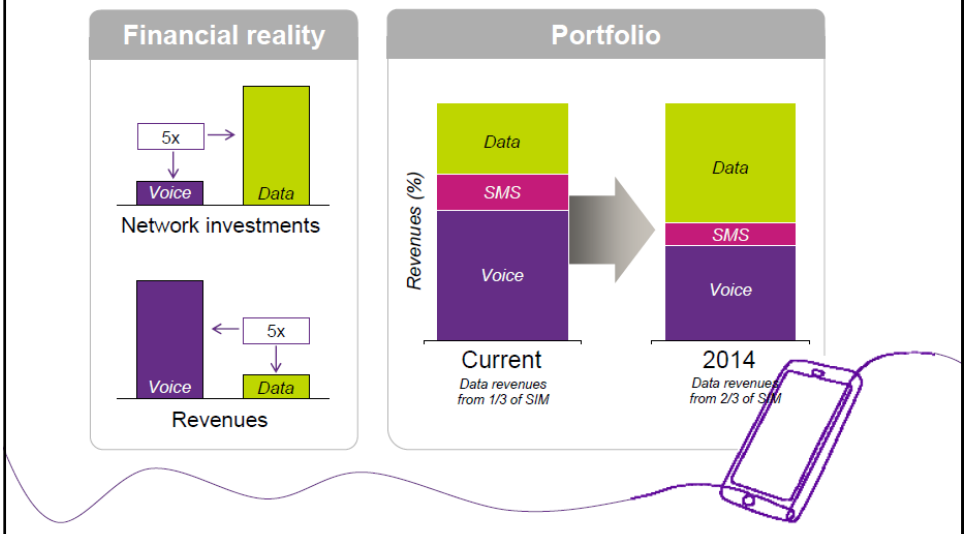
EUR per MB	2007	2008
Voice	1,46	1,36
SMS	439,5	351,6
Mobile data (laptop)	0,014	0,011

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

Traffic, prices and revenues

- Amount of voice data 10-20 MB per month
- Amount of mobile broadband data 1–20 GB per month
  - The number of mobile broad band bits are 100 – 1000 more than the number of voice bits
- But we pay more or less the same, i.e. the price per data bit is 100 – 1000 times lower => the cost per bit must be 100 – 1000 lower

Rebalancing of pricing model needed



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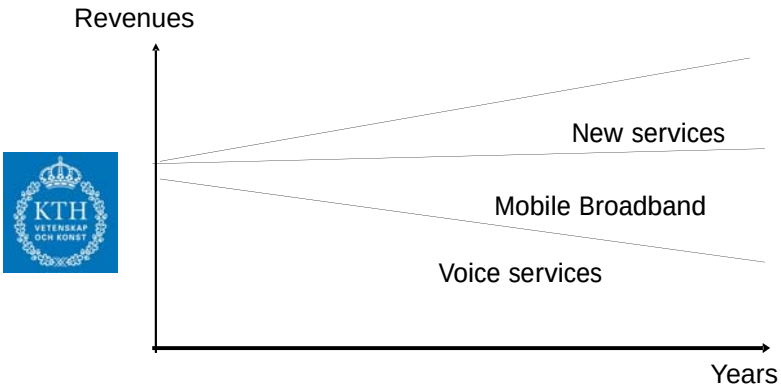
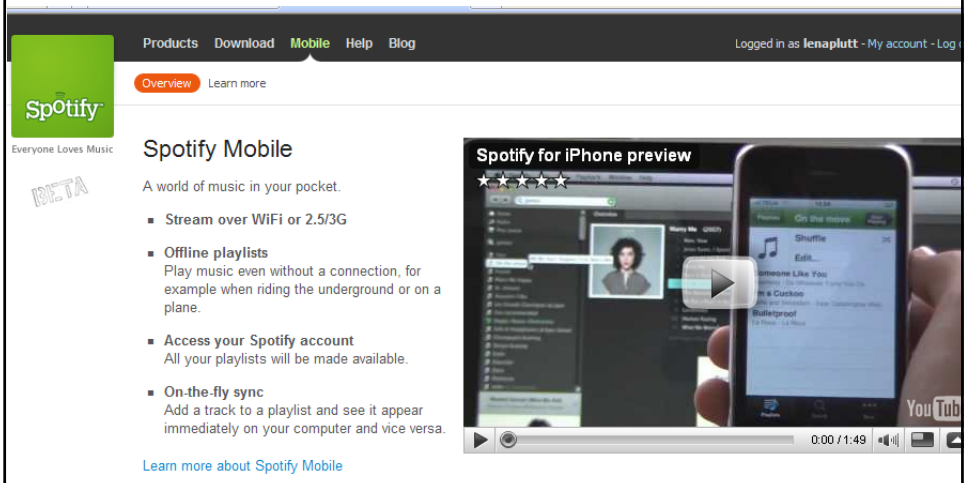
New services require new solutions



”New” services



Source: IDATE

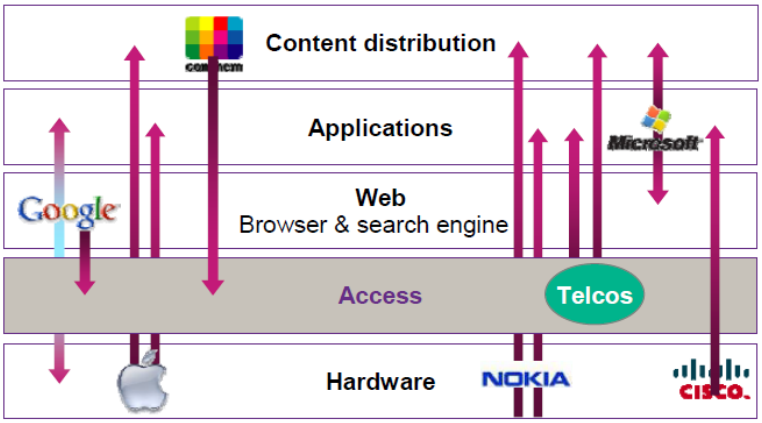
Revenue sharing for Apps?

Revenues from applications

	Previous	Now
Developer	20%	70%
Publisher	20%	0%
Aggregator	20%	0%
Operator	40%	0%
Handset supplier	0%	30%
	Type I-Mode	***Apple***

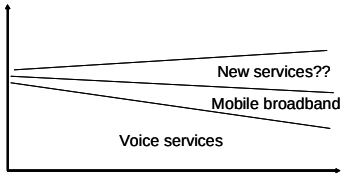
Changing competitive dynamics

Investor Day 2009

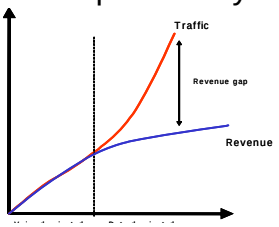


Operator challenges – business related

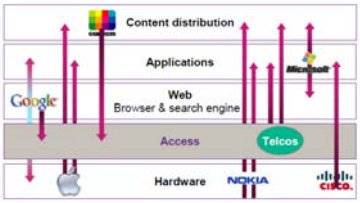
Revenue mix



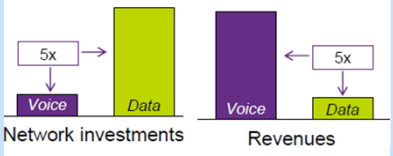
MBB profitability



The business landscape



Investments

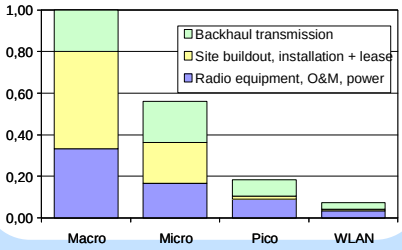


TODAY, the second part

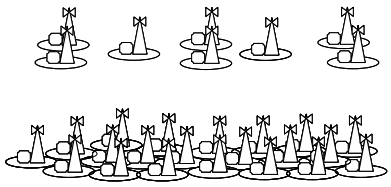
- Second part is about relationships and different solutions

Operator challenges – network related

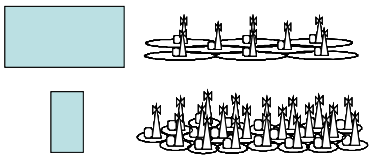
Cost structure



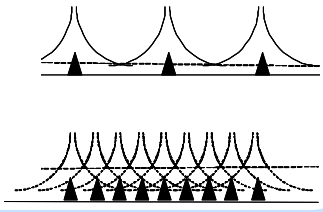
Scalability



Spectrum allocation

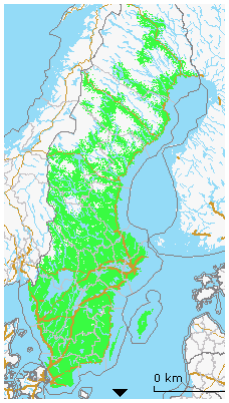


Data rate depends on range

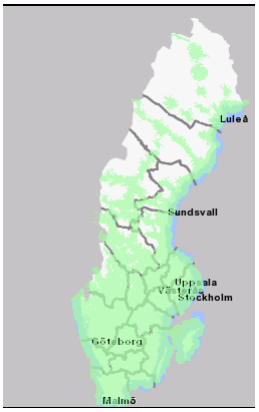


GSM Coverage

Tele2 - Telenor - Telia



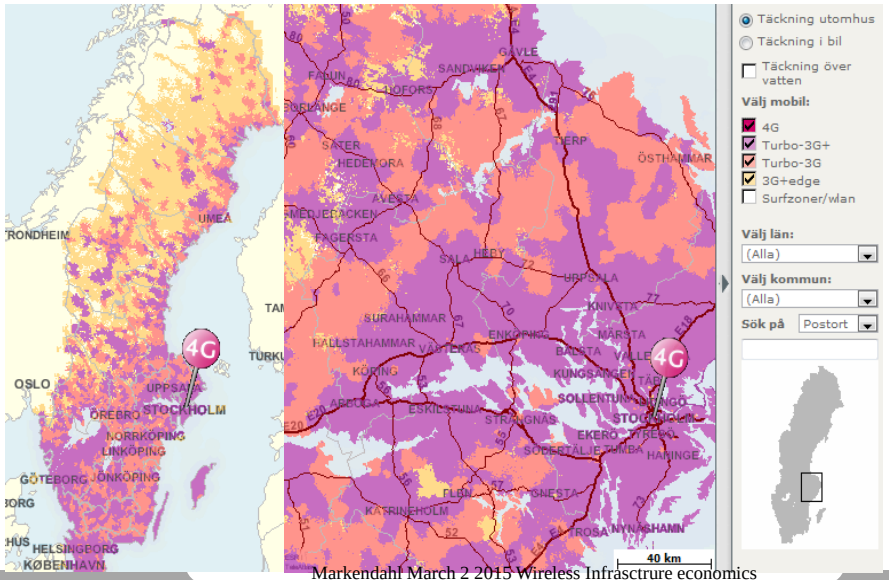
~70% covered area

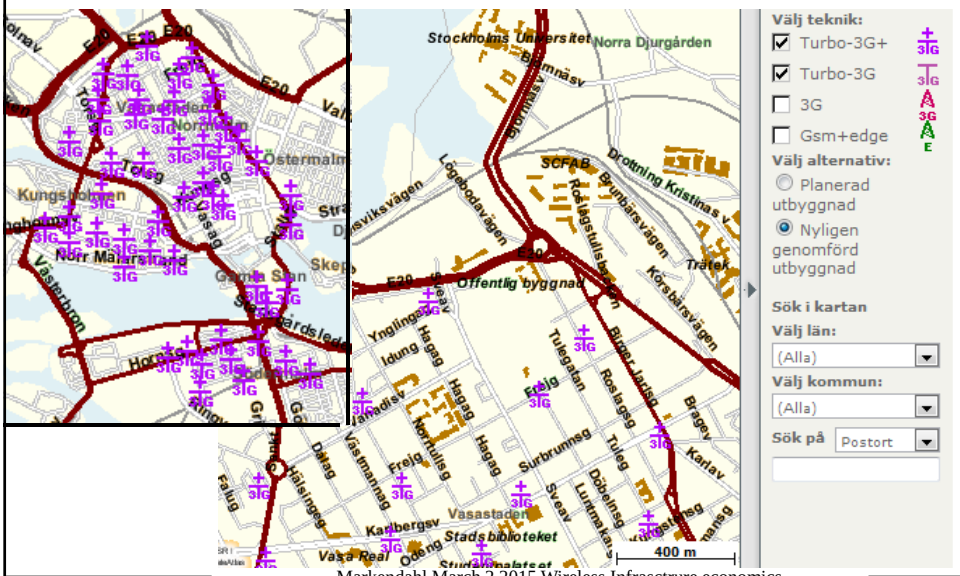


~65% covered area

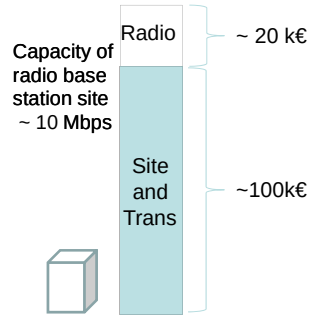
~90% covered area

Coverage maps – Telia web page





Cost structure, bandwidth and capacity



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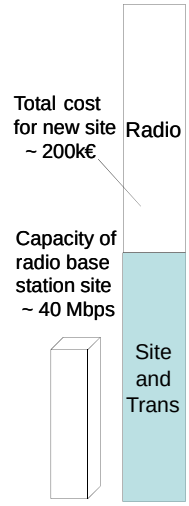
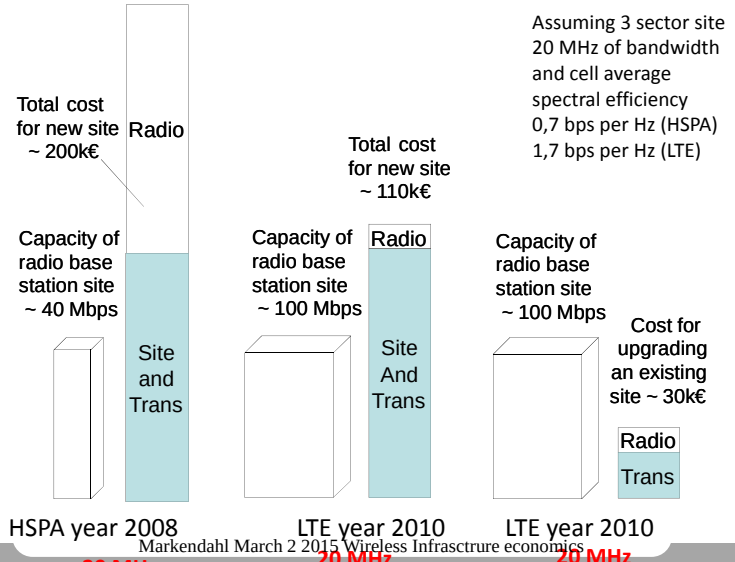


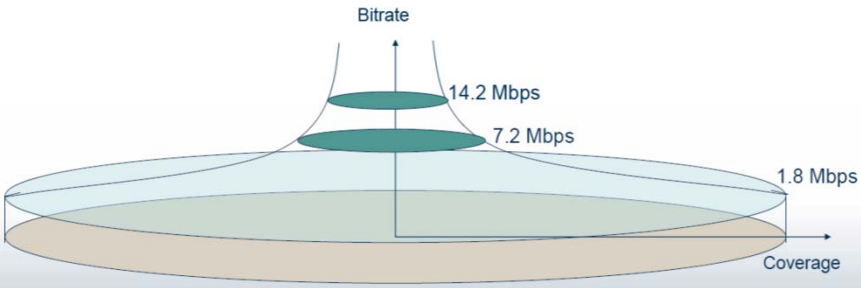
Cost structure, bandwidth and capacity

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)



From Ericsson:
Capital markets day, May 2008

Coverage vs. bitrate



Double peak rate does not correspond to double capacity

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Markendahl March 2 2015 Wireless Infrasctrure economics

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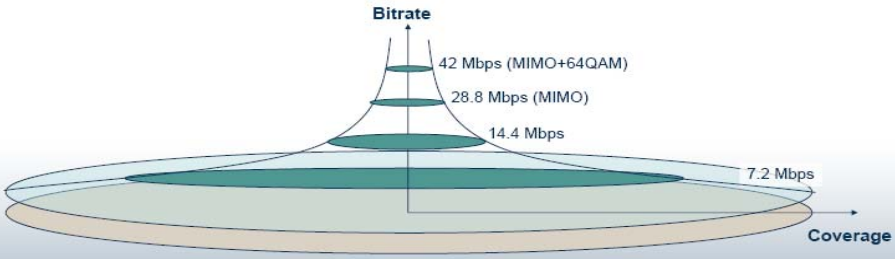
From Ericsson
Capital markets day
May 2009

Relation between Peak Rate & Coverage



Capacity does not scale with peak rate

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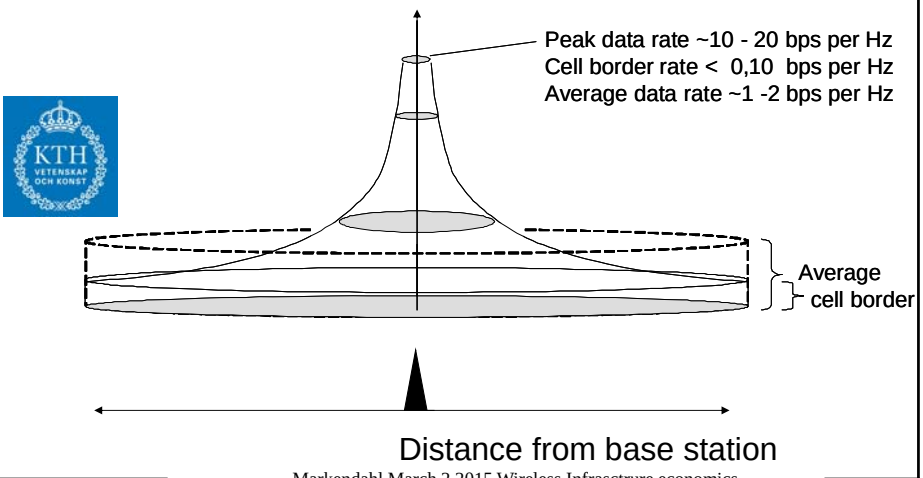
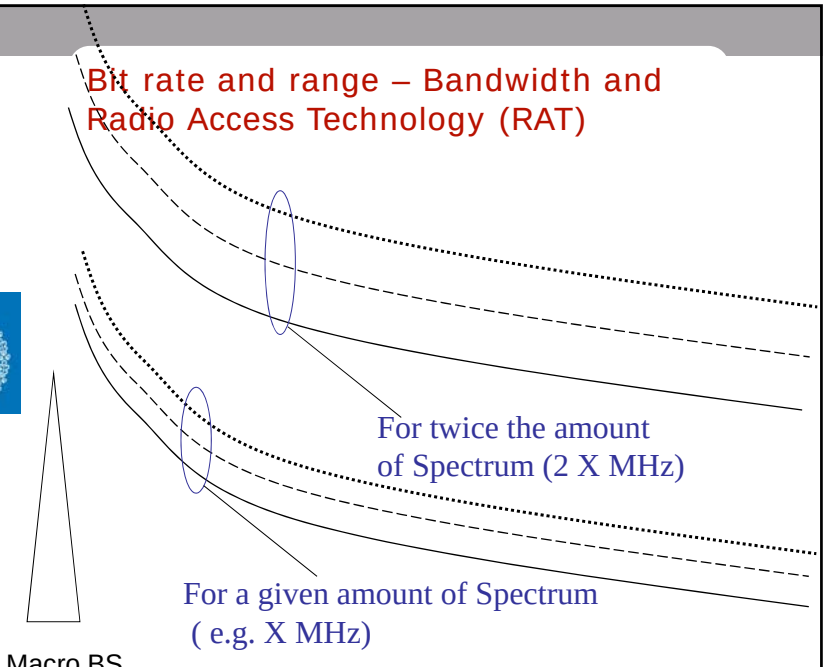
To improve the spectral efficiency
– i.e. more bits/second per Hz of spectrum



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



- Telenors löften helt orealistiska

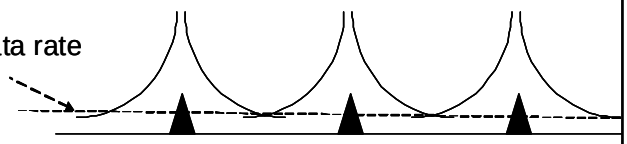
KTH-professor dömer ut kampanj om nya mobilnätet
Av: Helen Ahlbom 93 kommentarer
Publicerad 20 maj 2009 00:00

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.

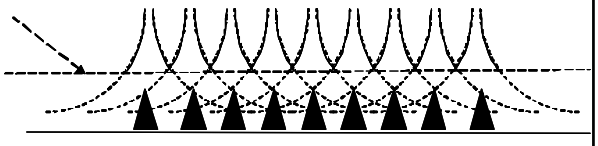
"Leve Allemansrätten!" utropar Telenor i reklamfilmer och stora affischer över hela landet. "Nu bygger vi Sveriges modernaste mobilnät. Det ger mer än 99 procent av svenska folket 150 Mbps via luften", utlovar bolaget på reklamplats.

”Offered” bit rate vs coverage & load

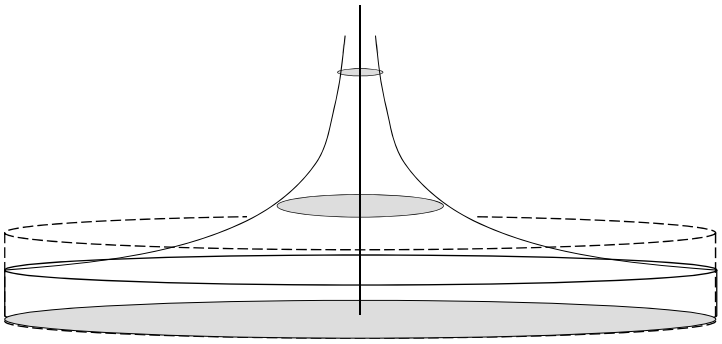
”promised” data rate at ”low” level



”promised” data rate at ”higher” level



Spectral effiency and cylinder model



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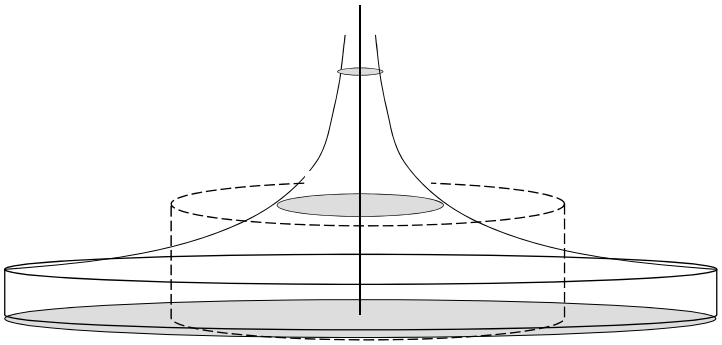
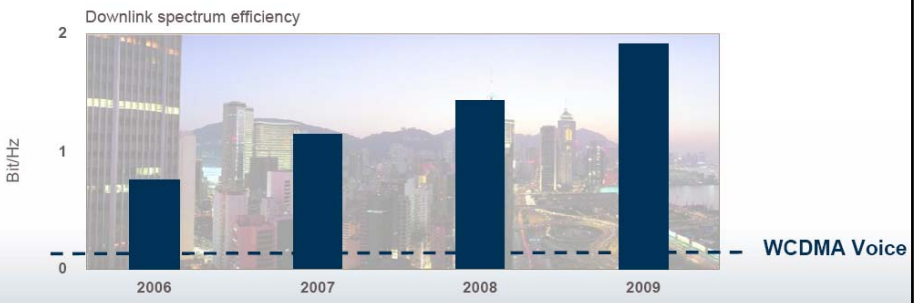


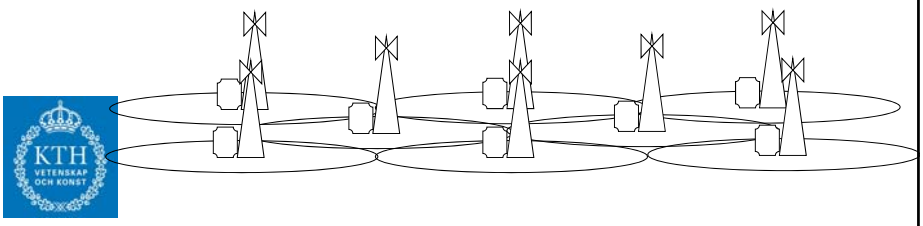
From Ericsson:
Capital markets day, May 2008

HSPA and LTE capacity evolution

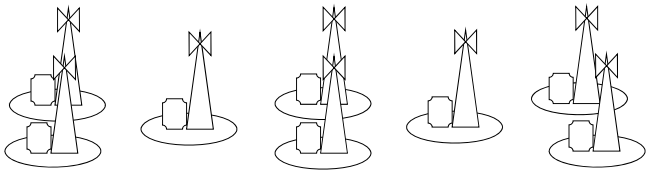


The capacity will double – but not 100 fold

ERICSSON

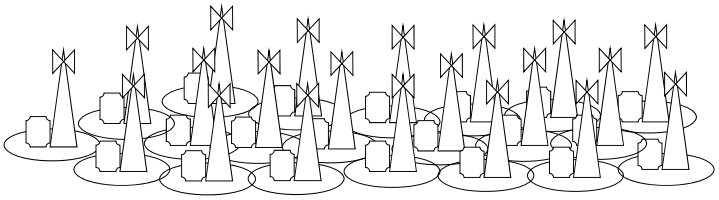


Cellular systems - low data rates



Cellular systems – higher data rates, the same sites

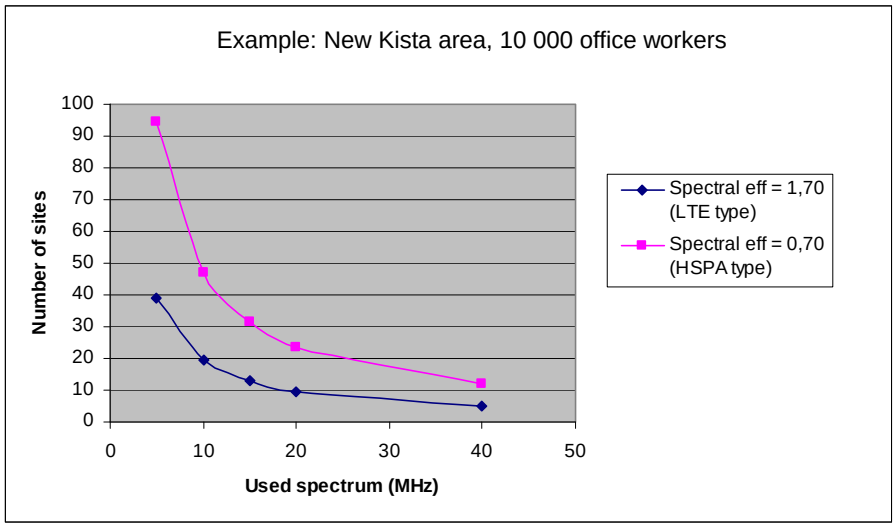
Zander formula

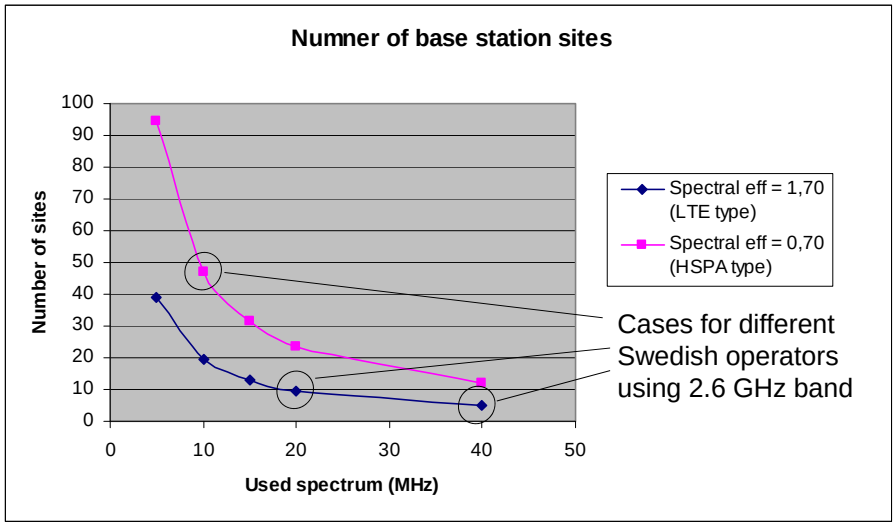


$$C_{system} \approx c_{AP} N_{AP} \approx c' N_{user} B_{user} A_{service} f(Q)$$

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.

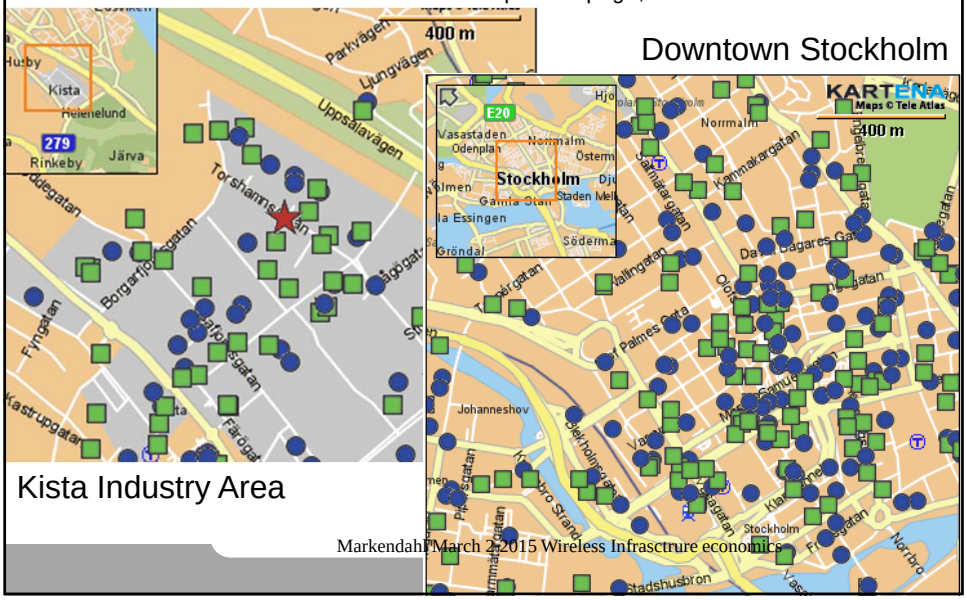
Amount of spectrum and number of sites





Base station site location in urban areas

from PTS “Transmitter map” web page, December 2009



Examples of Base station densities (Urban areas in Sweden)

Name and type of area	*Total density of sites*	*Typical densities for operators*
Residential area in Uppsala	~6 per km^2	1 3 per km^2
Residential area Akalla	~ 14 per km^2	3 5 per km^2
Central part of Uppsala	~ 20 per km^2	3 8 per km^2
Industry area Kista	~ 50 per km^2	7 20 per km^2
Central part of Stockholm	~ 130 per km^2	20 40 per km^2

The capacity needs to be increase at least 1000 times the coming years

Contributions

- One enabler is ”more spectrum”
- Another contribution comes from ”better technology” (improved spectral efficiency)
- A third contribution is from ”denser network”

3 minute discussion – discuss in groups

- How do you think the different aspects contribute?

(More spectrum)*(improved spectral eff.)*(denser network) = 1000

Cooper´s law

- “the number of “conversations” that can theoretically be conducted over a given area in all of the useful spectrum is doubled every two-and-a-half years (www.arraycomm.com/technology/coopers-law)
  - The improvement in spectrum utilization has been over a trillion times in the last 90 years and a million times in the last 45 years.
- “Of the million times improvement in the last 45 years,
  - 25 times were the result of being able to use more spectrum
  - 5 times can be attributed to the ability to divide the radio spectrum into narrower slices
  - Modulation techniques like FM, SSB, time division multiplexing, another 5 times or so
  - The remaining **sixteen hundred times** improvement was the result of confining the area used for individual conversations to smaller areas, what we call spectrum re-use”.

Industry focus

- Three main strategies to increase radio network capacity is described (Landström et al, 2011). ;
  - to improve the performance of the macro layer,
  - to build a denser macro layer (more base stations)
  - to add low power pico or femtocell base stations
- Current focus for R&D and standardization
  - To increase the peak data rate
  - To combine spectrum into larger chunks
  - To offload heavy data traffic from macro layer to local networks: picocells, femtocells or WiFI

To handle increasing user demand

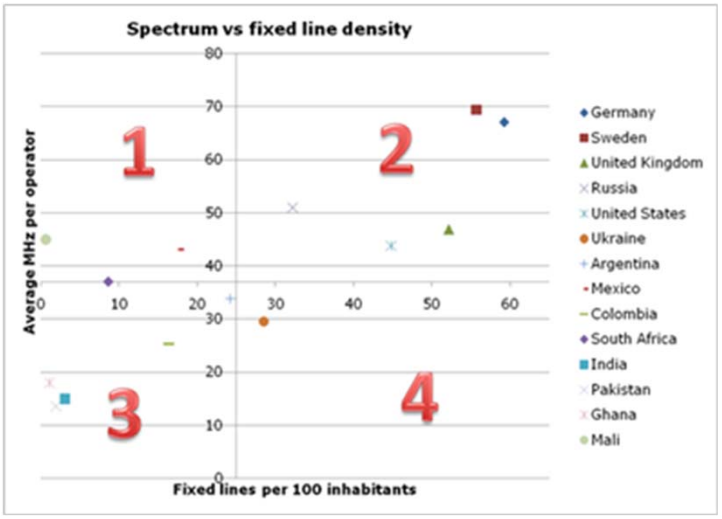
- Two main development paths
  - Improve network performance and capacity
  - Add more spectrum
- Current focus for R&D and standardization
  - To increase the peak data rate
  - To combine spectrum into larger chunks
  - To offload heavy data traffic from macro layer to local networks: picocells, femtocells or WiFI

BUT, there are two ”buts”

1. Spectrum alone is not the main issue
   - The traffic increases 1000 times the coming years
   - Only 2 – 5 times more spectrum is discussed

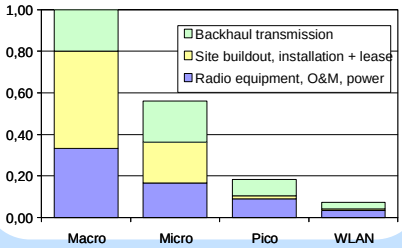
2. Regions and countries in the world are different
   - The world it is not like a ”Sweden XL”
   - In countries like Sweden and Germany :
     - There is a lot of fixed line infrastructure
     - Operators have ”quite a lot of” spectrum

Differencies between countries

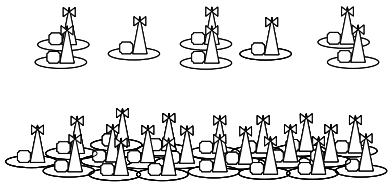


Operator challenges – network related

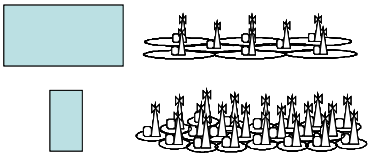
Cost structure



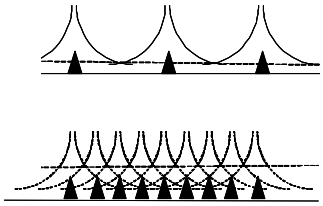
Scalability



Spectrum allocation



Data rate depends on range



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Thanks for your attention

- 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
- Link to Telia investor relation information
  http: //www.teliasonera.com/investors/reports-and-presentations/presentations/

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