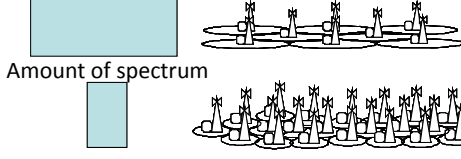


Wireless@KTH



Amount of spectrum

Track: Spectrum and Technology

On network deployment strategies for mobile broadband services taking into account amount of spectrum and fixed line penetration
- Comparison of network deployment in Europe and India

Jan Markendahl
Wireless@KTH, Royal Institute of Technology, Stockholm

Bengt G. Mölleryd
PTS, Swedish Post and Telecom Agency,
(Guest researcher at Wireless@KTH)

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Problem background

- Mobile broadband (MBB) services will require much more capacity than existing GSM voice services
 - GSM usage ~10-30 MB per user and month
 - MBB usage ~ 1 - 30 GB per user and month
 - => Capacity needs to increase 100 – 1000 times
- Spectrum is a limited resource
 - 2 – 4 times more spectrum will not solve the problem
- Higher capacity also means a denser network
 - More base station sites (towers and roof top sites)
 - Costly since site costs >> radio costs

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Main messages and areas of contributions

- Spectrum allocation is important
 - but it will itself not solve the problem – why?
- Regions in the world are different
 - Alternative types of network deployment are needed (“taking into account amount of spectrum and fixed line penetration”)
- How solutions are/can be used India/Sweden
 - Network sharing
 - Femtocells for in-building deployment
 - Secondary use of spectrum and (TV) white space

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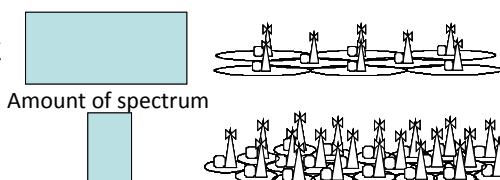
More capacity by adding more spectrum

– in combination with:

- To improve the macro layer performance (spectral efficiency, bps/Hz)



- To build a denser network (i.e. more base stations)



- To add low power base stations (mostly at indoor locations)



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Cooper's law

- “the number of “conversations” that can theoretically be conducted over a given area in all of the useful radio spectrum is doubled every two-and-a-half years (Webb, 2007). (www.arraycomm.com/technology/coopers-law)
 - The improvement in the effectiveness of total 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,*
 - *Roughly 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”.*

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Current focus for R&D and standardization

- To increase the peak data rate
- To combine spectrum bands
- To move heavy data traffic from macro layer to local networks: picocells, femtocells or WiFi

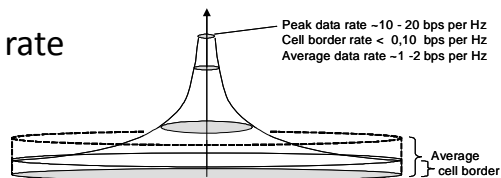
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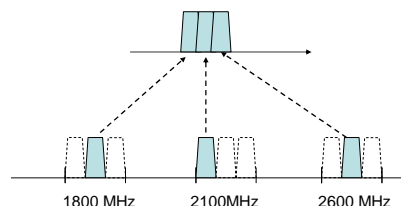
6

Current focus for R&D and standardization

- To increase the peak data rate



- To combine spectrum bands



- To move heavy data traffic from macro layer to local networks: picocells, femtocells or WiFi



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BUT

Regions and countries in the world are different

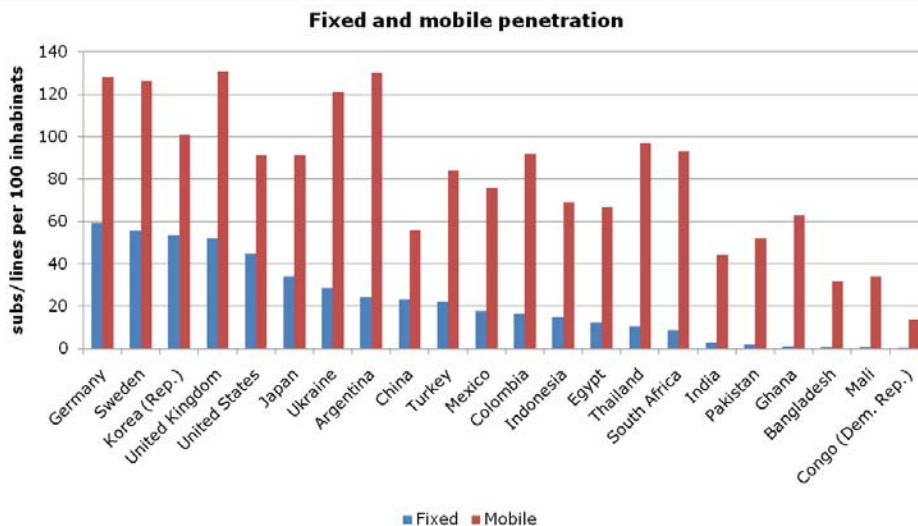
- The world it is not like a "Europe XL"
- In countries like Sweden and Germany :
 - There is a lot of fixed line infrastructure
 - Operators have "quite a lot of" spectrum
- In many countries the situations is different
 - Low level of fixed lines
 - Low amount of spectrum per operator

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Countries in the world are different

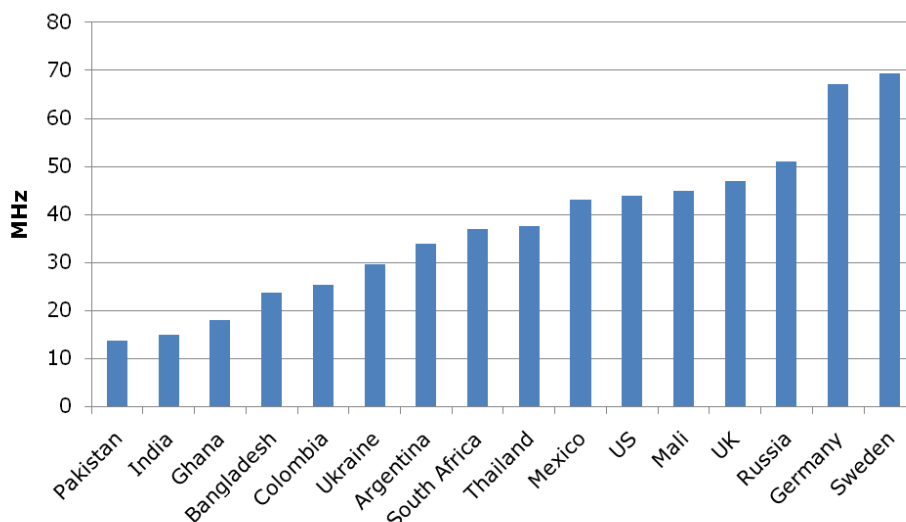


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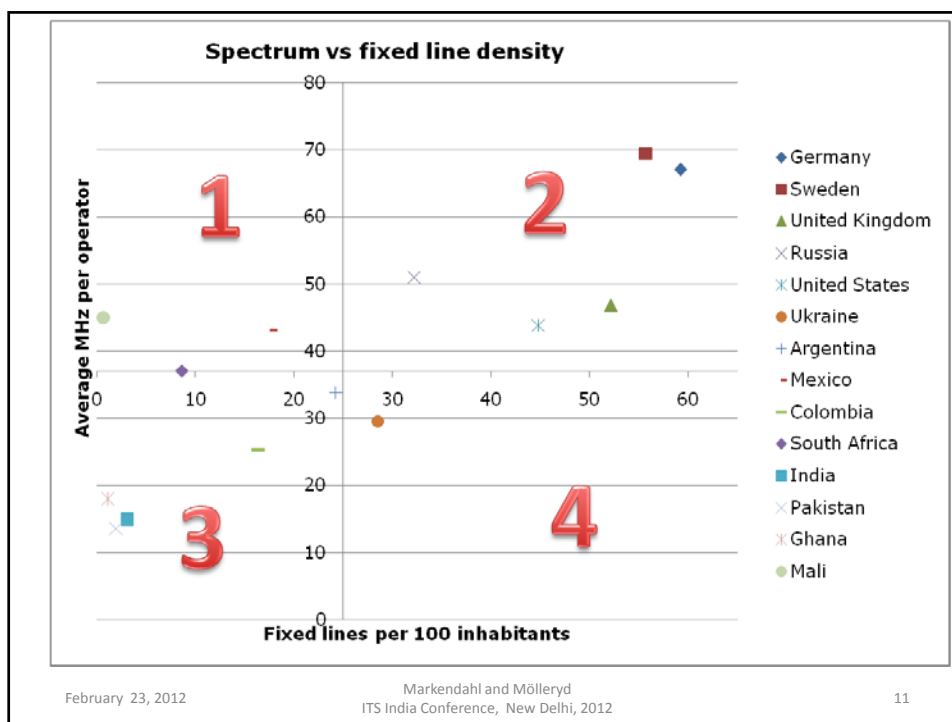
Average amount of spectrum for operators



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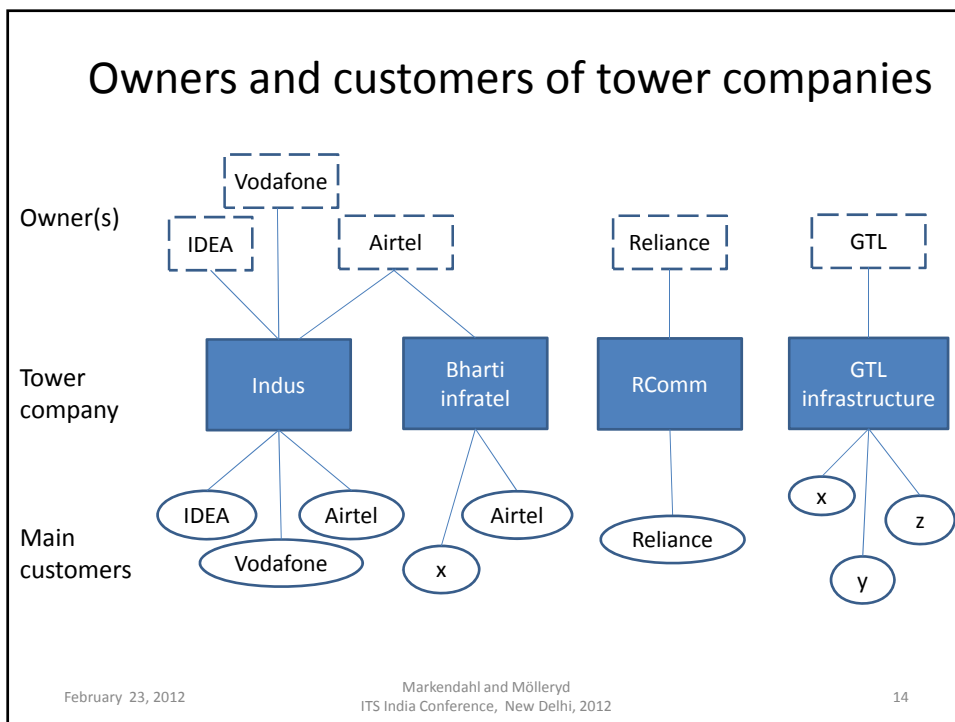
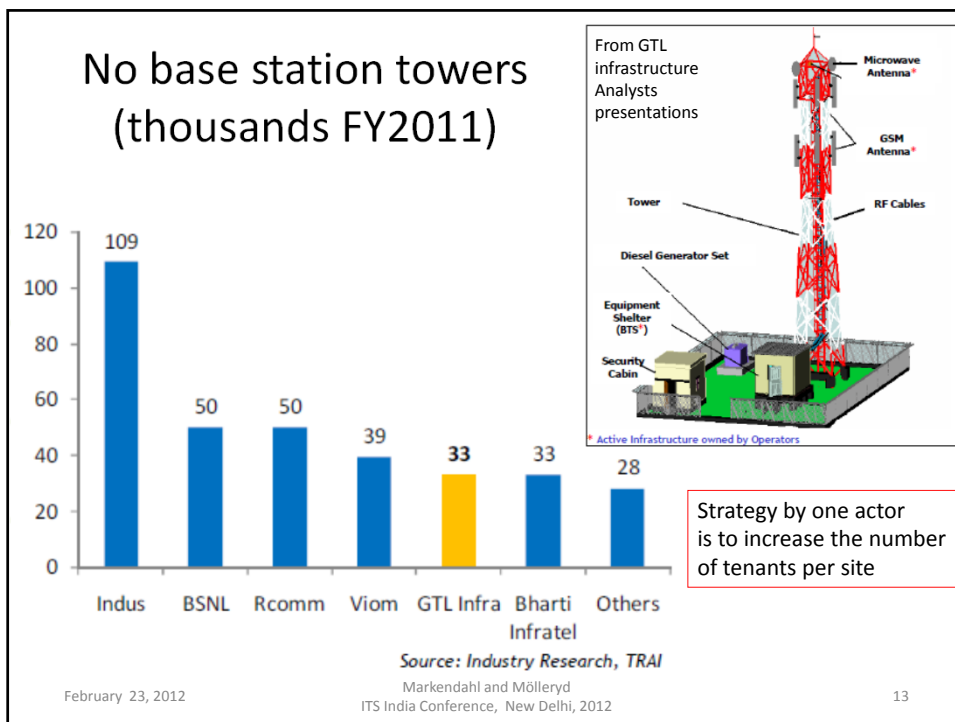
Conclusion - so far

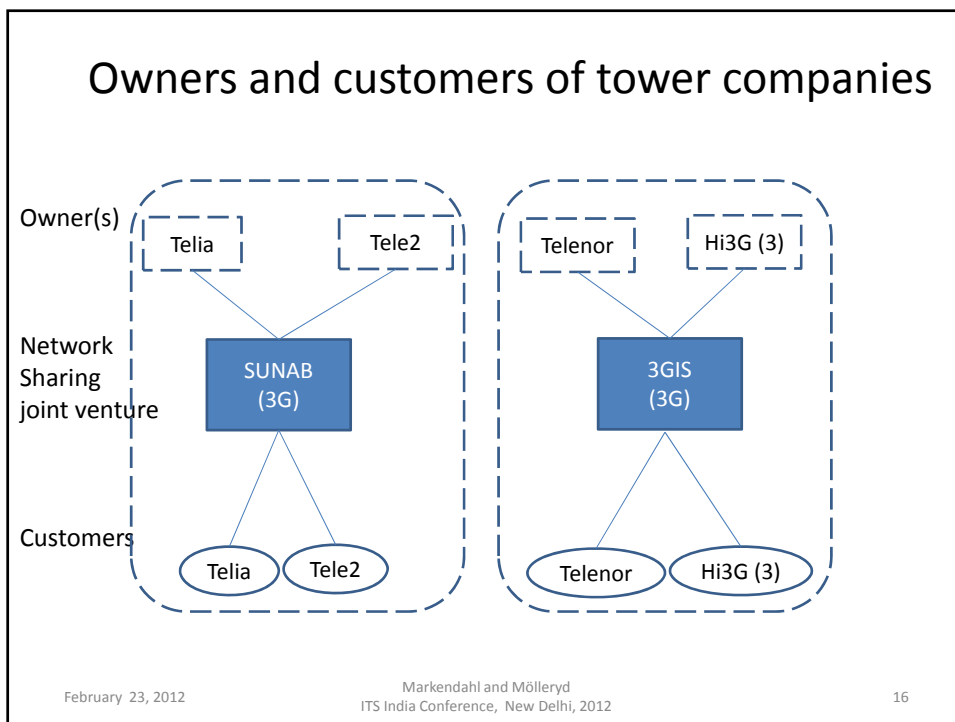
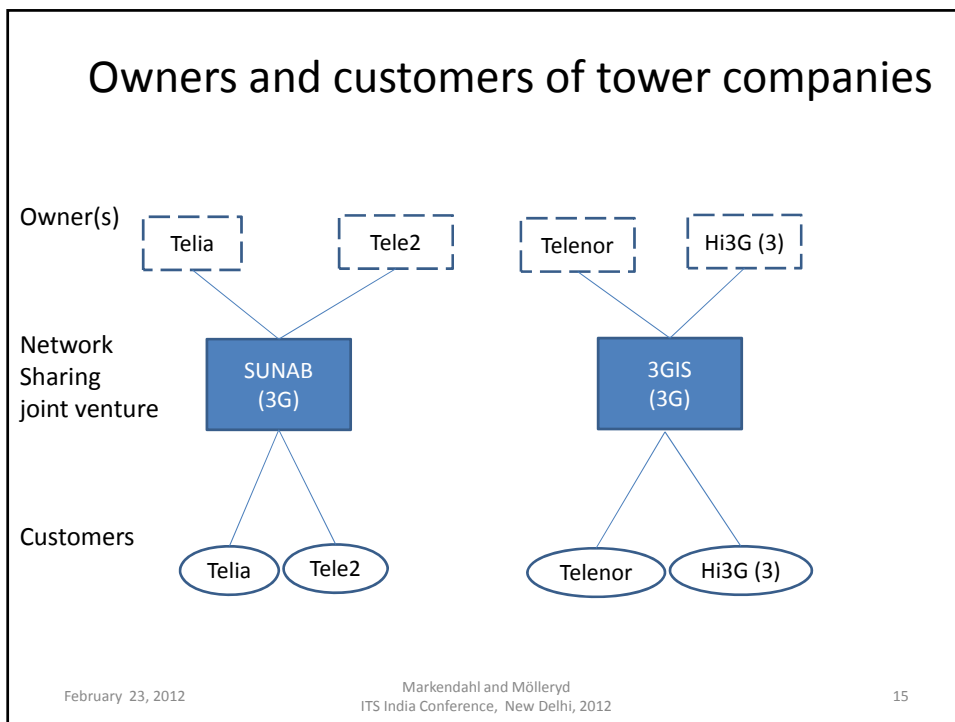
- There is a need to consider solutions that are not based on the availability of "many MHz" and fixed line infrastructure
- Examples:
 - Low cost macro BTS solutions with more sectors than three
 - Aggregation of small chunks of spectrum into medium size bands
 - Instead of combining many 10-20 MHz bands into a 100 MHz band
 - More efficient network sharing
 - Involving "more" operators and also active sharing
 - Narrowband "low capacity" femtocells where some fixed phone lines
 - Instead of using "high capacity" femtocells
 - Use secondary access of "white space" spectrum
 - As primary resource and/or as complement to licensed spectrum

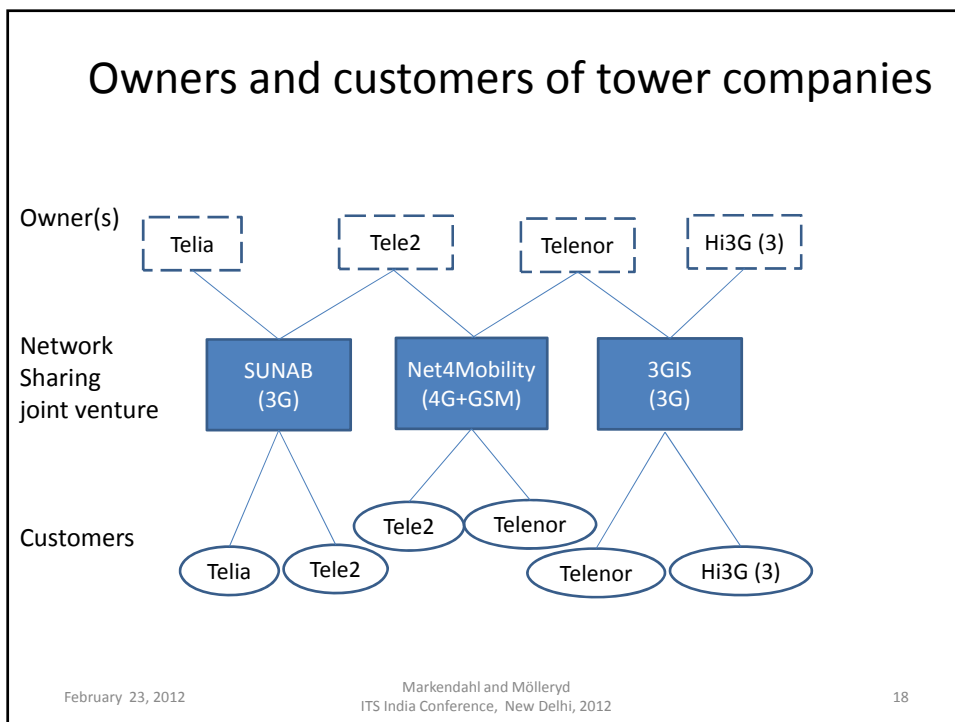
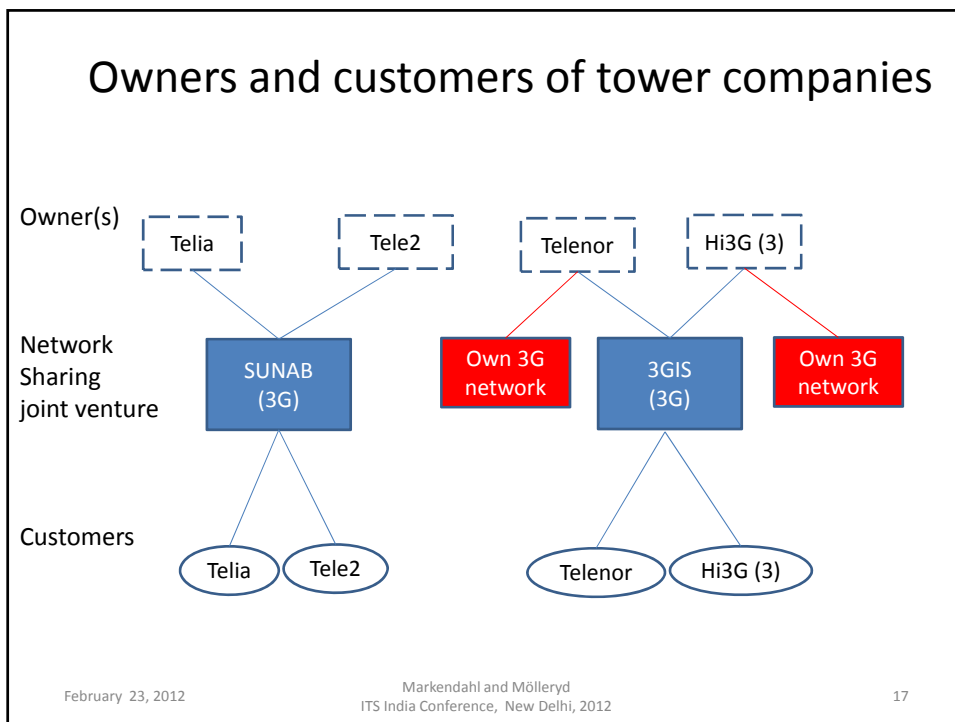
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Passive or Active network sharing?

- Sweden
 - Operators share active elements and spectrum
 - Multi-operator Core network solutions
- India
 - Passive sharing is used (sites, power, etc)
 - Active sharing is proposed for operators with 4,4 MHz
 - But spectrum fee proposal implies a "sharing cost"
- Options for LTE BTS supporting up to 20 MHz
 - Operators share sites and have own BTS using 5-10 MHz
 - Operators share BTS and combine spectrum resources
 - More cost efficient, in line with multi-operator site solutions
 - Can offer new opportunities and business models for tower companies

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To offload data traffic from the macrolayer

From Vodafone:
Investor relation
info, March 2008



- Assessing the technical potential of 3G Femtocells to:
 - improve indoor coverage
 - reduce the cost of wide area network rollout
 - reduce need for capacity in macro network
- Trials
 - lab trials successfully completed
 - field trials now underway with two vendors in Spain
- Potential benefits
 - brings dedicated 3G coverage into the home
 - offloads heavy data users from the wide area network in dense urban areas resulting in reduction in RAN capex where deployed

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“Low capacity and narrowband femtocells”

- State of the art Femtocells result in a large over-provisioning of capacity
- Femtocells using 5 MHz can offer a throughput above 40 Mbps.
- Instead use less bandwidth (~ 1 MHz) and serve less number of users

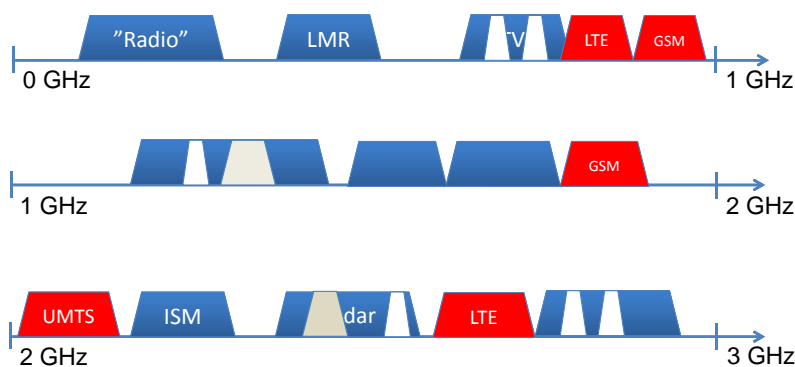
Examples of the offered capacity in terms of number of users

Data usage per person	Bandwidth 1 MHz	Bandwidth 5 MHz	Bandwidth 20 MHz
1 GB/month	100-200	500 - 1000	2000 - 4000
10 GB/month	10 - 20	50 – 100	200 - 400

Assumptions: Spectral efficiency 1-2 bps/Hz, data is consumed 8 hours/day 30 days /month
 Comments: Low bandwidth better from an interference perspective

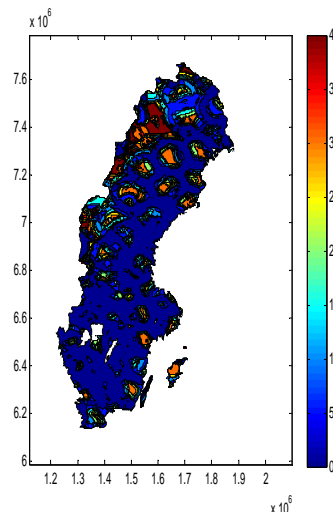
Use secondary access of “white space” spectrum

White space is a region in time and space where licensed spectrum is not used by the license holder



Number of available TV channels in Sweden

- Figure 4.14 in Quasar deliverable 5.1
- 1 TV channel ~ 8 MHz
5 TV channels ~ 40 MHz
- Compare with LTE deployment in 800 MHz and 2.6 GHz bands with bandwidth 10 – 20 MHz

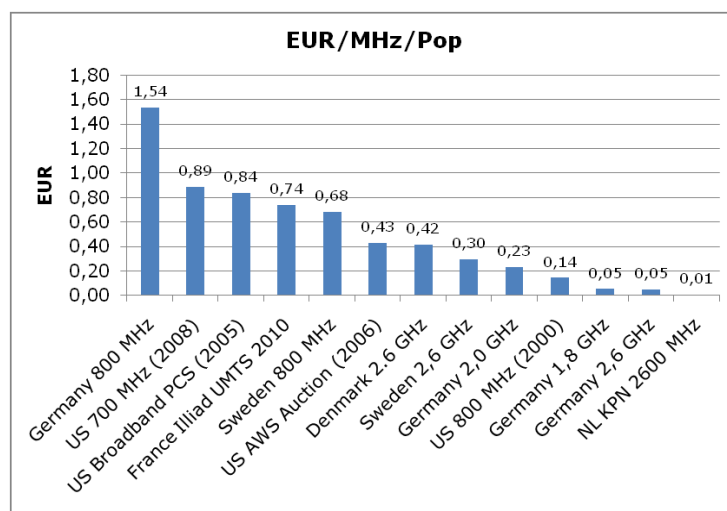


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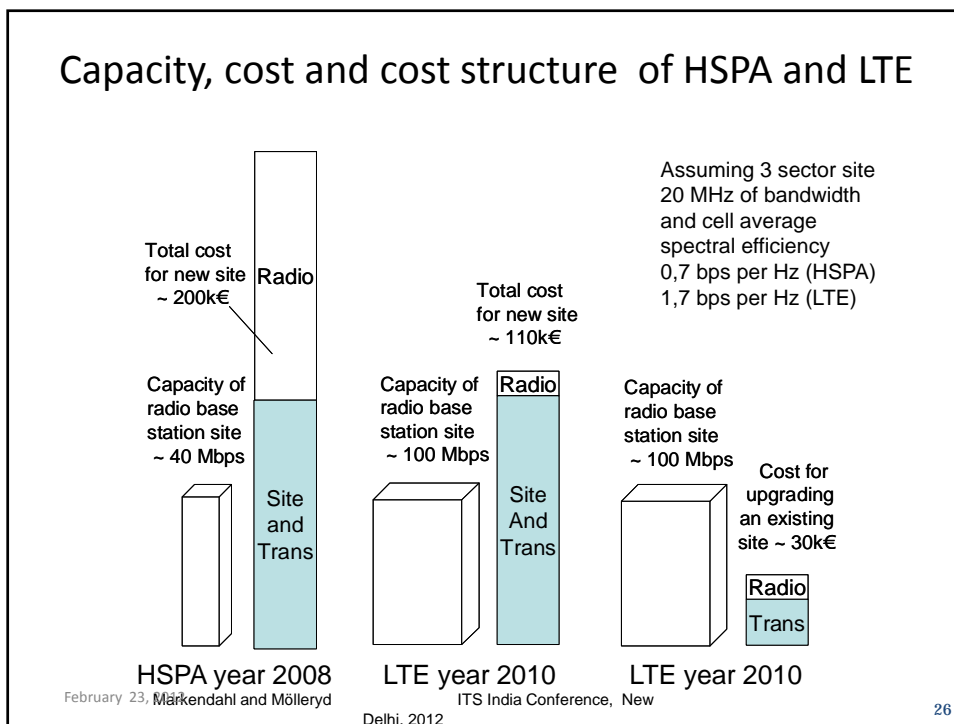
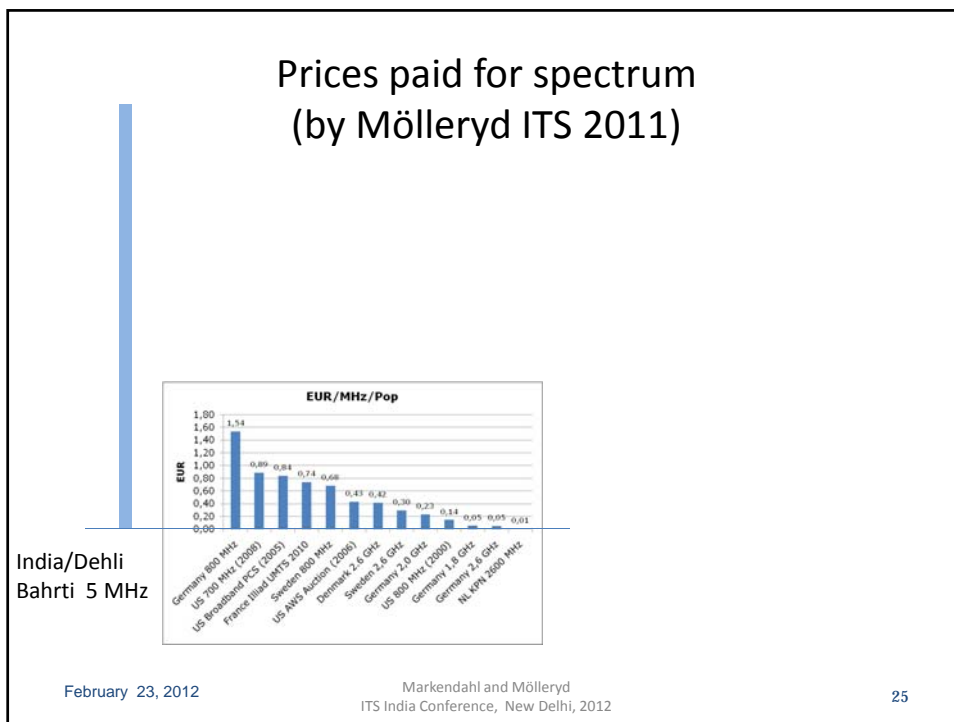
Prices paid for spectrum (by Mölleryd ITS 2011)

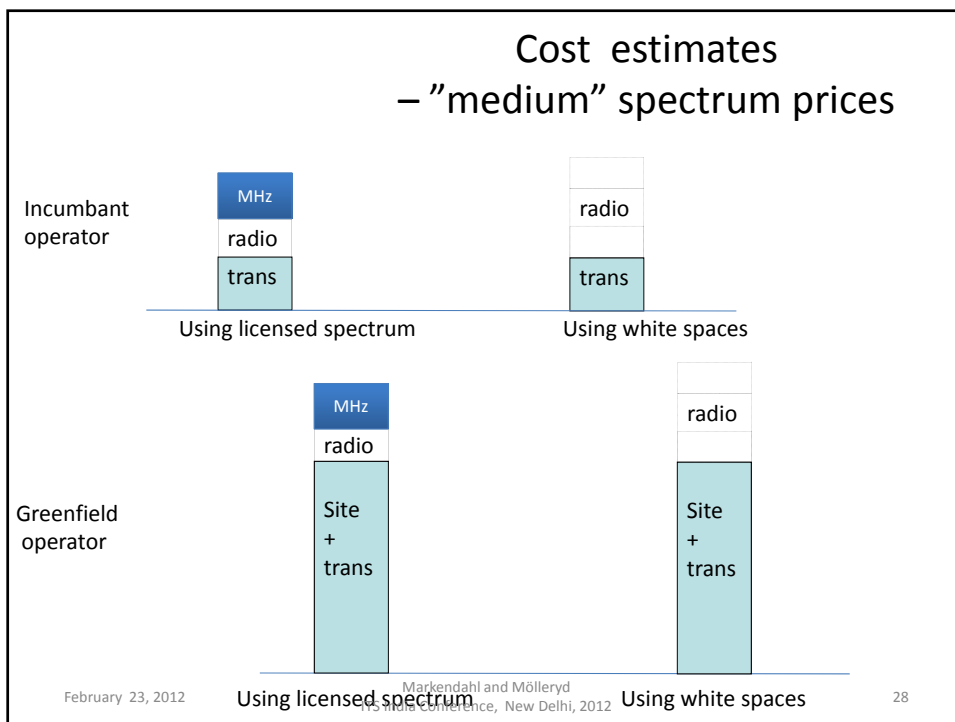
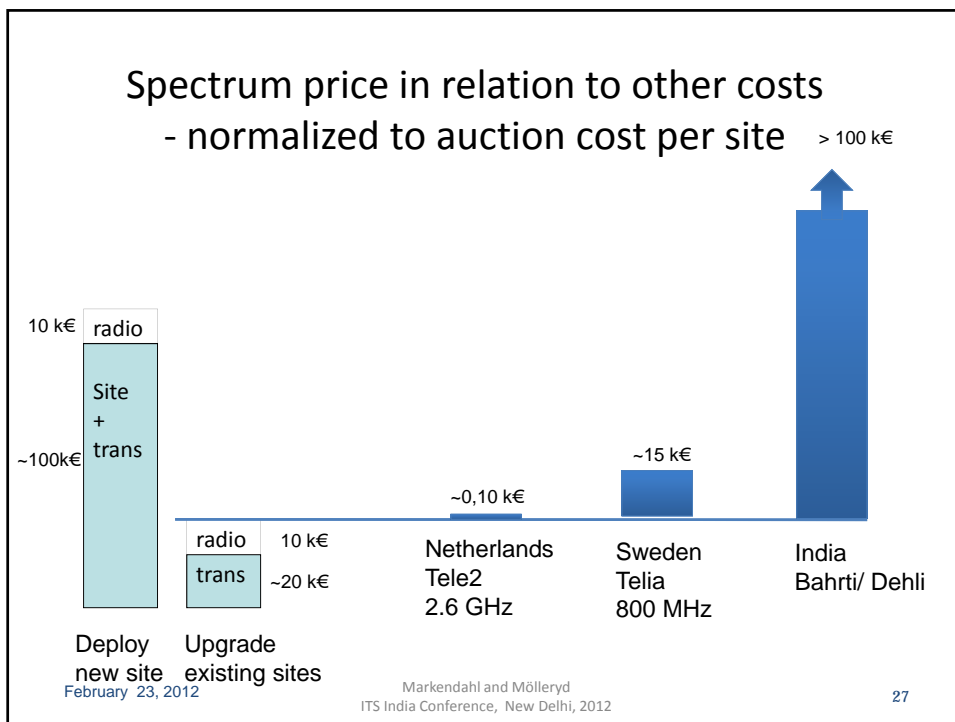


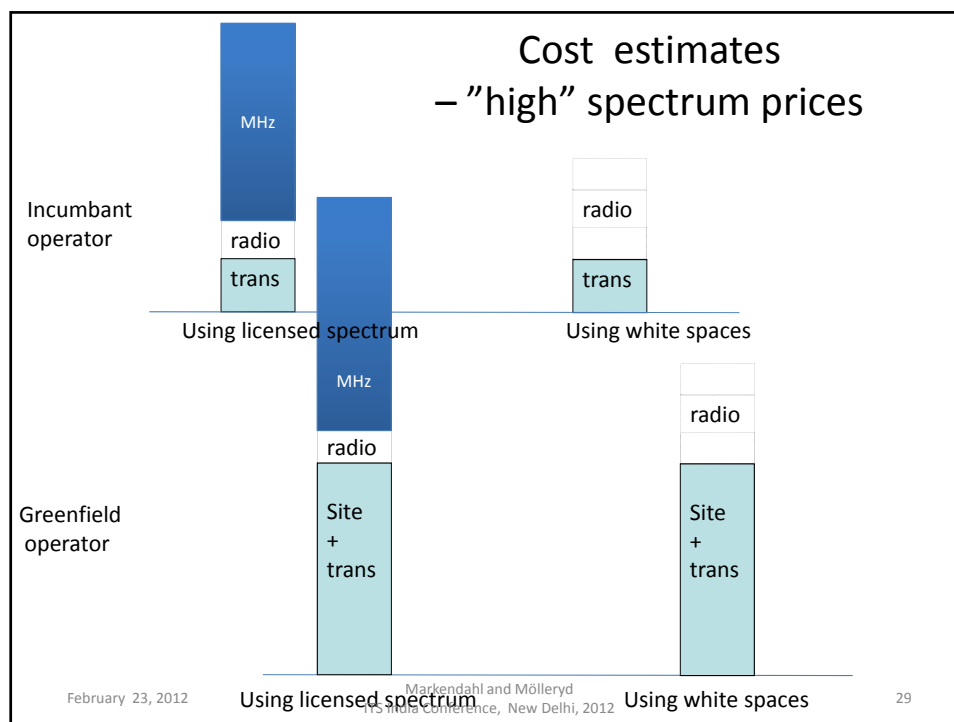
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To conclude

- Sweden
 - All operators are in a (very) good position
 - There is a high density of existing sites (that can be re-used)
 - 50 – 60 MHz per operator is available for mobile broadband
- India
 - Some operators have 5 MHz of 3G spectrum
 - Currently difficult to enable large scale mobile broadband services without deployment of (many) new sites
 - Allocation of 700 MHz spectrum + National optical fiber initiative + more efficient site sharing are promising
- About R&D and standardization
 - The focus on high peak rates, aggregation and offloading is useful only for some regions of the world

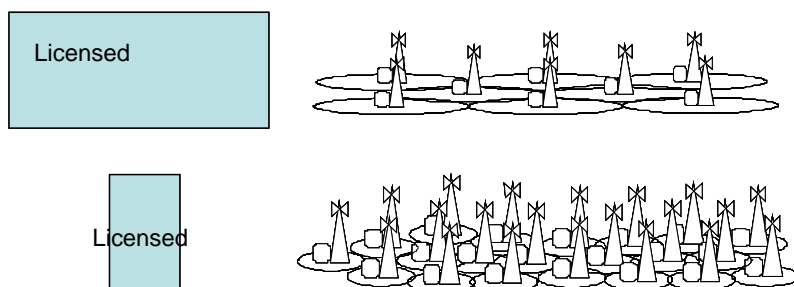
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Amount of spectrum, capacity and cost

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



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Thank you

- There is a need to consider solutions that are not based on the availability of "many MHz" and fixed line infrastructure

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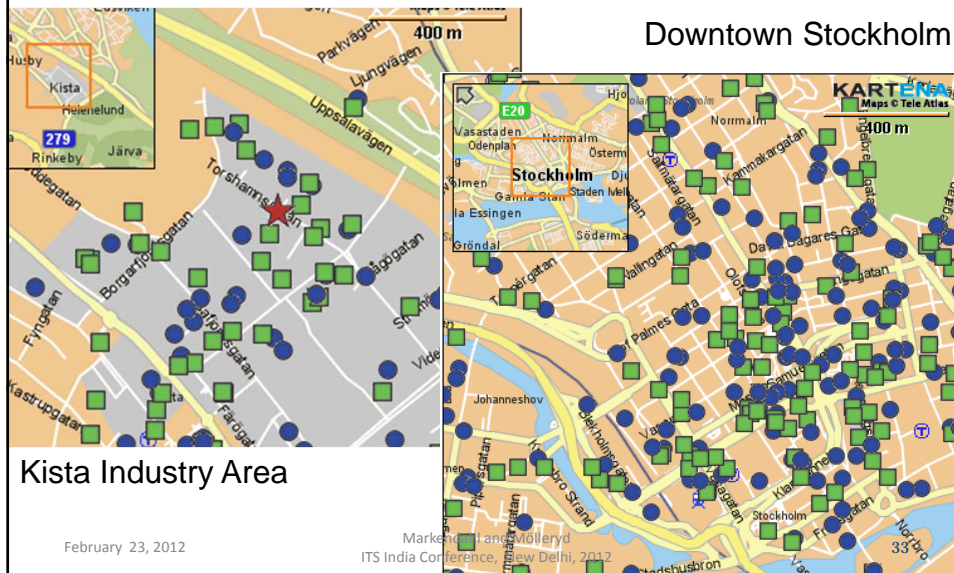
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Base station site locations in urban areas

from PTS "Transmitter map" web page.

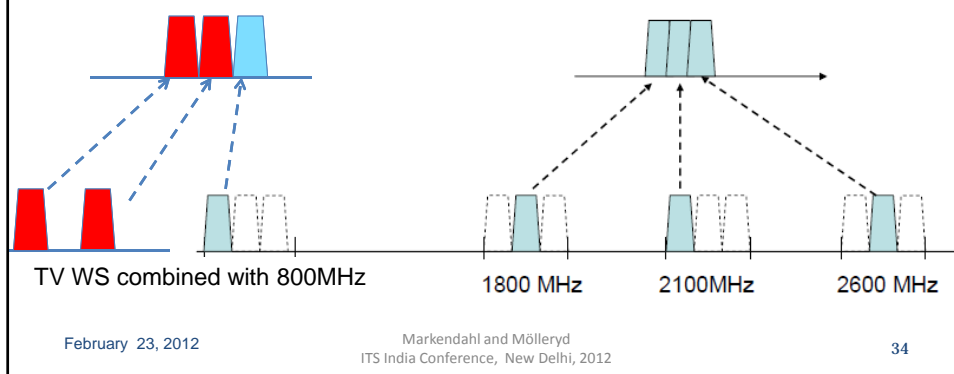
Downtown Stockholm



Data rate, bandwidth and aggregation of carriers or bands

- The higher bandwidth the higher

Higher bandwidth by use of aggregation



“low capacity and narrowband femtocells”

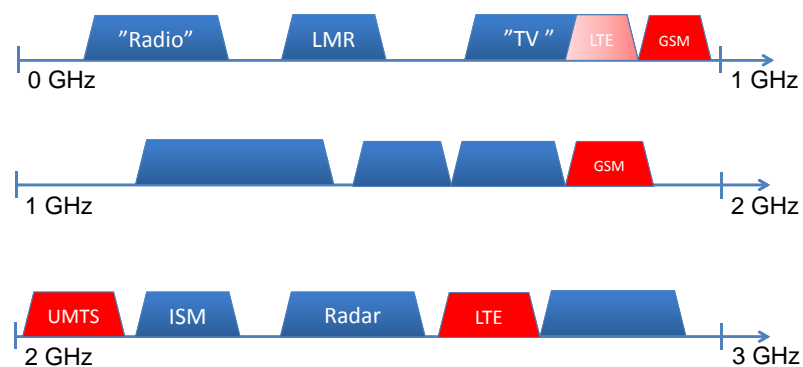
- Femtocells concepts presented so far result in a substantial over-provisioning of capacity.
 - State of the art femtocells (5 MHz) can offer a throughput above 40 Mbps.
 - This corresponds to very large number of data users.
 - With 5 MHz of bandwidth and an assumed spectral efficiency of 4 bps per Hz we get a capacity of 20 Mbps.
 - This corresponds to 200 or 2000 users with a monthly usage of 10 GB and 1 GB respectively.
- Instead use less bandwidth (1 MHz or below) and serve less number of users 20 - 40 is perfectly OK

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Generic spectrum allocation in Sweden



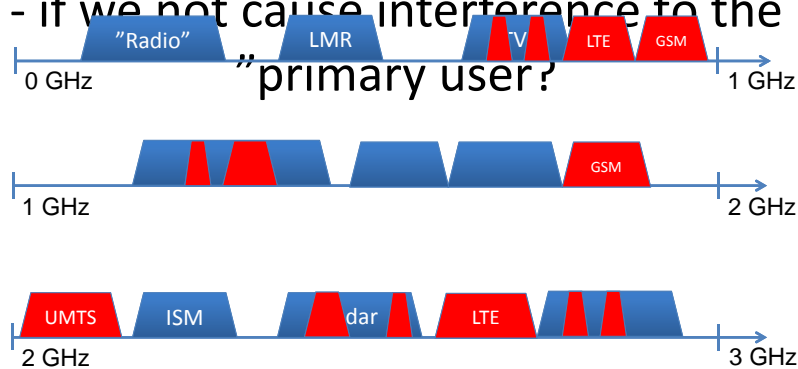
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What about allocated spectrum that is not used?

Can we use it for other purposes - if we not cause interference to the "primary user?"

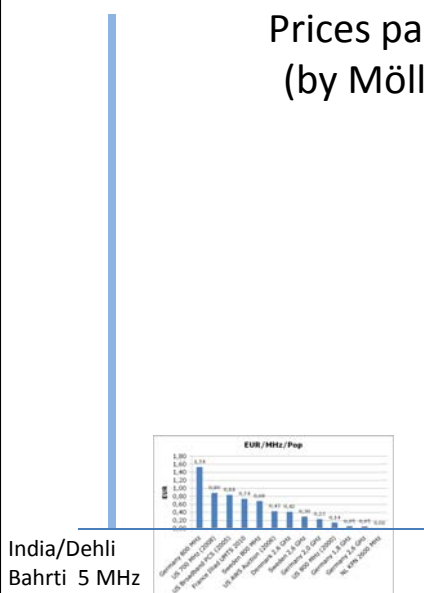


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Prices paid for spectrum
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