

# Is there enough Spectrum for Future Wireless Access ?

**Jens Zander**

Scientific Director, Wireless@KTH  
KTH – The Royal Institute of Technology,  
Stockholm, Sweden



# Some key trends in Wireless Systems

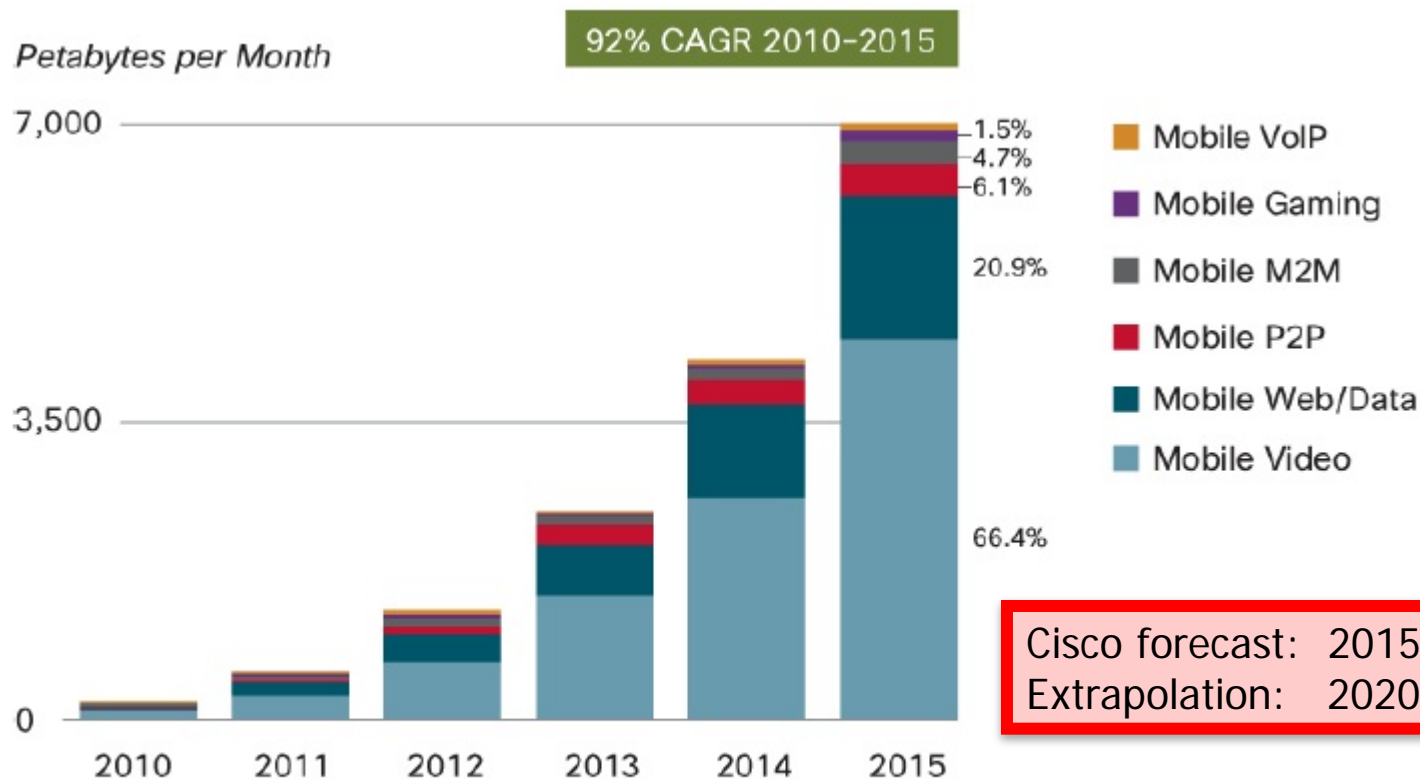
# Dominant designs



- No "killer apps" or "one trick ponies"
- **Internet access** + Cloud based solutions =  
The dominant design for ALL services (fixed & mobile)
- Marginalizes other technical solutions – e.g. Wireless P2P, Mesh, ..



# Mobile Data avalanche



Cisco forecast: 2015 – 26x  
Extrapolation: 2020 – 1000x

VoIP traffic forecasted to be 0.4% of all mobile data traffic in 2015.

Source: Cisco VNI Mobile, 2011

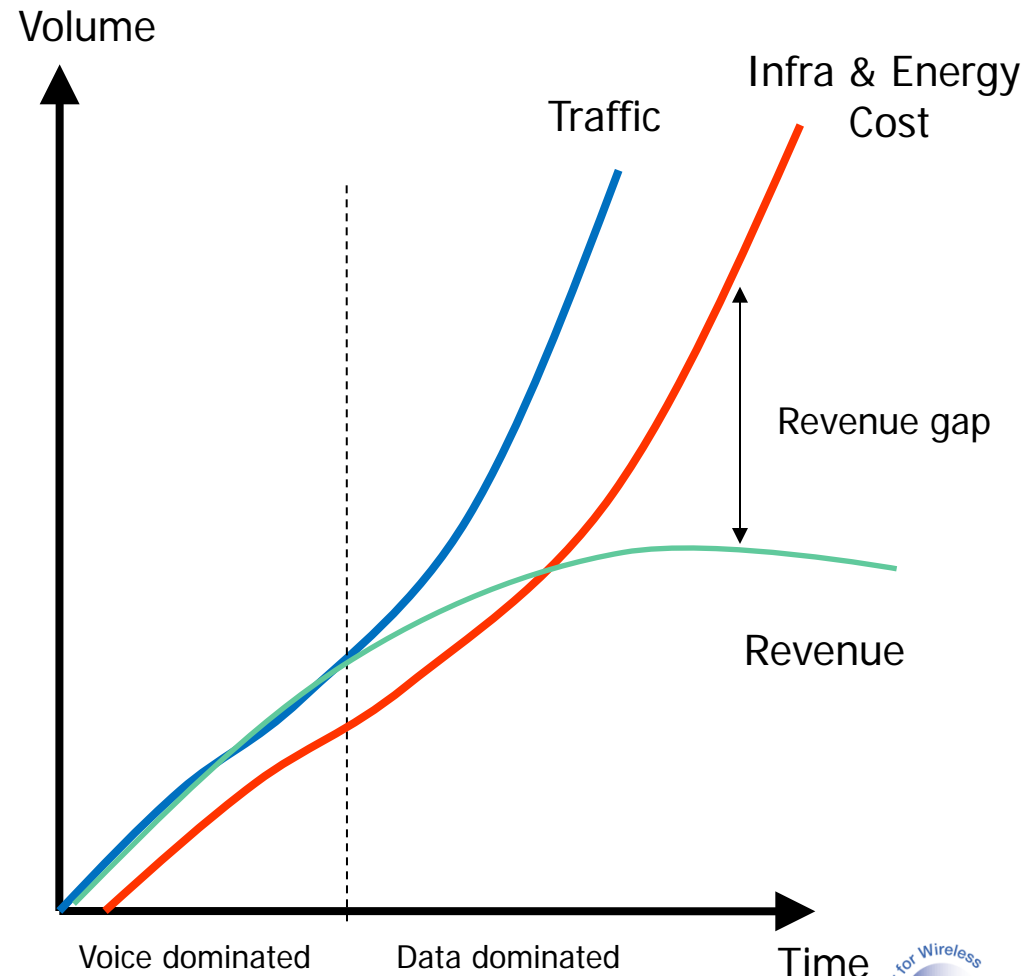
Exponential growth  
Assumes zero marginal cost for access  
How long can this be sustained ?

Wireless@KTH

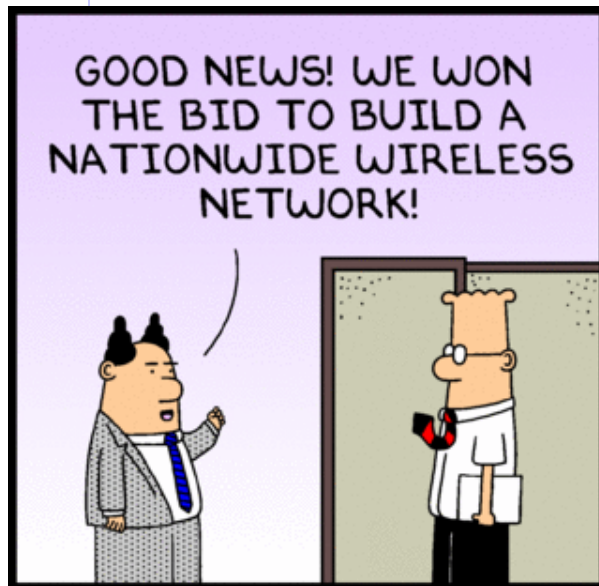


# Operator dilemma: More for less money

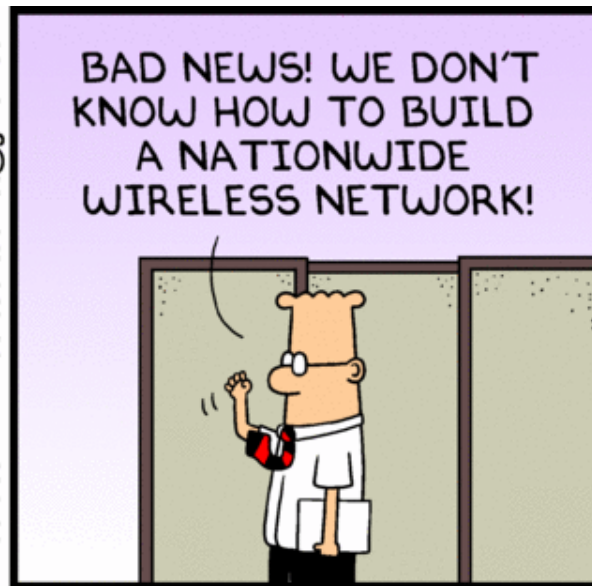
- Spending capability of user increases with GNP growth (<10% annually)
- Capacity requirements increase by 100% annually



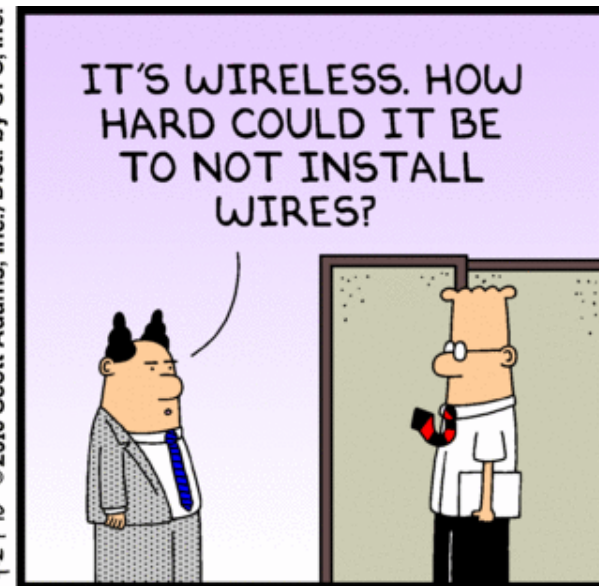
# How difficult can it be ?



Dilbert.com DilbertCartoonist@gmail.com



4-24-10 © 2010 Scott Adams, Inc./Dist. by UFS, Inc.



# Candidate Approaches



- Improved Spectral Efficiency (Moore's Law)
  - PHY-layer (Modulation, MIMO)
  - Interference Management (COMP/ICIC)
- Denser infrastructure
- More Spectrum

# In search for 5 G 1000 times more capacity ..but how ?

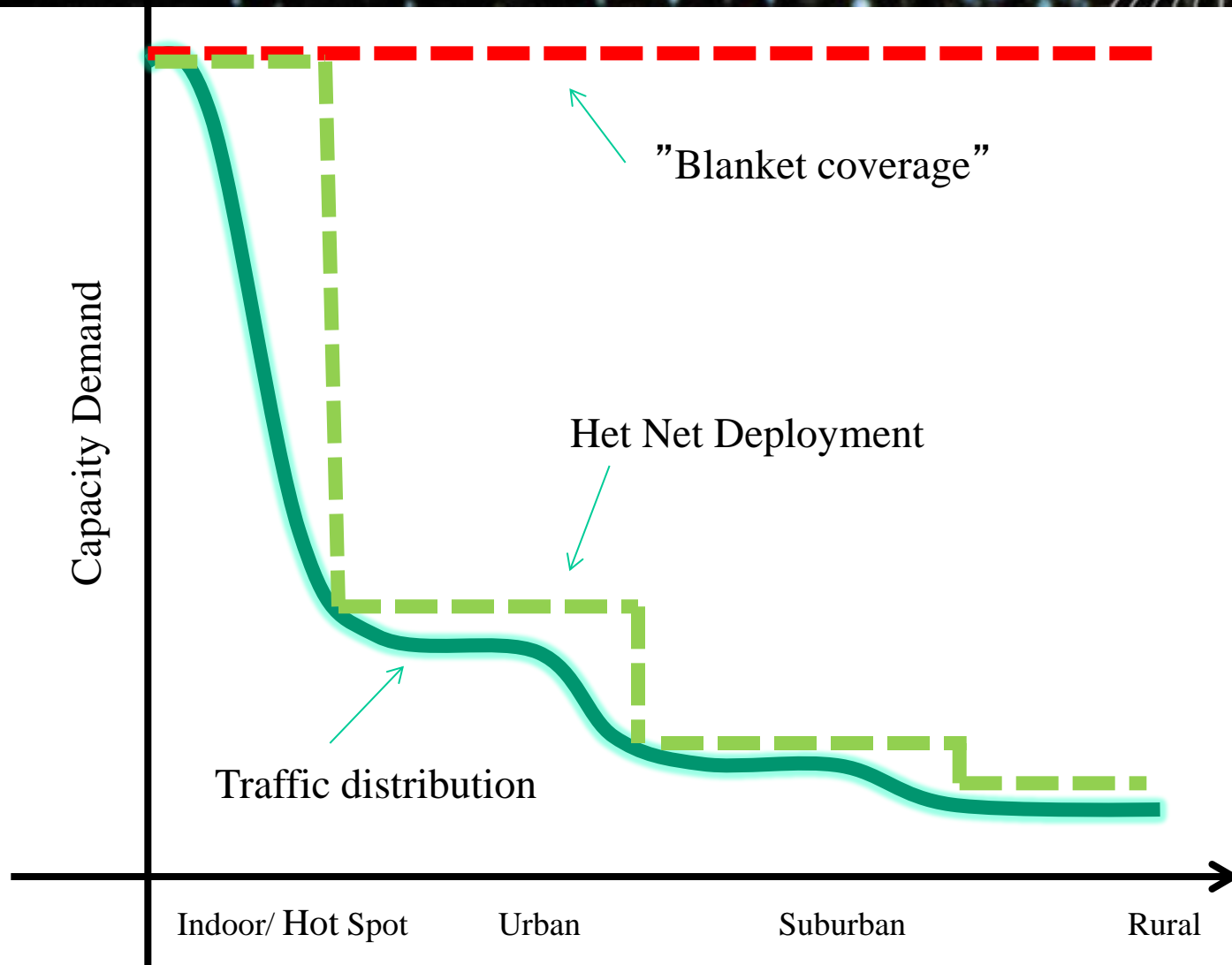
What does the “market” think ?

Company	Spectrum	Spectral efficiency	Densification	Total capacity increase
Nokia Siemens	10X	10X	10X	1000
Huawei	3X	3.3X	10X	100
NTT DoCoMo	2.8X	24X	15X	1000
Our suggestion	3X	5X	66X	1000



# How to lower the cost

## "HET NET"s – deploy according to demand



# HET NETs - The Light Analogy -



- Outdoor – Wide Area

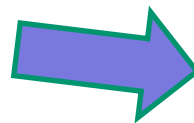
- Indoor – Short Range



# Densification: Technology shift



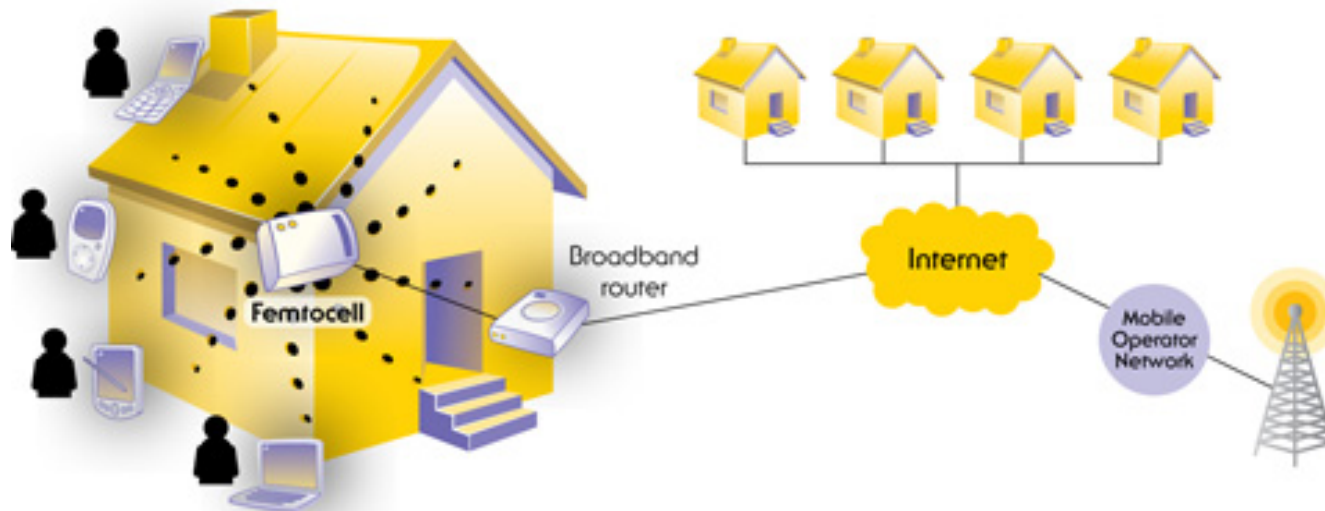
- Industry grade eq
- High power
- 24-7 availability
- High **system** complexity



- Consumer grade eq
- Low power/Short range
- Low **system** complexity (P&P, SON)
- Massive deployment – mainly indoor
- Reliability through redundancy
- Deploy where backhaul available



# Sharing infrastructure: A new ways to low-cost capacity



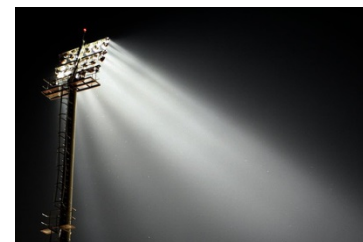
- Technology: Not an issue !
- Business model: Cooperation !
- Key vendor issue: "Herbal medicin" of Wireless
  - Low complexity, Low cost... where is the profit ?
- Key operator fallacy:
  - With "flat rate", why not hand-off my customers for free ?
  - Operator "owns" customer and gets paid anyway
  - Customers pay for availabilty – not for Mbytes



# In summary ...

## Characteristics of future (high volume) wireless systems (=system for which low cost end-user equipment)

- Provide IP Access – not services
- Wide-area infrastructure
  - Provides coverage
  - Cost dominated by physical infrastructure, energy, backhaul
  - Long time-horizon investment in radio equipment
- Short range infrastructure
  - Provides high capacity
  - Cost dominated by fixed backhaul ( long-term investment independent of wireless system)
  - Short time-horizon investment in radio equipment



# Is Spectrum availability a problem ?

# Spectrum shortage ?

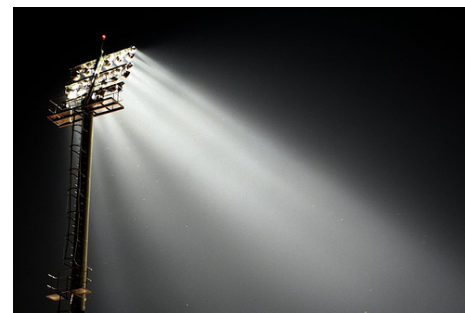
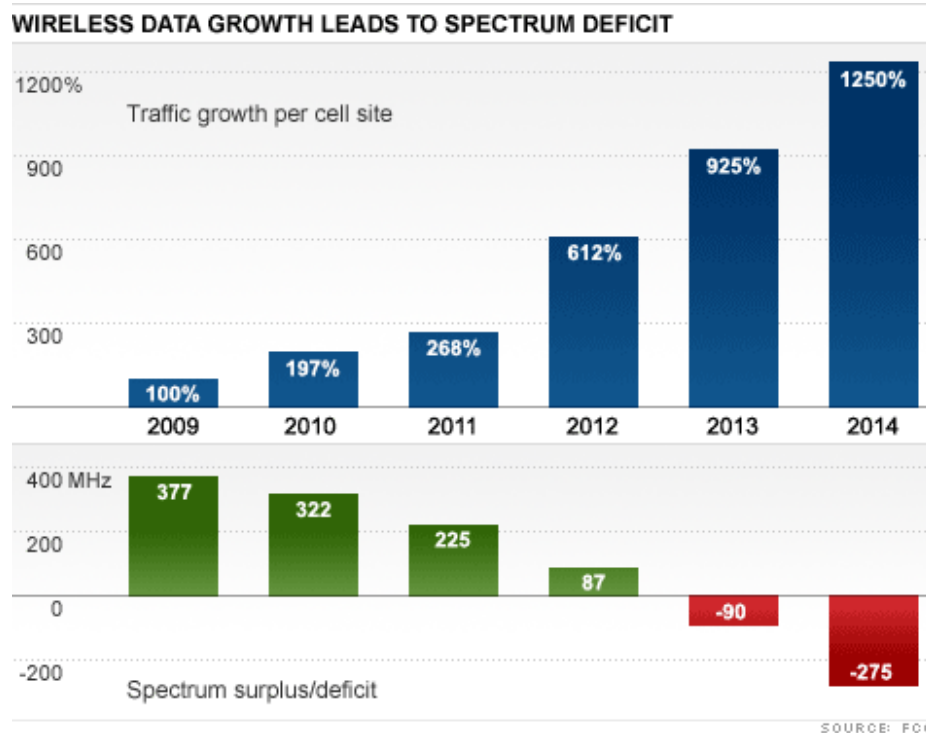


- Spectrum availability (fundamental)
  - Long-term, fundamental – time-scale: Decades
  - Regulatory/planning process, licensing
  - Important for large scale, long-term infrastructure deployment
- Spectrum access (business, policy)
  - Short-term, "Can I get access for my product now ?"
  - Issue: "Temporary" under-utilization of spectrum
  - Important for innovation, products with short life cycle
- Efficiency
  - Is the spectrum efficiently used ?
  - Are we achieving specific (political) targets?  
(Innovation, Competition, USO..)

# Is there a "spectrum deficit" ?

Yes:

- in high density areas
- for the "business as usual" paradigm





# The cost of spectrum

$$R_{tot} \approx \frac{C_{sys}}{c_{BS} A} \eta W_{sys} = \frac{\eta}{A} N_{BS} W_{sys}$$

$$R_{tot} + \Delta R \approx \frac{\eta}{A} N_{BS} W_{sys} + \frac{\eta}{A} \Delta N W_{sys} + \frac{\eta}{A} N_{BS} \Delta W$$

More base stations

More spectrum

$$C_{sys} + \Delta C \approx C_{sys} + c_{BS} \Delta N + \Delta c_{BS} N_{BS} + c_{sp} \Delta W$$

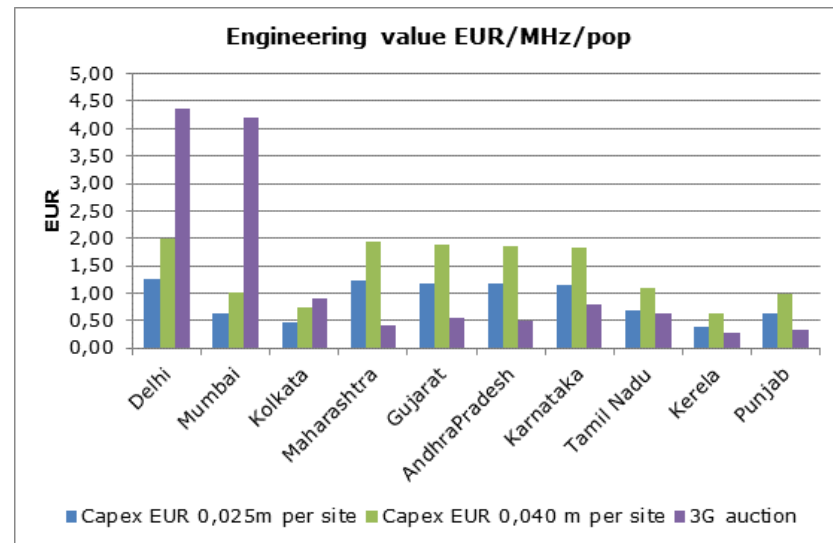
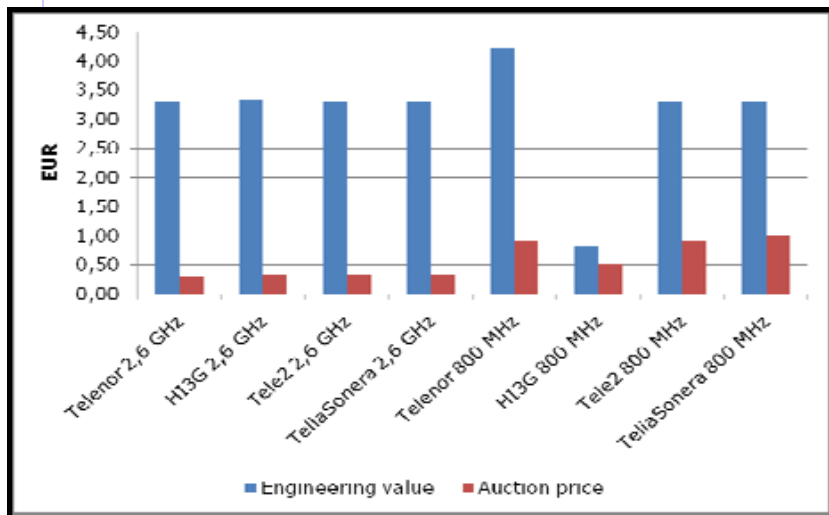
Spectrum Upgrade cost

$$\min \Delta C = \min \left( c_{BS} \frac{\Delta R}{\eta W_{SYS}} A, \Delta c_{BS} N_{BS} + c_{sp} \frac{\Delta R}{\eta N_{BS}} A \right)$$

$$c_{sp}^* = \left( \frac{c_{BS}}{W_{SYS}} - \Delta c_{BS} N_{BS} \right) N_{BS}$$

Engineering value of spectrum

# Is mobile spectrum still "cheap"?



Source: B G Mölleryd and J Markendahl

Valuation of spectrum for mobile broadband services - The case of Sweden and India

ITS Regional Conference, New Dehli, Feb 2012

Wireless@KTH

# Buzzword Bingo

<b>Dynamic Spectrum Access</b>	<b>Cooperative Sensing</b>	<b>Cognitive Pilot Channel</b>
<b>Geolocation Database</b>	<b>Spectrum Opportunities</b>	<b>Secondary Spectrum Access</b>
<b>Software Defined Radio</b>	<b>Cognitive Radio</b>	<b>Flexible spectrum access</b>
<b>White Space</b>	<b>Radio Enviroment Maps</b>	<b>Spectrum Holes</b>

# Spectrum options



	Exclusive <6 GHz	Shared < 6 GHz	Secondary <6 GHz	Exclusive > 10 GHz
Availability	Very Low	Moderate	Good (>1 GHz) for <u>indoor use</u>	Very good
Advantages	<ul style="list-style-type: none"> <li>Guaranteed QoS</li> <li>Long-term investments</li> </ul>	<ul style="list-style-type: none"> <li>Spectrum available</li> <li>Low cost equipment/deployment</li> </ul>	<ul style="list-style-type: none"> <li>Spectrum available</li> <li>Low cost equipment/deployment</li> </ul>	Very high capacity Low interference
Disadvantages	High deployment cost	<ul style="list-style-type: none"> <li>No QoS guarantees</li> <li>Low availability</li> </ul>	<ul style="list-style-type: none"> <li>Limited QoS guarantees</li> <li>Regulatory uncertainty</li> </ul>	LOS propagation, Dedicated Deployment

Plenty of spectrum for short range indoor  
- in total close to 1 GHz for wireless access



# Not all bands are equal - limitations to spectrum use

- New "distant" frequency band
  - Requires new hardware(technology)  
"Yet another radio" in base stations, terminals etc
- Unsuitable propagation conditions
  - Too short(coverage), too long range (interference)
- Access limitations
  - Sharing with other users (Secondary spectrum)
- Wide band radios & antennas
  - Efficiency loss outweighs spectrum access benefit ?

# Is "Cognitive Radio" going to make a difference ?



Some findings of the FP7 QUASAR Project:

- Plenty of spectrum available for secondary use– but **very scenario, time & location** specific, which limits the commercial value
- "Cognitive" sensing **not very effective** in many popular scenarios – geolocation based techniques preferable
- Rural/Wide-area applications possible but spectrum is not the fundamental bottleneck - infrastructure deployment is
- The "Commercial Sweetspot" of secondary spectrum
  - **Short range/indoor high capacity systems** =where large demand for and technical availability of spectrum meet

# Where are we(should we be) heading?

## Wide area access

- Licensed spectrum to match long-term RF-specific investments (<3 GHz)
- Repurposing of UHF from TV -> IP access
  - Digital dividends 800, 700, 600 MHz etc

## Short range access

- Higher frequencies (>3 GHz) for high capacity (lower interference)
- Local & temporal spectrum regimes (National Block-licensing inefficient)
- Unlicensed, Secondary, LSA, "Instant licensing"

# Research Challenges



- Self-organizing networks
  - Wireless access will be seen as a commodity (like electricity, heating..), we need to deploy it that way
- Centralized/Distributed resource management
  - Needs to work across network and business boundaries over existing fixed backhaul
  - Virtualized service ?
- Ultra-dense networks
  - Interference management

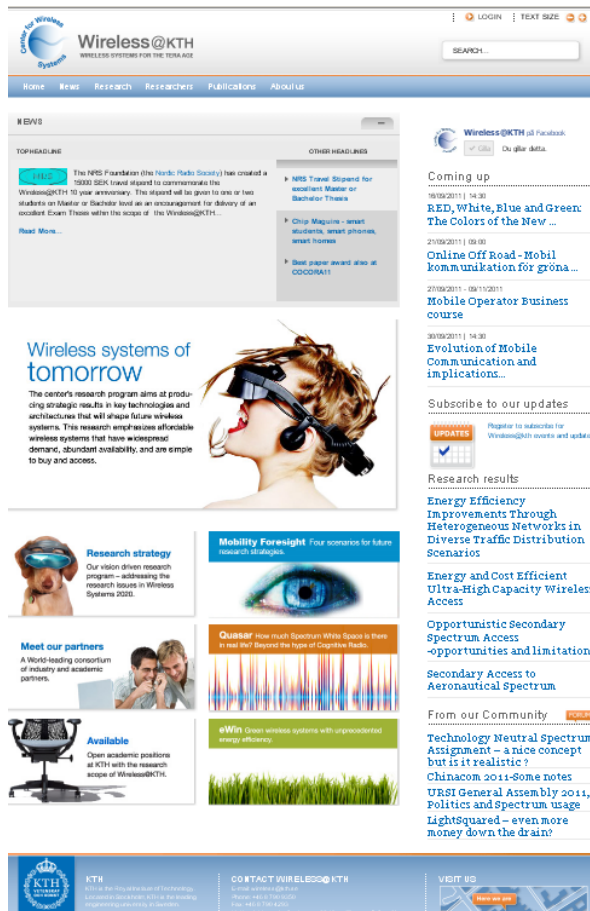
# Some conclusions

- Wireless Cloud Access – the dominant design of future services
- Designs for dense, high capacity infrastructure will dominate market place (  $> 3$  GHz) and widen gap to rural solutions that struggle with performance and profitability
- Spectrum not really a fundamental limiting factor
  - when properly managed
  - Mobile/fixed internet access replaces other dedicated services



# Read more & Interact !

wireless.kth.se



**Wireless@KTH**  
WIRELESS SYSTEMS FOR THE FUTURE

Home News Research Researchers Publications About us

**NEWS**

**TOP HEADLINE**

The NPS Foundation (the Nordic Parks Society) has created a 1000 SEK fund award to commemorate the Wireless@KTH 10 year anniversary. The award will be given to one or two students on Master or Bachelor level as an encouragement for delivery of an excellent Exam Thesis within the scope of the Wireless@KTH.

**OTHER HEADLINES**

- NPS Travel Stipend for excellent Master or Bachelor Theses
- Chip Magazine - smart students, smart phones, smart homes
- Best paper award also at COORDINATE

**Coming up**

20/09/2011 14:30  
**RED, White, Blue and Green: The Colors of the New ...**

20/09/2011 09:40  
**Online Off Road-Mobil Kommunikation for grönä...**

20/09/2011 09:11/2011  
**Mobile Operator Business course**

20/09/2011 14:30  
**Evolution of Mobile Communication and implications...**

**Subscribe to our updates**

Register to subscribe for Wireless@KTH events and updates.

**Research results**

**Energy Efficiency Improvements Through Heterogeneous Networks in Diverse Traffic Distribution Scenarios**

**Energy and Cost Efficient Ultra-High Capacity Wireless Access**

**Opportunistic Secondary Spectrum Access - opportunities and limitations**

**Secondary Access to Aeronautical Spectrum**

**From our Community**

**Technology Neutral Spectrum Assignment - a nice concept but is it realistic?**

**Chinacom 2011-Some notes**

**URSI General Assembly 2011, Politics and Spectrum usage**

**LightSquared - even more money down the drain?**

**Research strategy**  
Our vision driven research program - addressing the research issues in Wireless Systems 2020.

**Meet our partners**  
A World-leading consortium of industry and academic partners.

**Available**  
Open academic positions at KTH with the research scope of Wireless@KTH.

**Mobility Foresight** Four scenarios for future research strategies.

**Quaser** How much Spectrum White Space is there in real life? Beyond the hype of Cognitive Radio.

**eWin** Green wireless systems with unprecedented energy efficiency.

**KTH**  
KTH is the Swedish Institute of Technology, established 1829. It is the leading engineering university in Sweden.

**CONTACT WIRELESS@KTH**  
L. Eriksson, l.rik@kth.se  
P. Nilsson, p.ni@kth.se  
Tel: +46 8 790 6000  
Fax: +46 8 790 6000  
Web: wireless.kth.se

**VISIT US**  
Have an open house

theunwiredpeople.com



**theunwiredpeople.com**

Home Events About us Join us

**LET'S TALK WIRELESS**

**Recent Posts**

- Technology Neutral Spectrum Assignment - a nice concept but is it realistic?
- Chinacom 2011-Some notes
- URSI General Assembly 2011, Politics and Spectrum usage
- LightSquared - even more money down the drain?
- "Big Brother" says streaming more than 10 times is illegal

**Categories**

- Business
- Conferences
- Devices and Gadgets
- Education
- Green radio
- Job openings
- Security
- Spectrum
- Systems
- Uncategorized

**Comments**

**PEOPLE RECENT POPULAR**

**Recent Comments**

jander Absolutely, I think this is one of the problematic areas for secondary spectrum use ("cognitive radio") in densely populated areas. There is plenty of spectrum in many places on paper, but when you...

Syed Farhad Yunus H, If I am not wrong, Spectrum Sensing Cognitive Radio also work almost on the same spectrum neutral principles isn't it? Do you think their usage will also be limited by

**Technology Neutral Spectrum Assignment - a nice concept but is it realistic ?**

Posted on September 9, 2011 by Jari St. Zander

**Recommender** **Bi** den första bland dina vänner att rekommendera detta.

We learn from Economics theory that if you want to trade goods effectively, these shall be as general as possible, usable by anyone on preferably for many purposes. In this way we attract a large crowd of willing buyers and the market becomes an effective instrument to share these goods. However, if the goods are very specific (like left lady's high-heels shoes in pink, size 49) the demand is very limited and few buyers will show up to facilitate effective trading.

This exactly the concept behind technology neutral spectrum licensing .. instead of prescribing in detail when, where and how to use the spectrum, the new policy (e.g. "WAVECS") is to provide a "block edge mask", restricting what emission are allowed outside the allocated band. Any system conformant with these rules will be allowed and the market for licenses is now large.

What's the catch ? Well, its what in the business is called "Legacy Equipment", i.e. anything that is out there before these new regulations are put into place. We have already numerous examples of interference problems. Air-port radars, GSM-R (railway) systems, TV-receivers are facing interference from new LTE/UMTS systems that are put into operation in neighboring bands. Is something wrong with these systems ? No. Are they violating the spectrum mask rules ? Not likely. Would the problems go away with perfect new equipment? Unfortunately not.

You see, most of this equipments was not designed to have a LTE or UMTS base station next door. The were designed with the implicit assumption that the neighboring band was empty or used in a very specific way. In this way receiver designers could cut some corners and save a few bucks in production cost. So it's clear where to put the blame. But will the airport-radar uses, the television set manufacturers or railways modify their systems ? Not likely. There seems to be "squatters rights" in the spectrum domain - the guys that where there first (and have significant investments made) are protected and the new users have to modify their equipment, restrict their use or even pay for the modification of legacy equipment. In Sweden a recent study show that using UMTS in the 900 MHz band is OK as long as you stay a kilometer away from the nearest railroad (i.e. where the highest population density are likely to be). If a different system is used LTE, GSM there may be different restrictions. Instead of having a technology neutral spectrum, specific rules apply for each technology and exact how close to the band edge the spectrum chunk is located. Will the bidders in a spectrum auction need to take this into account - yes of course, with a significantly lower valuation as consequence.

So Tech Neutrality is a nice concept but difficult in practice. It again exposes the shortcomings of our current paradigm of transmitter licensing. Here (and in many similar cases) its the receivers that cause the problems. The concept of [Spectrum Usage Rights](#) is a step in the right direction, but not a solution to these problems.

Posted in [Spectrum](#), [Systems](#) | 2 Comments and 1 Reaction

Wireless@KTH



# Backup Slides