Is there enough Spectrum for Future Wireless Access ?

Jens Zander

Scientific Director, Wireless@KTH

KTH – The Royal Institute of Technology, Stockholm, Sweden

Wireless@KTH Center for Wireless Systems

Some key trends in Wireless Systems

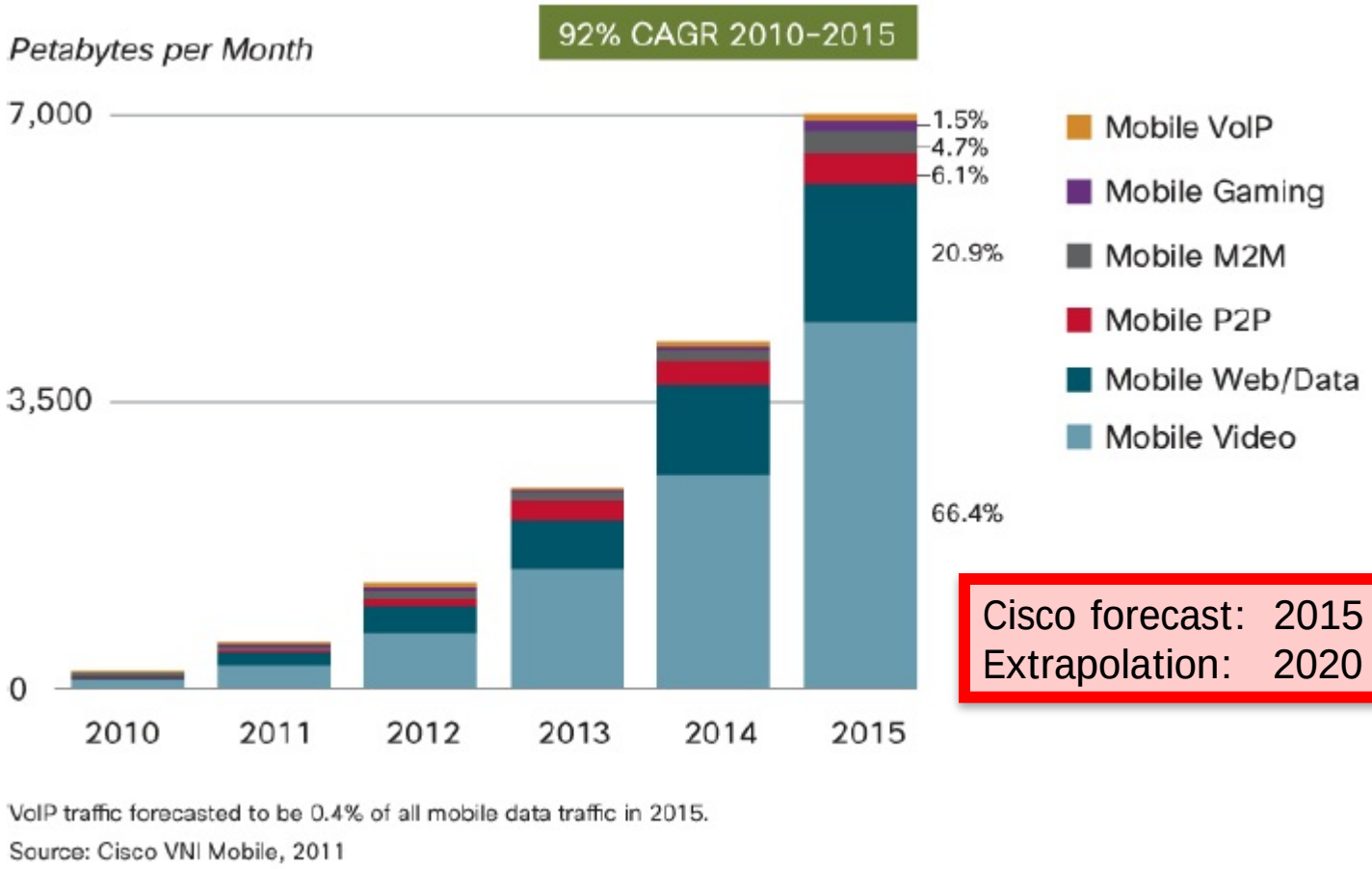
Dominant designs

- 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, ..

H

Center for Wireless Systems

Mobile Data avalanche



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

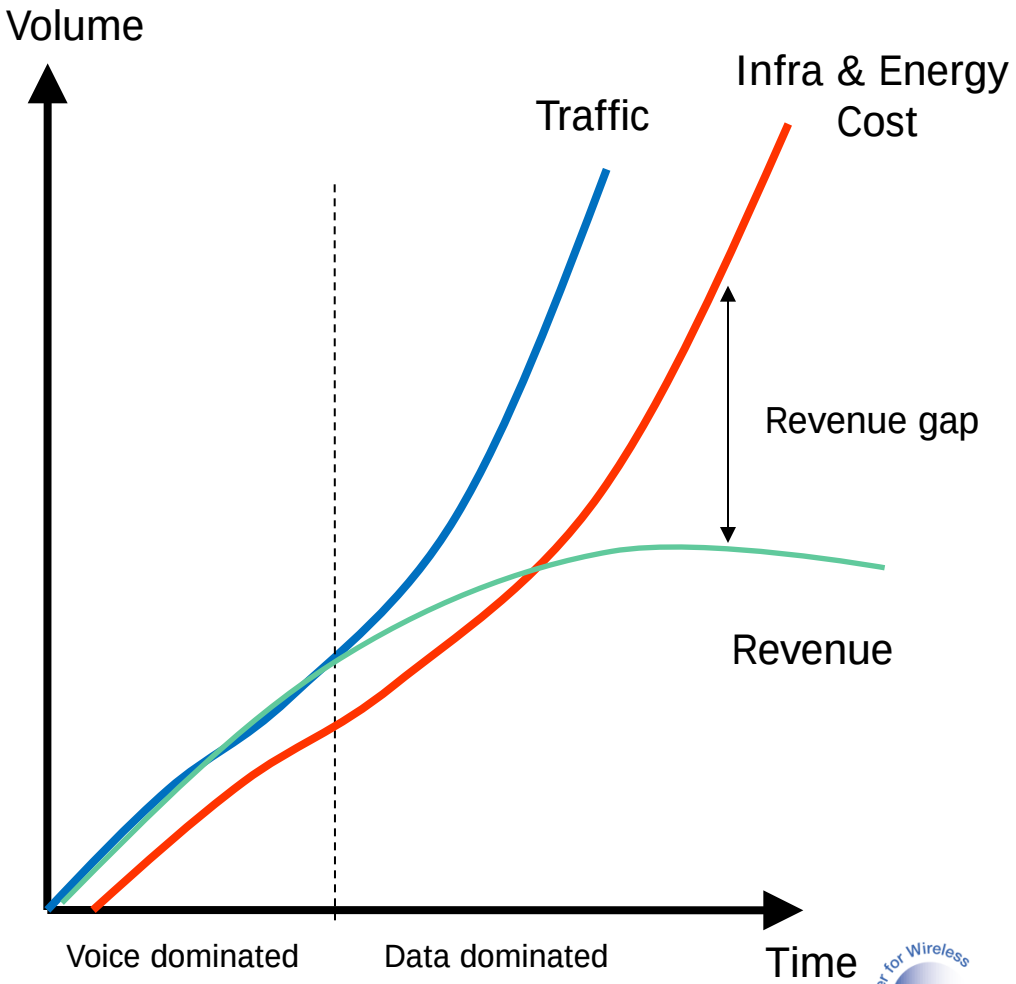
Source: Cisco VNI Mobile, 2011

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

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

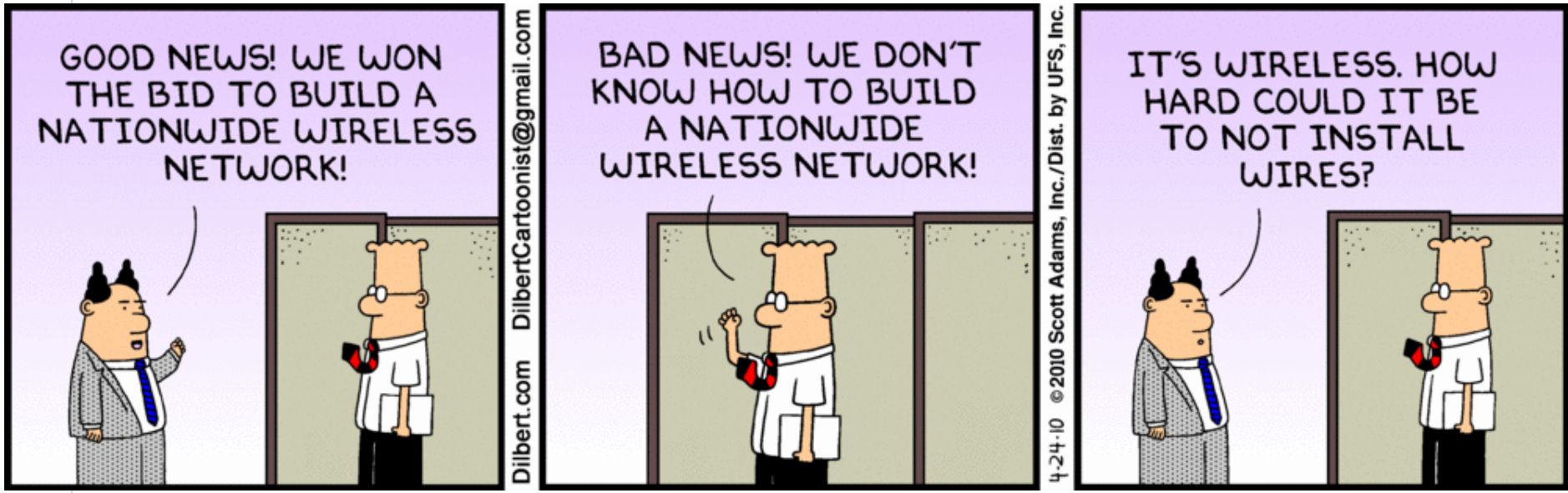
Operator dilemma: More for less money

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



Wireless@KTH

How difficult can it be ?



Candidate Approaches

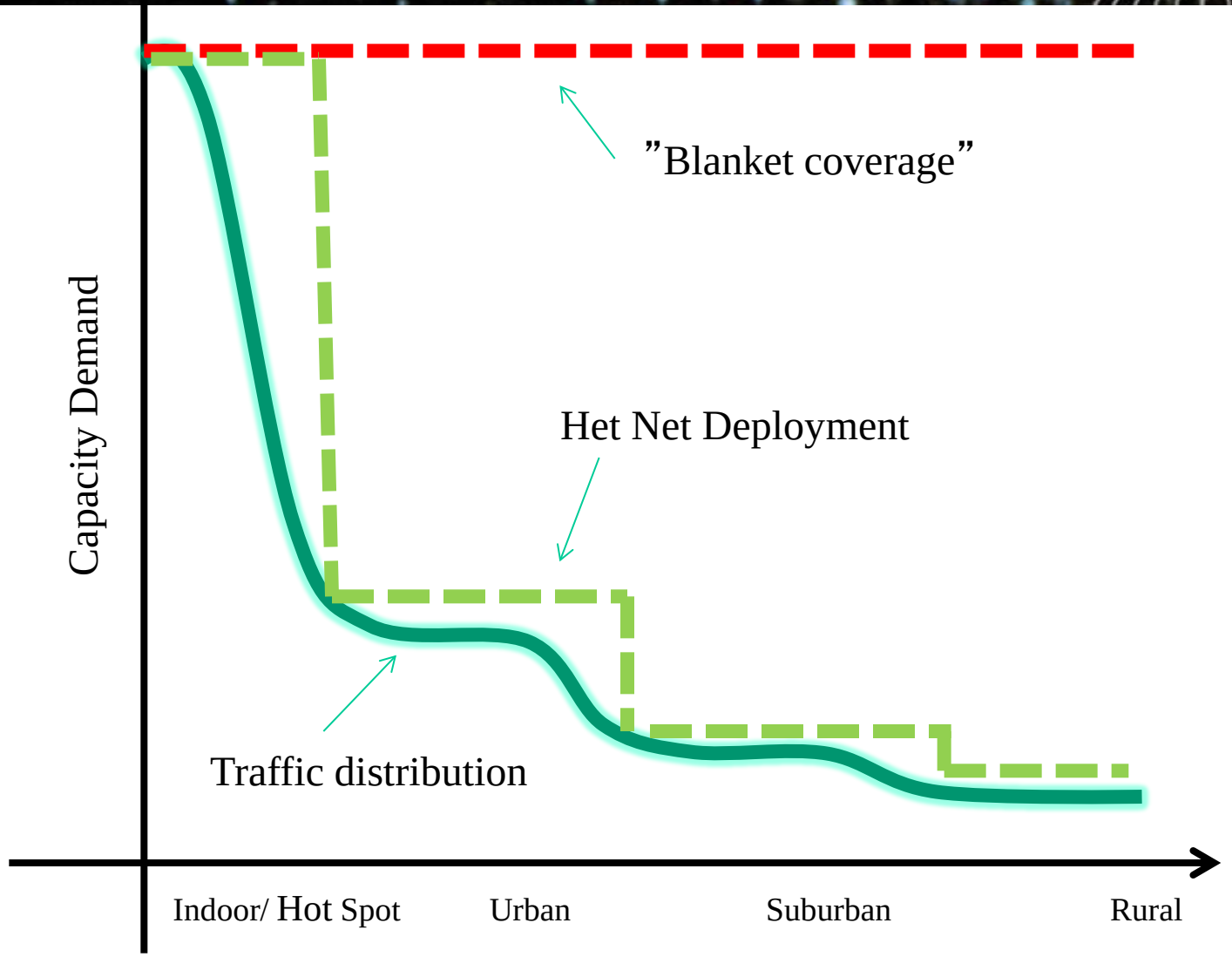
- Improved Spectral Efficiency (Moore's Law)
  - PHY-layer (Modulation, MIMO)
  - Interference Management (COMP/ICIC)
- Denser infrastructure
- More Spectrum

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

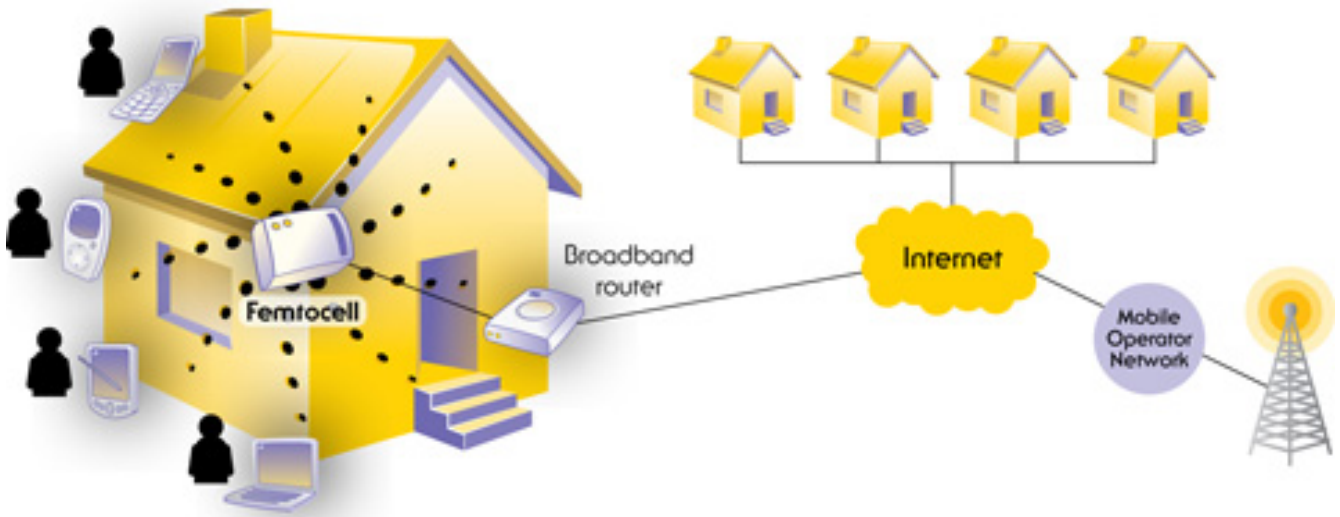
Densification: Technology shift

- Industry grade eq
- High power
- 24-7 availabilty
- 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

Wireless@KTH Center for Wireless Systems

Sharing infrastructure: A new ways to low-cost capacity

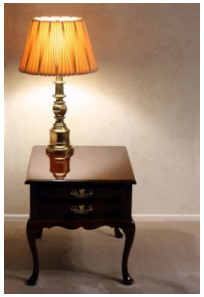


- Technology: Not an issue !
- Business model: Cooperation !
- Key vendor issue: ”Herbal medicin” of Wireless
  - Low complexity, Low cost... where is the profit ?
- Key operator fallacy:
  - With ”flat rate”, why not hand-off my customers for free ?
  - Operator ”owns” customer and gets paid anyway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

In summary ...

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

- 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



Wireless@KTH

Is Spectrum availability a problem ?

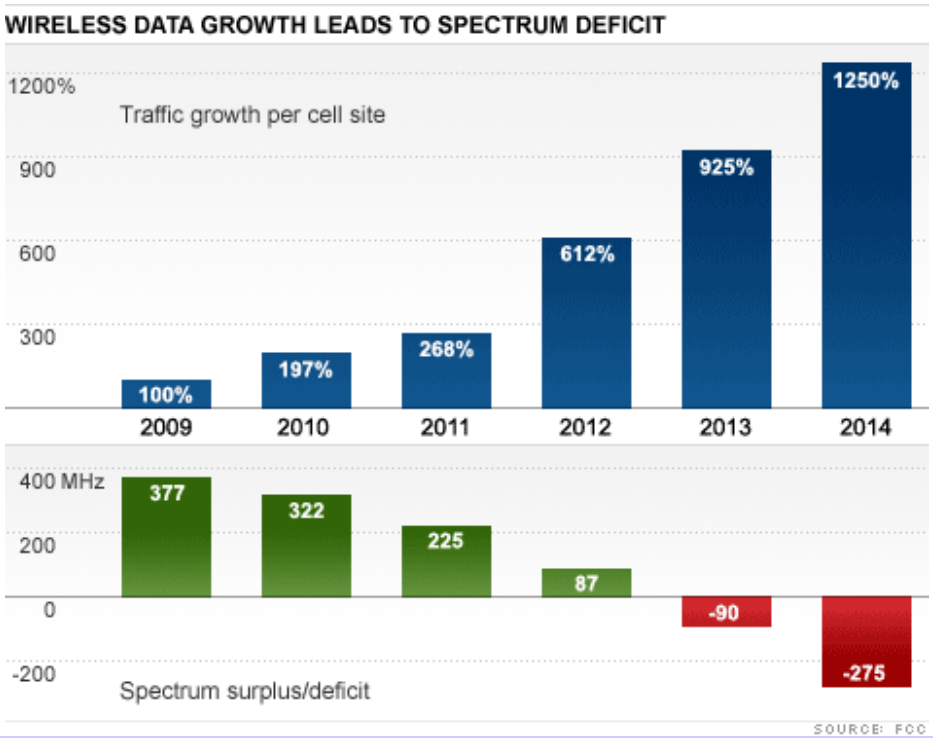
Spectrum shortage ?

- 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



Wireless@KTH Center for Wireless Systems

The cost of spectrum

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

More base stations

More spectrum

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

Spectrum Upgrade cost

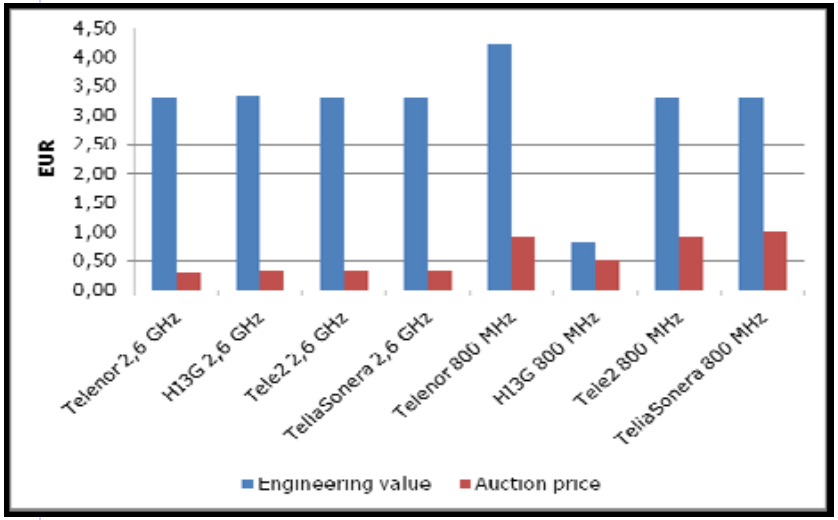
$$C_{sys} + \Delta C \approx C_{sys} + c_{BS} \Delta N + \Delta c_{BS} N_{BS} + c_{sp} \Delta W$$

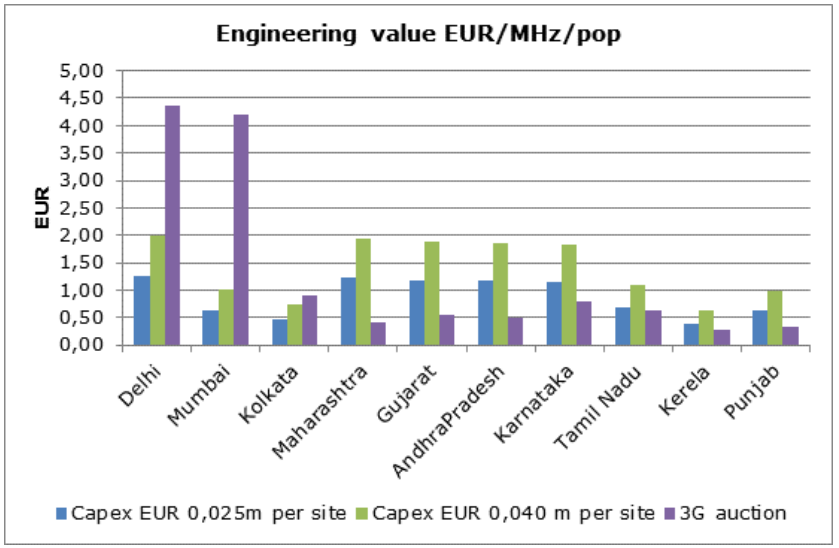
$$\min \Delta C = \min \left(c_{BS} \frac{\Delta R}{\eta W_{SYS}} A, \Delta c_{BS} N_{BS} + c_{sp} \frac{\Delta R}{\eta N_{BS}} A \right)$$

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

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 Center for Wireless Systems

Buzzword Bingo

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

Spectrum options

	Exclusive <6 GHz	Shared < 6 GHz	Secondary <6 GHz	Exclusive > 10 GHz
Availability	Very Low	Moderate	Good (>1 GHz) for indoor use	Very good
Advantages	• Guaranteed QoS • Long-term investments	• Spectrum available • Low cost equipment/deployment	• Spectrum available • Low cost equipment/deployment	Very high capacity Low interference
Disadvantages	High deployment cost	• No QoS guarantees • Low availability	• Limited QoS guarantees • Regulatory uncertainty	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 outweigths 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 deplyment 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

theunwiredpeople.com

Wireless@KTH Center for Wireless Systems

Backup Slides