





Some key trends in Wireless Systems

What problems are being addressed by the "Wireless Industry" = which products are likely to be cheaply and widely available ?





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, ...

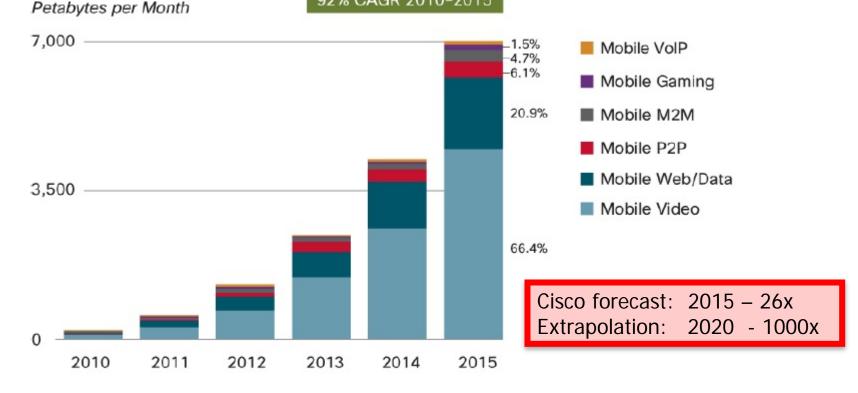


Syster



Mobile Data avalanche

92% CAGR 2010-2015



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

Source: Cisco VNI Mobile, 2011

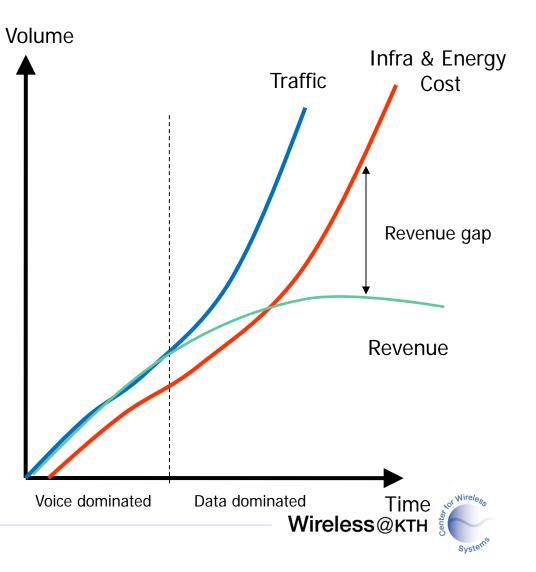
Exponential growth Assumes zero marginal cost for access How long can this be sustained ?





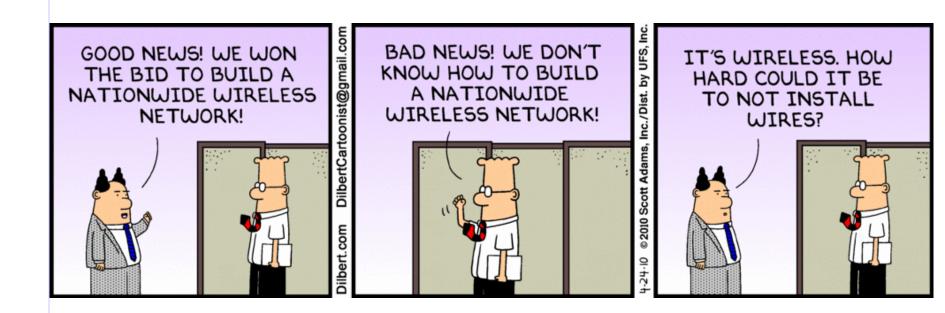
Operator dilemma: More for less money

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





How difficult can it be ?





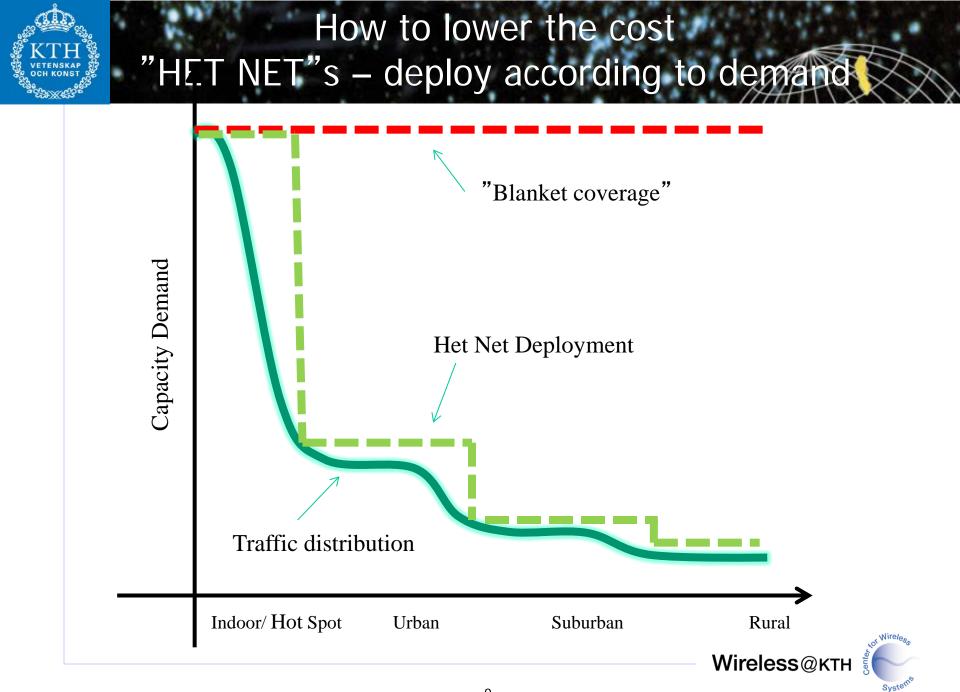


In search for 5 G 1000 times more capacity ...but how?

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



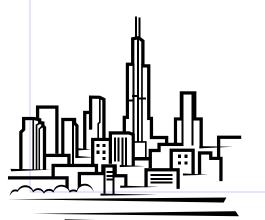




A world divided

Urban

- Issue: Capacity
 - Spectrum
- •Characteristics:
 - High data rates
 - Low power
 - Mass market drives product & service development
 - Profitable



Rural

- Issue: Coverage
 - Infrastructure Cost/User
- Characteristics:
 - Moderate data rates
 - High power
 - Limited market
 - Not profitable







HET NETs - The Light Analogy



Outdoor –
 Wide Area

Indoor –
 Short Range







Densification: Technology shift



Wide Area (Macro)

- Industry grade eq
- High power
- 24-7 availabilty
- High system complexity
- High site costs (towers, backhaul..)



Small cell (Micro)

- Industry grade eq
- Medium power
- 24-7 availability
- High system complexity
- Backhaul limited
- Wall loss limitation



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





Is Spectrum availability a problem ?





Spectrum shortage?

- Spectrum availability
 - Long-term, fundamental time-scale: Decades
 - Regulatory/planning process, licensing
 - Important for large scale, long-term infrastructure deployment

About 1 GHz of spectrum available for IP-Access (<6 GHz)

- Spectrum access
 - Short-term, "Can I get access for my product now?
 - Issue: "Temporary" under-utilization of spectrum
 - Important for innovation, products with short life cycle

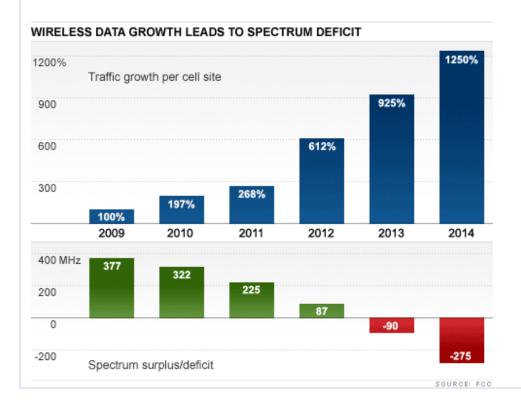
When is spectrum availability the barrier ?



Is there a "spectrum deficit" ?

Yes:

in high density areasfor the "business as usual" paradigm







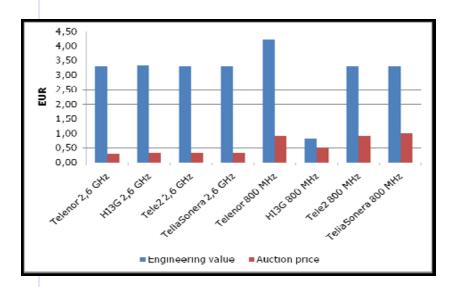


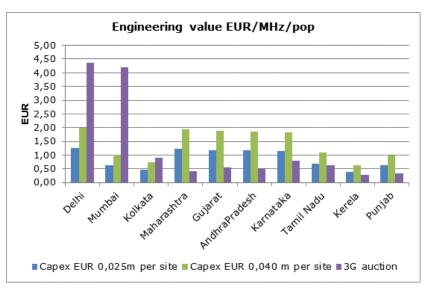
The cost of spectrum in Wireless Access

 $R_{tot} \approx \frac{C_{sys}}{C_{BS}A} \eta W_{sys} = \frac{\eta}{R_{Aot}} N_{SYS} \log \left(1 + \frac{\eta_R}{W_{SYS}} \left(\frac{N_{BS}}{A} \right)^{2/\alpha} \right) \approx \eta_R \left(\frac{N_{BS}}{A} \right)^{2/\alpha}$ 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 $C_{sys} + \Delta C \approx C_{sys} + c_{BS} \Delta N + \Delta c_{BS} N_{BS} \sigma (\Delta W) + c_{sp} \Delta W$ $\min \Delta C = \min \left(c_{BS} \frac{\Delta R}{\eta W_{SYS}} A, \Delta c_{BS} N_{BS} + c_{sp} \frac{\Delta R}{\eta N_{DS}} A \right)$ $\boldsymbol{c}_{sp}^{*} = \max \left| \left| \frac{\boldsymbol{c}_{BS}}{\boldsymbol{W}_{sp}} - \frac{\eta \Delta \boldsymbol{c}_{BS} \boldsymbol{N}_{BS}}{\boldsymbol{A} \Delta \boldsymbol{R}} \right| \boldsymbol{N}_{BS}; 0 \right| \text{ Engineering value of spectrum} \right|$ Wireless@ктн



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





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	 Guaranteed QoS Long-term investments 	 Spectrum available Low cost equipment/depl ment 	у	 Spectrum available Low cost equipment/deploy ment 	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 (High Δc_{BS})
 - Requires new hardware(technology) "Yet another radio" in base stations, terminals etc
- Unsuitable propagation conditions (low η)
 - Too short(coverage), too long range (interference)
- Wide band radios & antennas
 - Efficiency loss outweigths spectrum access benefit ?
- Access limitations & business uncertainty
 - Sharing with other users (e.g. Secondary spectrum)
 - Mismatch between licensing regime and usage
 - Mismatch between licensing regime and investments





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

Seconday access = "temporary" or localized solution





Where are we(should we be) heading?

Wide area access

- Licensed spectrum to match long-term RFspecific 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"





Some conclusions

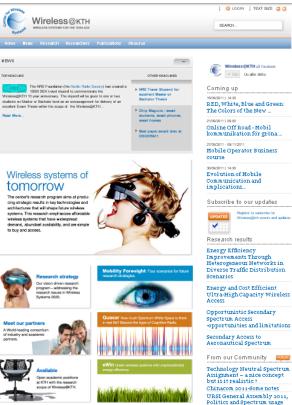
- Wireless Cloud Access the dominant design of future services
- Designs for dense, high capacity infrastructure will dominate market place (> 3 GHz) and widen gap to rural solutions that struggle with performance and profitability
- Spectrum not really a fundamental limiting factor
 - Matching to infrastructure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





Read more & Interact !

wireless.kth.se





RED, White, Blue and Green:

Heterogeneous Networks in **Diverse Traffic Distribution**

Ultra-High Capacity Wireless

URSI General Assembly 2011, Politics and Spectrum usage LightSquared - even more money down the drain?



theunwiredpeople.com

1. (1.) Login LET'S TALK WIRELESS NWORED

PEOPLE

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

Posted on September 9, 2011 by Jens Zander

Rekommendera

We learn from Economics theory that if you want to trade goods effectively, these shall be as general as possible, usable by anyone an 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. "WAPECS") 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 ratch 2 Well, its what in the business is called "Lenacy Environment", i.e. anything that is get there before these new regulations are put into place. We have already numerous examples of interference problems. Air-out 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 7 No. Are they violating the spectrum mask rules ? Not likely, Would the problems on away with perfect new equipment? Unfortunately 200

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 7. Not likely. There seems to be "souratters 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 a you stay a kilometer away from the nearest railroad (i.e. where the highest condition 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

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PEOPLE RECENT POPULAR

jzander 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 Technology Neutral Spectrum Assignment - a nice concept but is it realistic ? 1 day ago

Syed Fahad Yunas Hi, 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





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