Spectrum need and options for future wireless access

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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, ..

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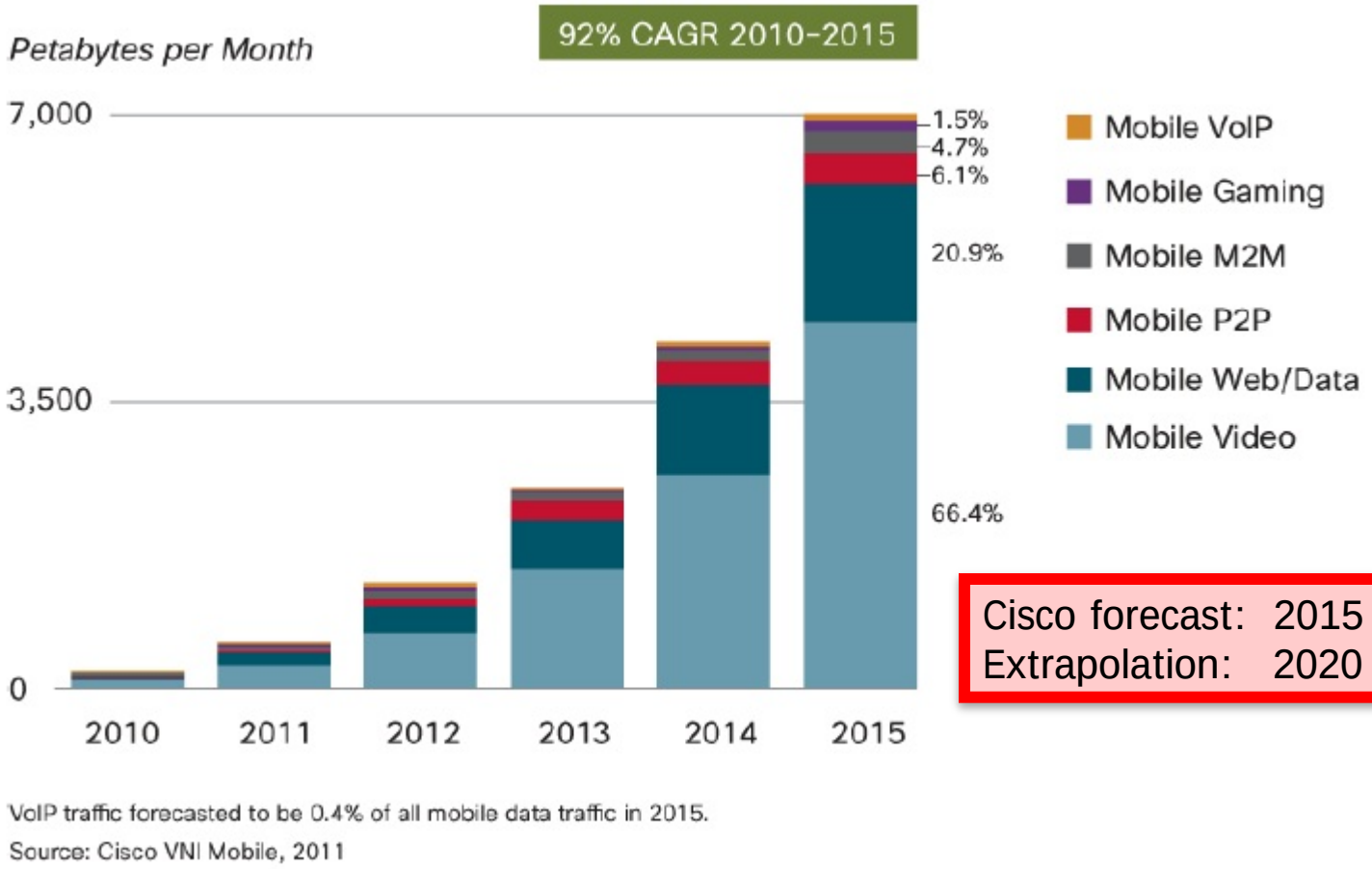
Mobile Data avalanche



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

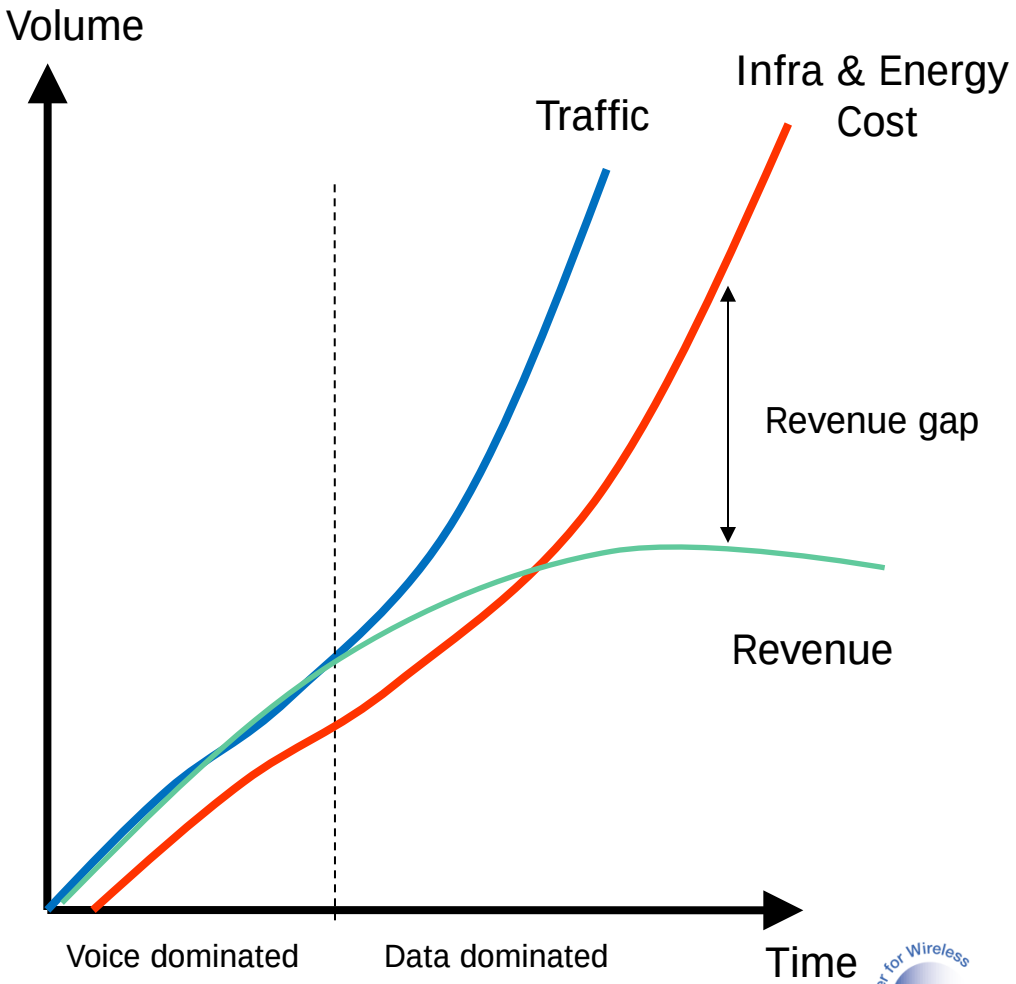
Source: Cisco VNI Mobile, 2011

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



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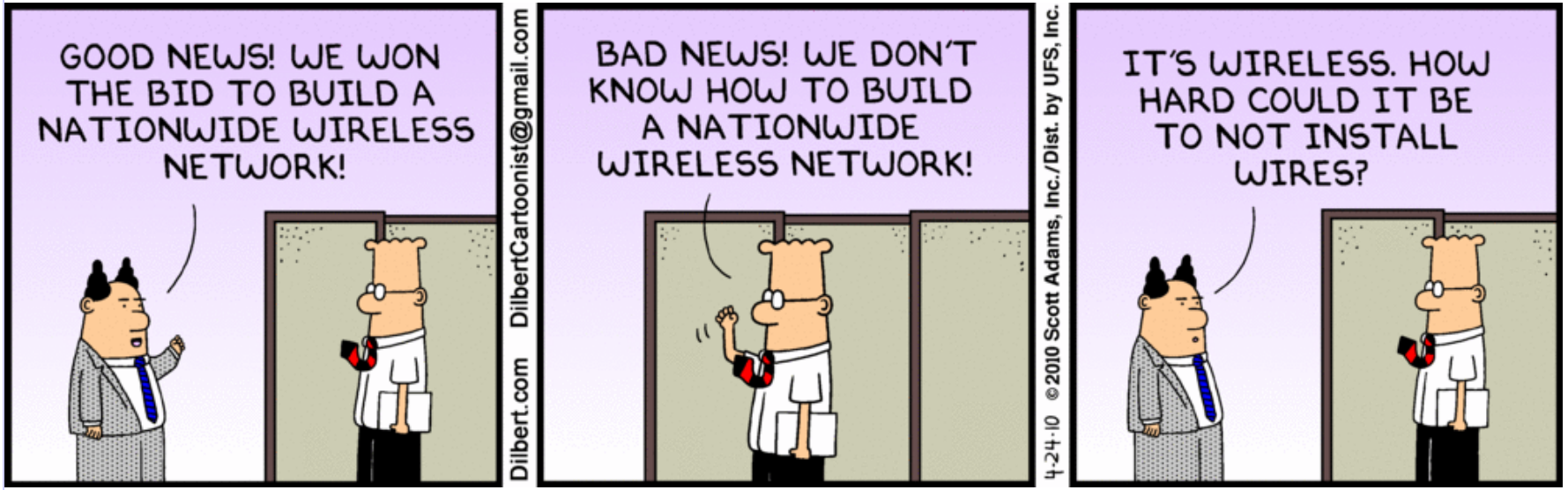
How difficult can it be ?

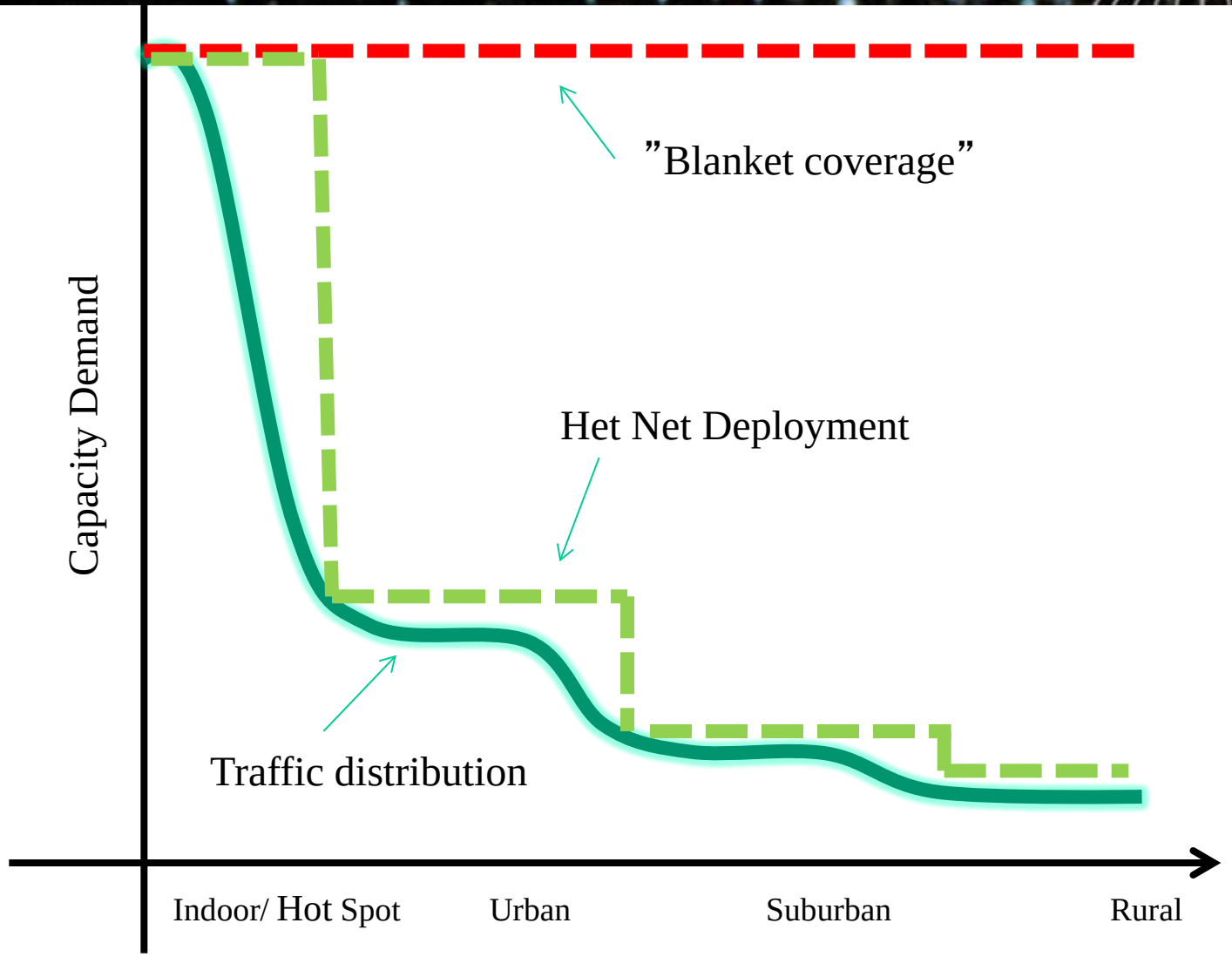


In search for 5 G
1000 times more capacity ..but how ?

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

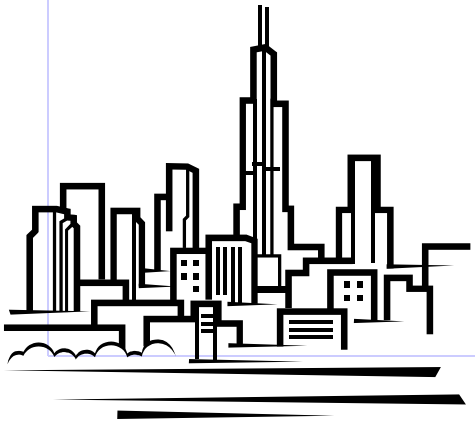
How to lower the cost ”HET NET”s – deploy according to demand



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 availabilty
- High **system** complexity
- Backhaul limited
- Wall loss limitation

Indoor (Pico/Femto)

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

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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)

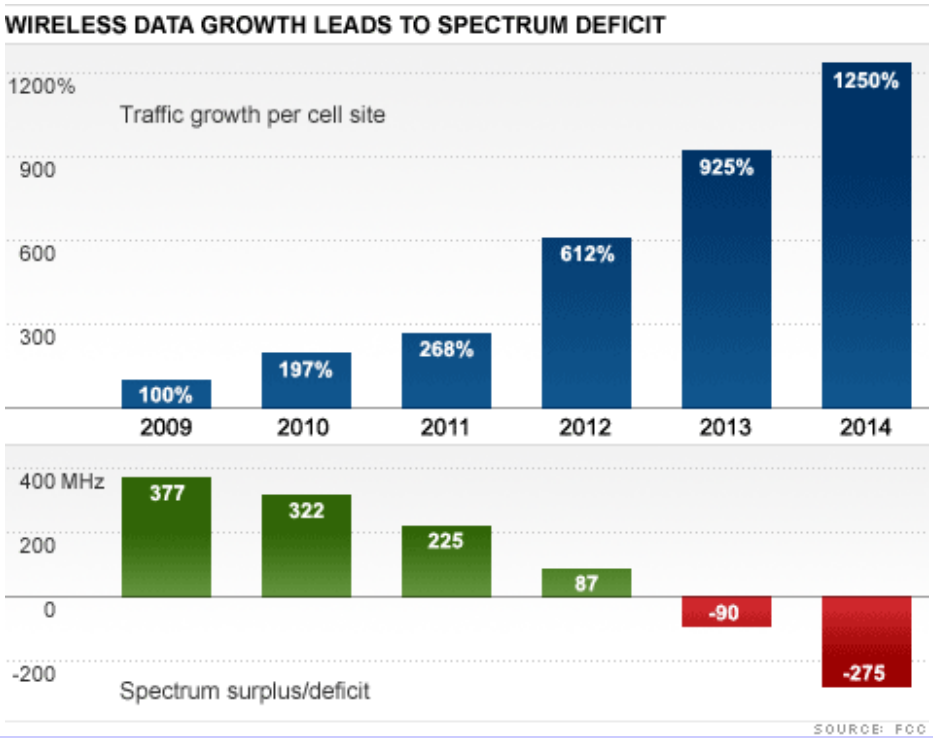
- Spectrum access
  - Short-term, ”Can I get access for my product now ?
  - Issue: ”Temporary” under-utilization of spectrum
  - Important for innovation, products with short life cycle

  When is spectrum availability the barrier ?

Is there a ”spectrum deficit” ?

Yes:

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



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The cost of spectrum in Wireless Access

$$R_{tot} \approx \frac{C_{sys}}{c_{BS} A} \eta W_{sys} = \frac{\eta}{A} N_{BS} W_{sys} \approx W_{SYS} \log\left(1 + \frac{\eta_R}{W_{SYS}} \left(\frac{N_{BS}}{A}\right)^{2/\alpha}\right) \approx \eta_R \left(\frac{N_{BS}}{A}\right)^{2/\alpha}$$

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

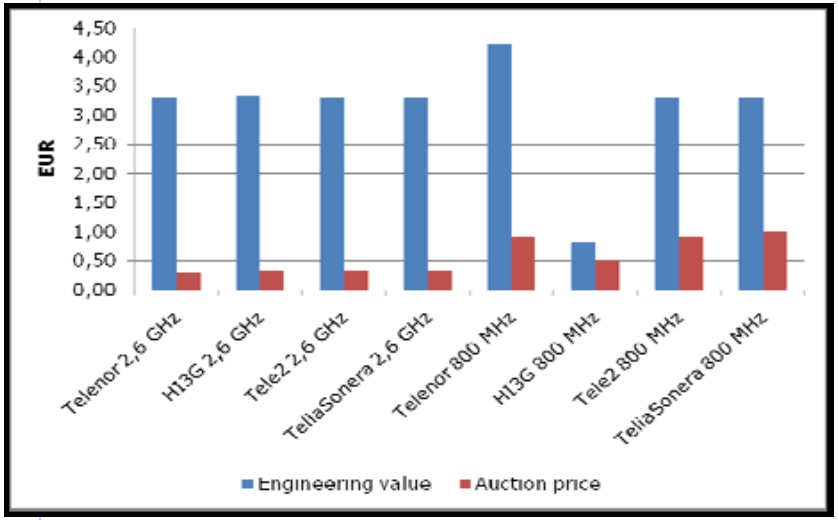
$$C_{sys} + \Delta C \approx C_{sys} + c_{BS} \Delta N + \Delta c_{BS} N_{BS} \sigma(\Delta W) + c_{sp} \Delta W$$

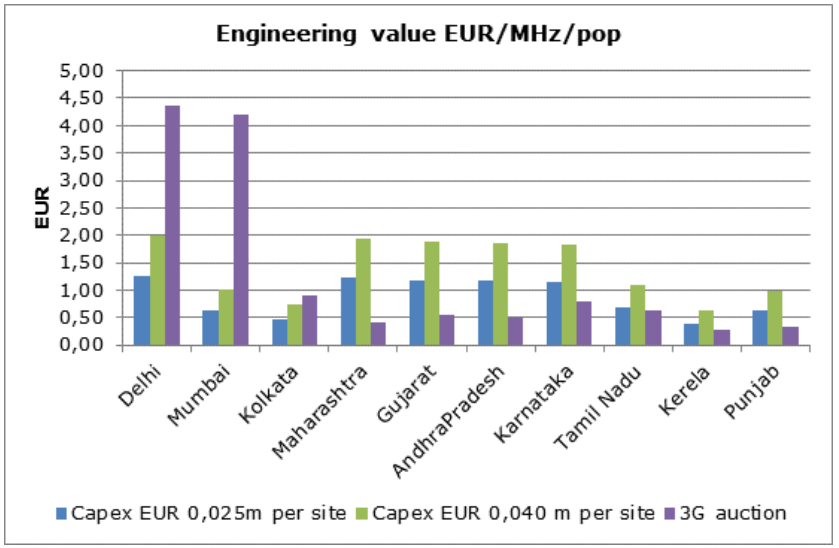
$$\min \Delta C = \min\left(c_{BS} \frac{\Delta R}{\eta W_{SYS}} A, \Delta c_{BS} N_{BS} + c_{sp} \frac{\Delta R}{\eta N_{BS}} A\right)$$

$$c_{sp}^{*} = \max\left[\left(\frac{c_{BS}}{W_{SYS}} - \frac{\eta \Delta c_{BS} N_{BS}}{A \Delta R}\right) N_{BS}; 0\right]$$

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

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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 (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 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”

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

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