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ETSI Future Mobile Summit
21 November 2013

Spectrum for 5G – a big deal ?

KTH VETENSKAP OCH KONST

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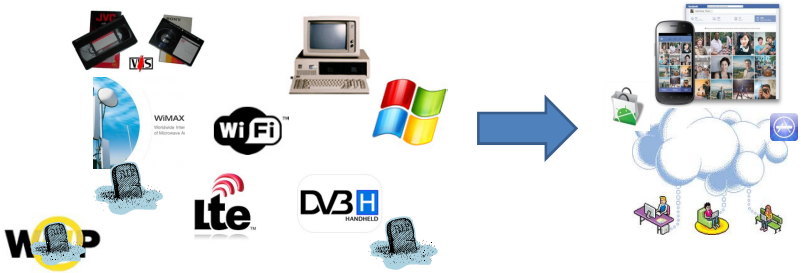
A lessons from History - Dominant designs



- From infrastructures driven by ”killer apps” and ”one-trick ponies”
  → general IP-based access infrastructures
- Internet access = dominant design for ALL services (fixed & mobile)
  - Marginalizes other technical solutions – e.g. Wireless P2P, Mesh, ...

”IP is the answer - now, what was the question ?”
G Q Maguire

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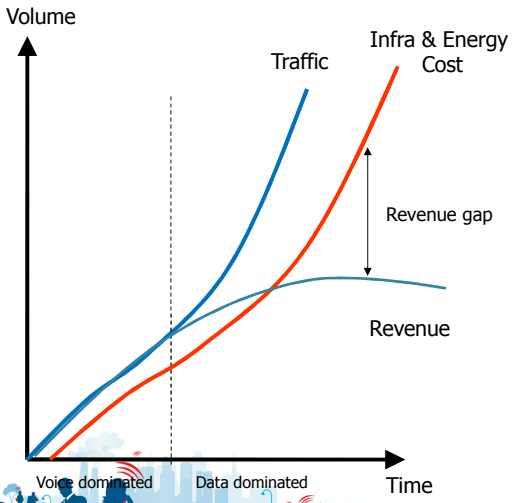
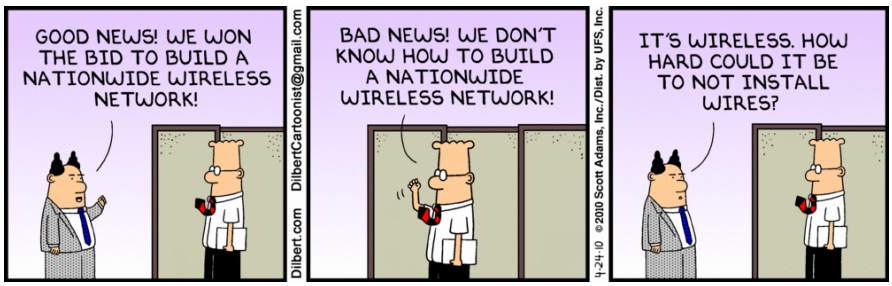
Operator dilemma: More for less money

- Spending capability of user increases with GNP growth (<10% annually)
- Capacity requirements increase by 80-100% annually

$$C_{SYS} = c_{BS} N_{BS}$$



How difficult can it be ?



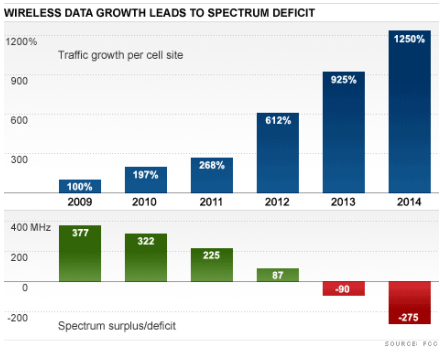
..and is more spectrum the solution ?

How to increase capacity ?

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

- Increase η, spectral efficiency (signal processing)
  - Close to theoretical limits
- More base stations, N_{BS}
  - Expensive
- More spectrum, W_{SYS}
  - Shortage ?

Solving ”all” problems with more spectrum - the ”FCC – Spectrum deficit”



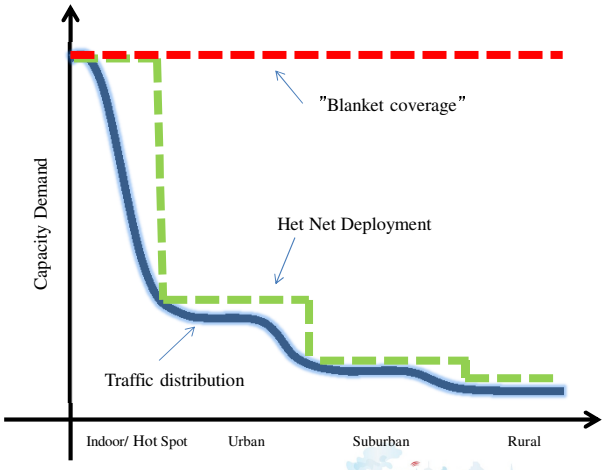
Key assumptions

Reasonable extrapolation of

- current deployment strategies (=moderate increase in base stations)
- transmission technologies.

How to lower the cost:

”HET NET”s – deploy according to demand



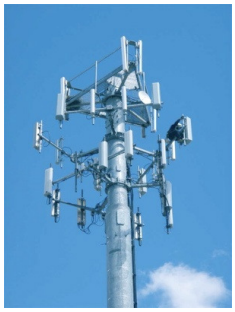
HET NETs - The Light Analogy

- Outdoor – Wide Area

- Indoor – Short Range

A World Divided

The coverage world



- Industry grade equipment
- High power/Wide area
- 24-7 availabilty
- High **system** complexity

The capacity world

- Consumer grade equipment
- Low power/Short range
- Reliability through redundancy
- **Deploy where backhaul available**
- Low **system** complexity

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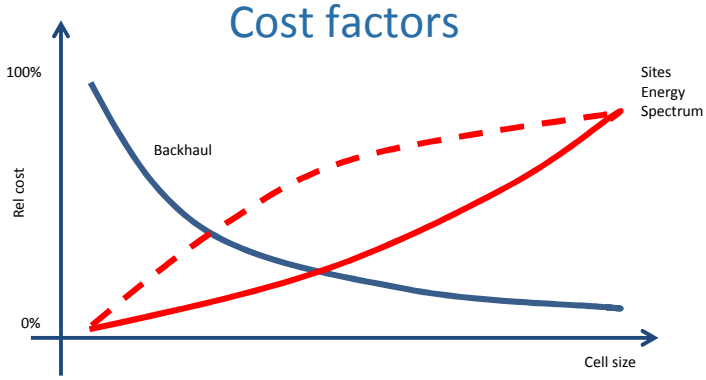
Cost factors



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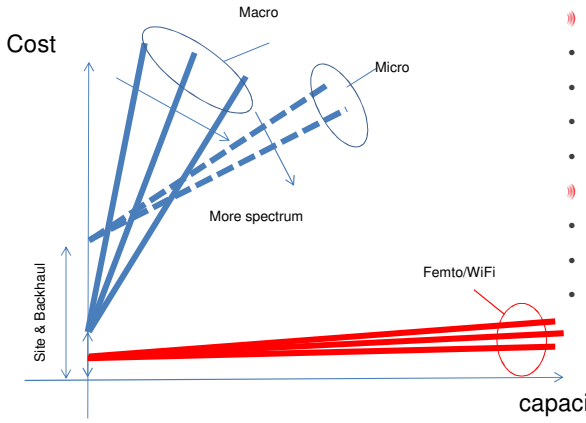
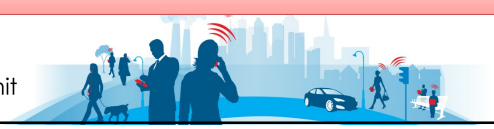
The cost for capacity



- **Outdoor Macro/Micro**
  - Site aquisition
  - Backhaul
  - Outdoor equipment
  - Wall penetration loss
- **Indoor Femto/WiFi**
  - Cheap equipment
  - No dedicated backhaul
  - Wall loss = benefit!

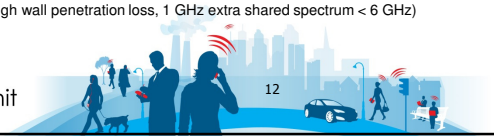
Capacity (were needed) is ”cheap” - coverage is expensive



Is there enough capacity ?

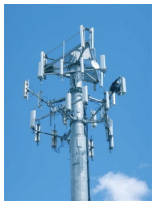
	Outdoor		Indoor capacity			
	Macro	Micro	Macro	Micro	WiFi conservative	WiFi ideal *
Inter base distance (m)	300	100	300	100	30	10
Density BS/Sqkm	11	100	11	100	1 111	10 000
Avg Spectral eff (bit/s/Hz)	2	2	2	2	2	4
Available spectrum (MHz)	500	500	500	500	1 000	2 000
Aggregate max rate (Gbit/s)	1	1	1	1	2	8
No Sectors	3	3	3	3	1	1
"Effective" Reuse factor	3	3	3	3	3	1
Capacity/BS (Gbit/s)	1	1	1	1	0,67	8
Effective Wall penetration loss(dB)	-	-	10-30	10-30	0 - 10	-
Capacity/sqkm	11	100	1 -3	10 - 30	250 -750	80 000

* 1 AP/room, High wall penetration loss, 1 GHz extra shared spectrum < 6 GHz)



A World Divided – business aspects

The coverage world



- **Public operators**
- Access any-time, anywhere
- "Insurance" – guaranteed acces
- Monthly fee

- Power/Site/Backhaul
- Exclusive spectrum licensing

The capacity world

- **Facility owners**
- Sanitary requirement / no charge
- User experience – high data rates

- Ultra dense deployment – Interference
- (Low power, no site cost, existing backhaul)

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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 >1 GHz for wireless access

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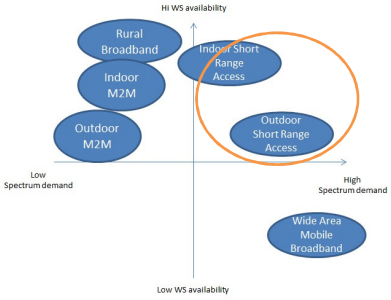
Secondary spectrum use ?



The **"Commercial Sweetspot"** of secondary spectrum :

Short range/indoor high capacity systems

Success due to physics - not due to smart regulation or "cognitive" technology

Where are we heading - spectrumwise?

Wide area access

- Spectrum need to lower cost
- Block-licensed spectrum to match long-term RF-specific investment (<3 GHz)
- Repurposing of UHF from TV -> IP access
  - Digital dividends 800, 700, 600 MHz etc

Short range access

- Plenty of potential spectrum <6 GHz
- 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
- Indoor ultra-dense deployment – a completely different ballgame
  - Systems constraints
  - Spectrum
- Spectrum not really a fundamental limiting factor for capacity
  - Matching to infrastructure investment life cycle

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BACKUP SLIDES

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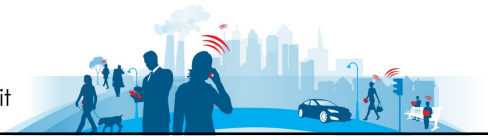
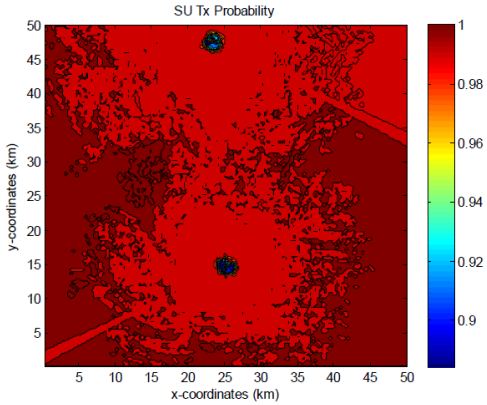
Not all bands are equal - limitations to spectrum use

- **New "distant" frequency band**
  - Requires new hardware(technology)
    "Yet another radio" in base stations, terminals etc
- **Unsuitable propagation conditions (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



SECONDARY USE OF ATC RADAR BANDS



Probability of SU transmission for overlapping channel access; Temporal decision scheme is considered; SU transmit power is 10 dBm; SU height is 1.5m.