# Spectrum for "5G" – where is the problem ?

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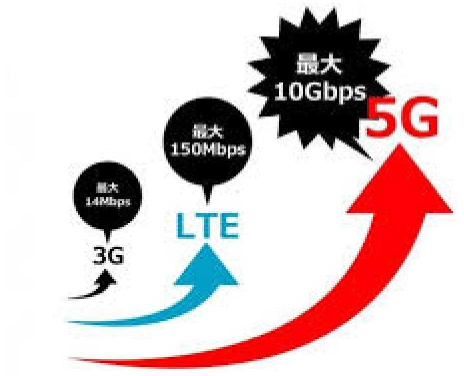




# Outline

- **Why do we need 5G ?**
  - Transparency & mobile data tsunami
  - Things that communicate & the Internet of Senses
- **Who needs more spectrum ?**
  - The two worlds – or are they three ?
- **What spectrum should we be looking for ?**


# Key trend 1: Transparency eats efficiency for breakfast

# Why do we have a Data Tsunami? Dominant designs

- Internet access + Cloud based solution = the Dominant Design for all application involving communication – since 2007 also on mobile

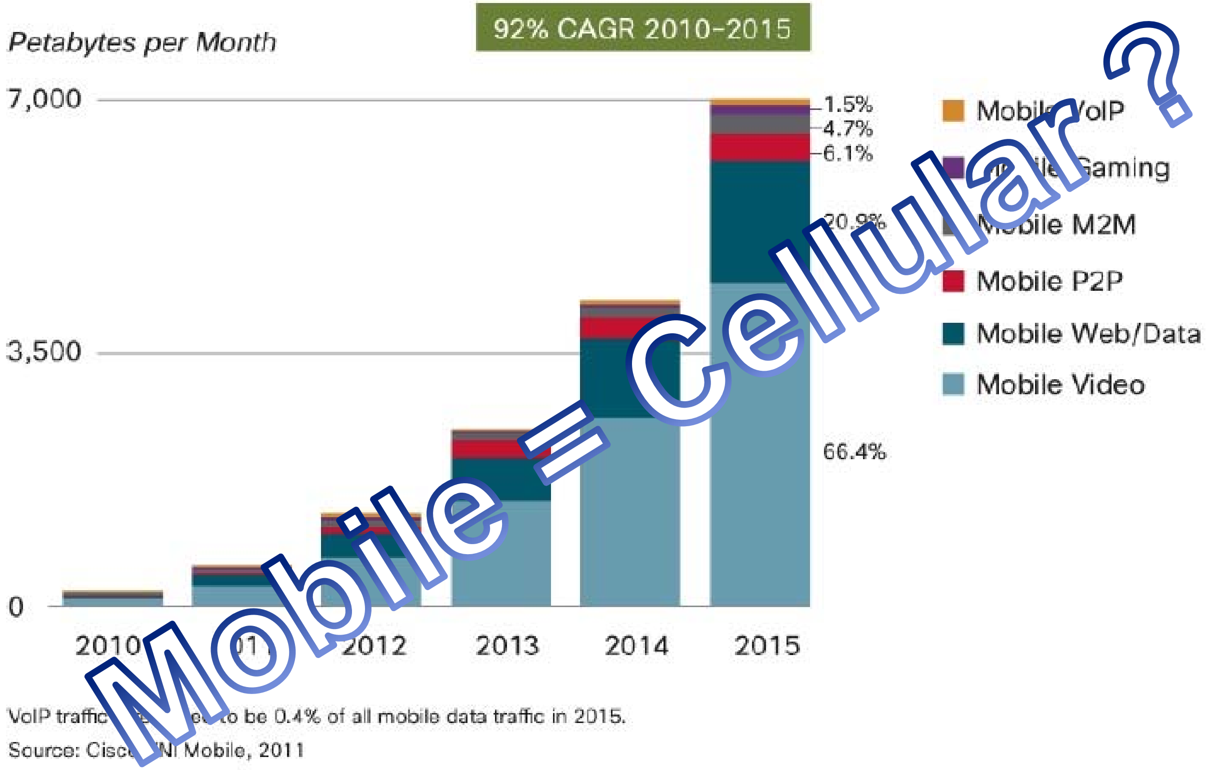
- Simple interface **IP** for all ”apps” creates explosive growth – works on all platforms

- Inefficient for (almost) all apllications: we buy flexibility at the expense of large data volumes data

- Other specific communication technologies (e.g. P2P, Multi-hop) and ”one trick ponies” (e.g Broadcast Radio/TV) become marginalized

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

# The price tag for transparency
# – the <u>Mobile</u> Data avalanche (as seen in 2010)



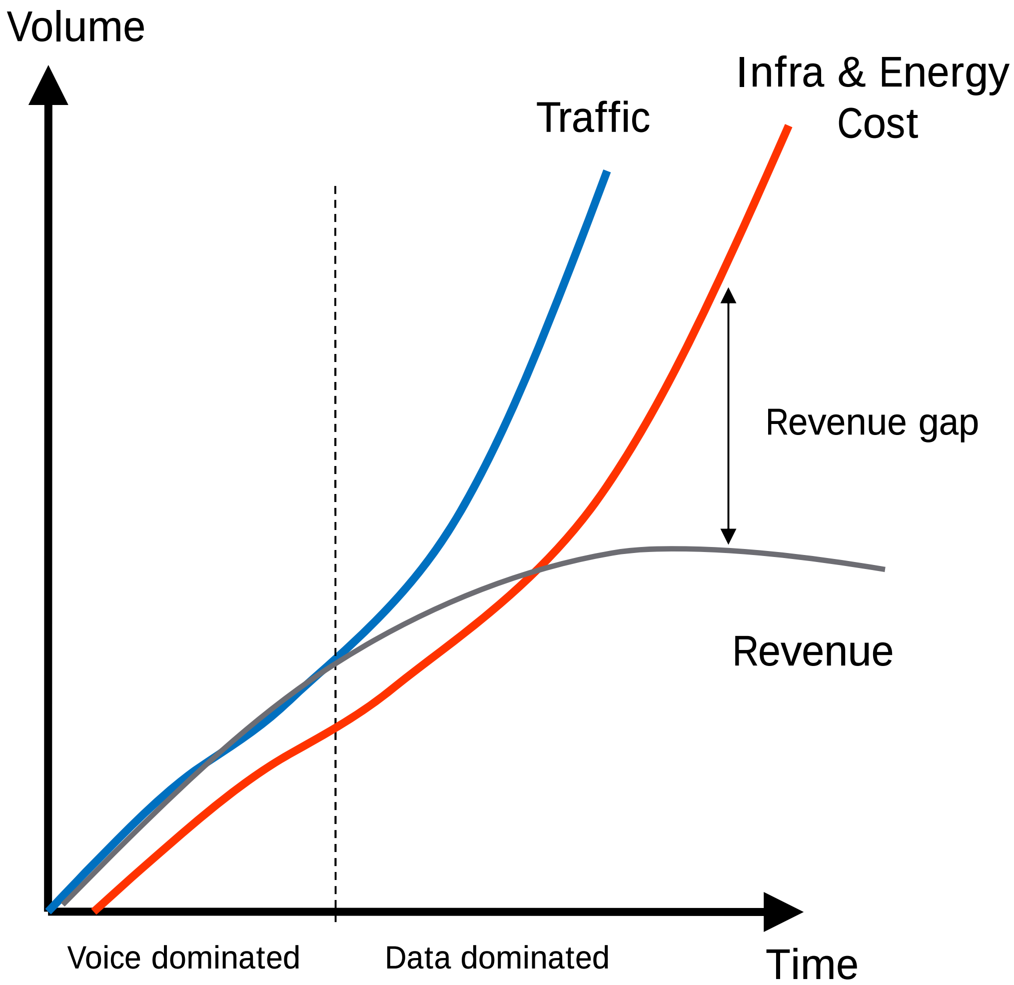

Exponential growth
Assumes **zero marginal cost** for access
How long can this be sustained ?

# Operator dilemma: More for less money

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

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

Challenge:
1000x lower cost/bit





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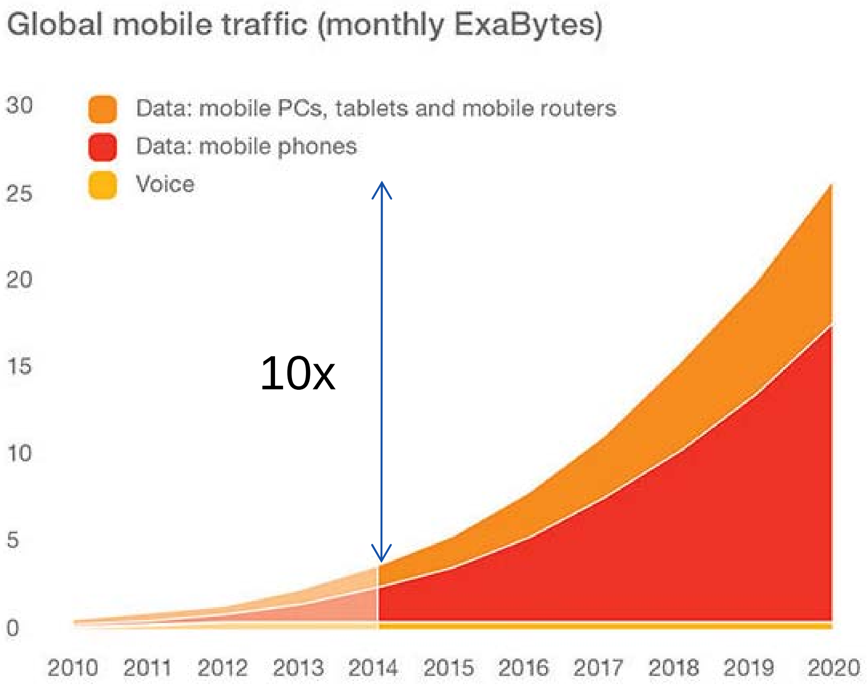
# Cellular traffic estimates now more modest




Source: Ericsson Mobility Report, Nov 2014

- Market saturation ?
  - Everyone has a smartphone?
- Volume based charging ?
  - ”Buckets” instead of ”all-you-can-eat”
- Bulk of the traffic off-loaded elsewhere ?
  - WiFi

Why 5G?


# Key trend 2: Things that communicate & the Internet of Senses

# Things that communicate

Internet of Things

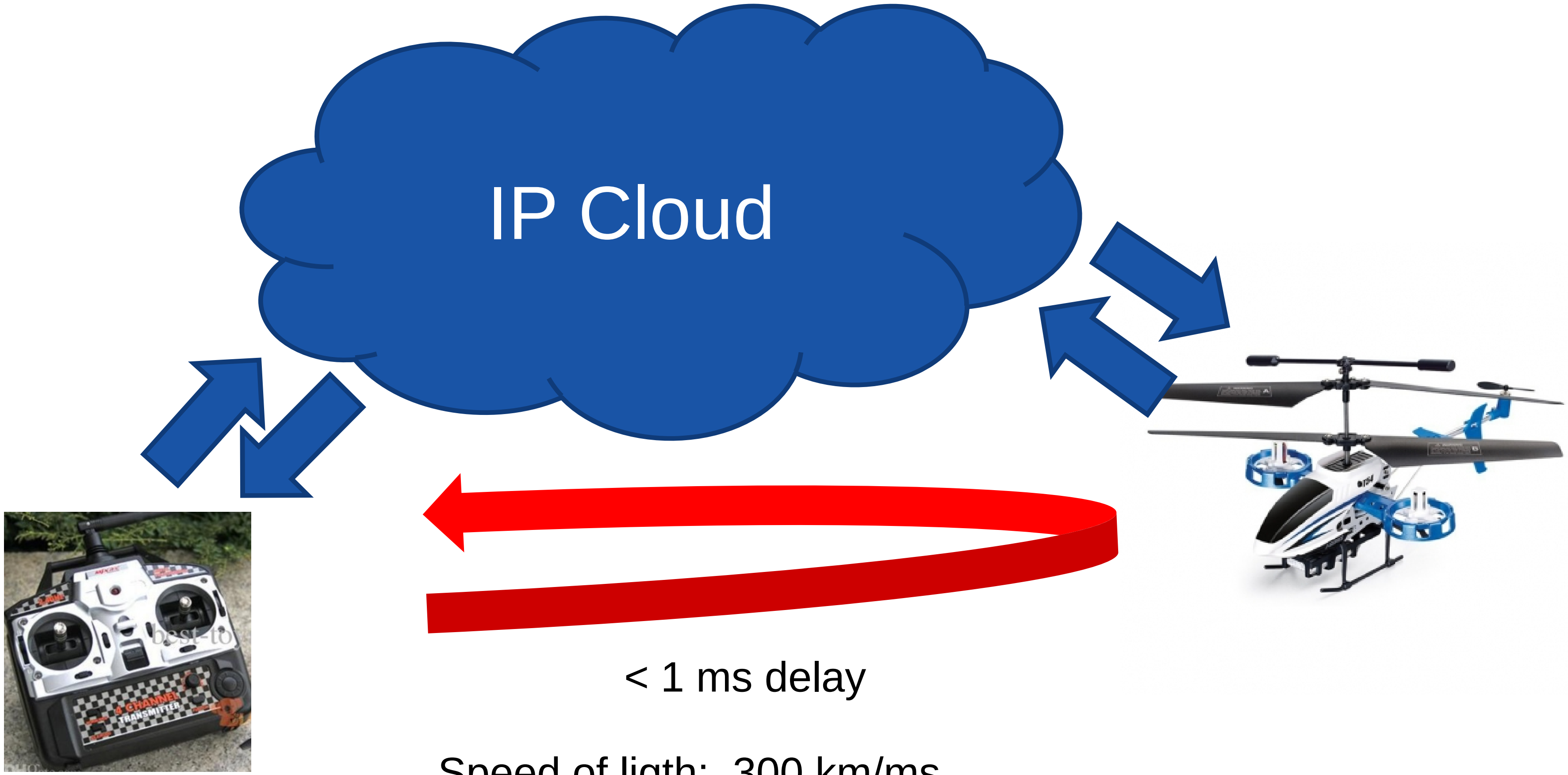
- Billions of devices
- Low power
- Low cost
- High reliability
- Low delay

4G not a scalable solution

SIM-cards in every device ?

# ”The internet of senses”

## (a.k.a. ”The Tactile Internet”)




< 1 ms delay

Speed of ligth:  300 km/ms

# Everything under one roof ?
## Transparancy vs Efficiency

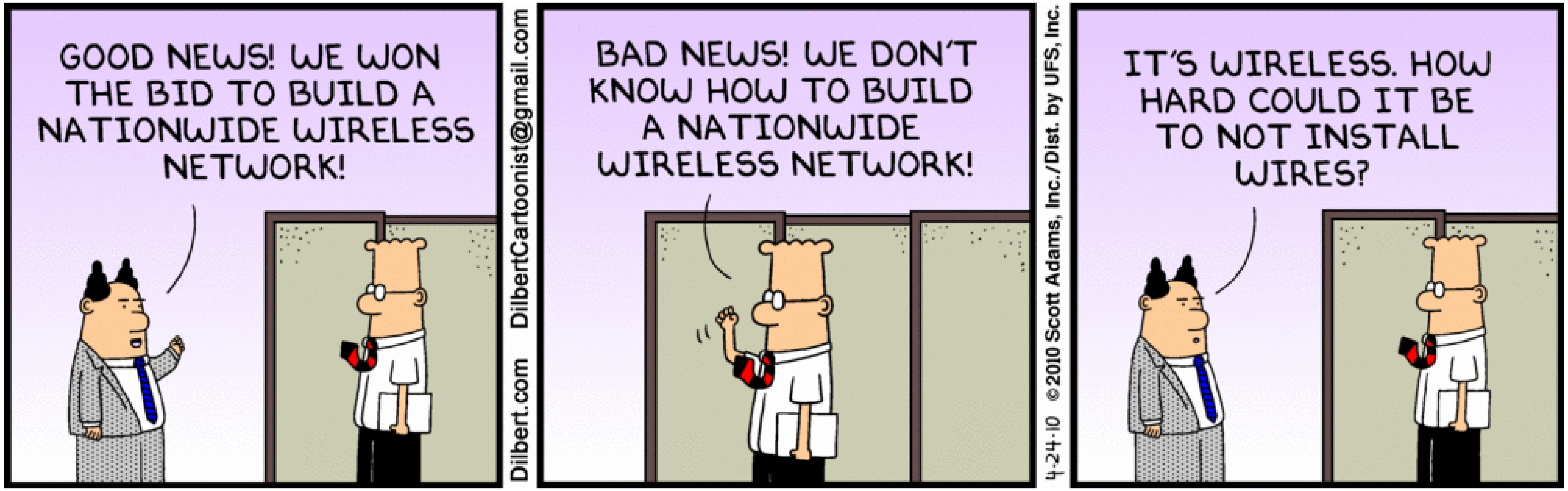
**The IP-access world**

- Large volumes of standardized equipment, unified platforms
- Low efficiency, overprovisioning of resources
- Willingness to pay for flexibility

**The MTC world**

- Large volumes
- Very diverse requirement on power, delay, cost…
- Non-standardized equipment, no unified platforms
- Rational decisions based on savings

# How difficult can it be ?




..and is more spectrum the solution ?

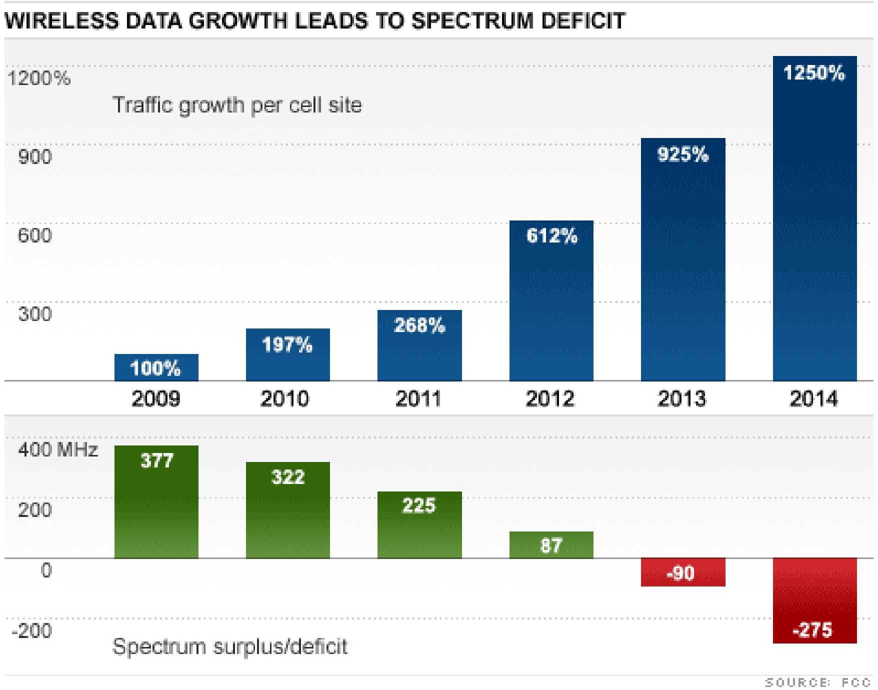
# Who needs more spectrum ?

# 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 $\eta$ , 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"



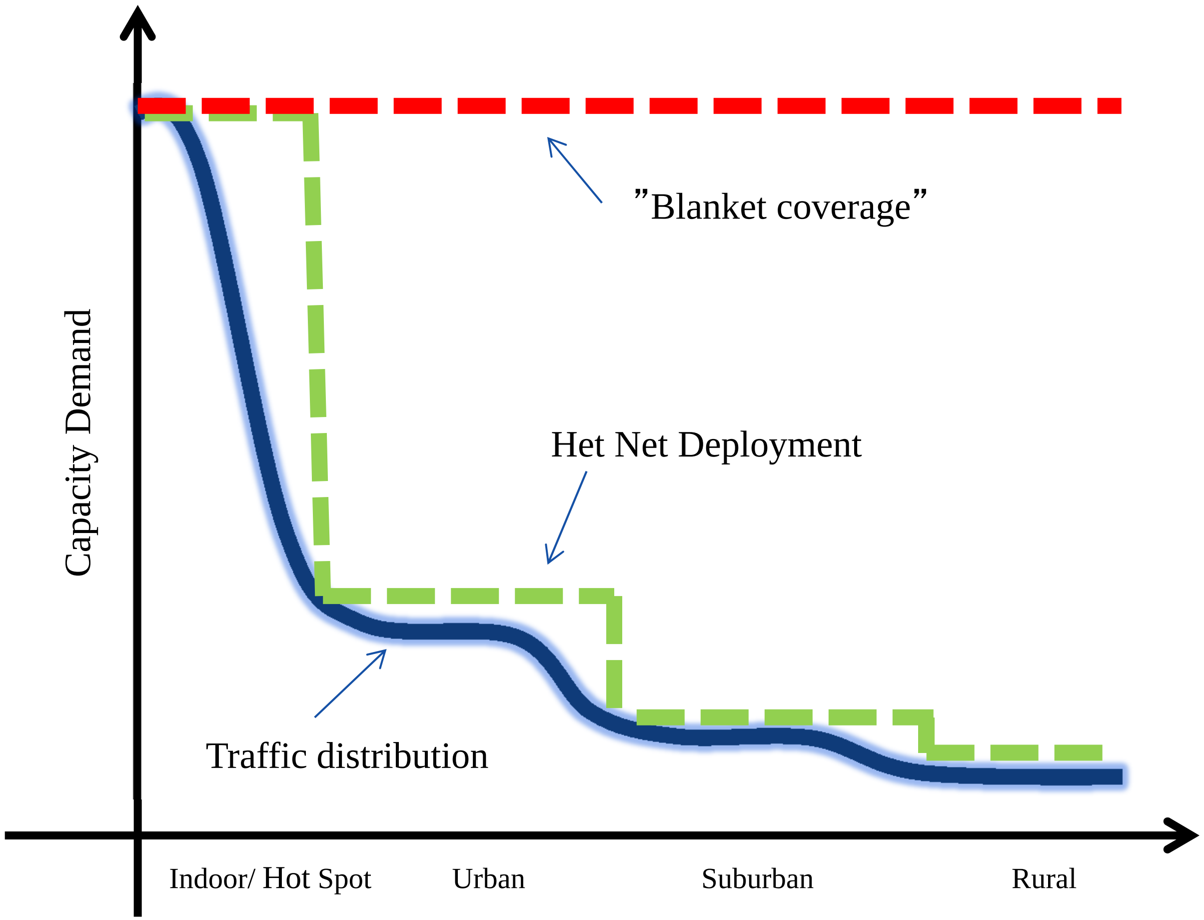

**Key assumptions**

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



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# A World Divided – business aspects

## The coverage world

**Public operators**

Access any-time, anywhere

”Insurance” – guaranteed access

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)

# Where is the ”new” spectrum ?


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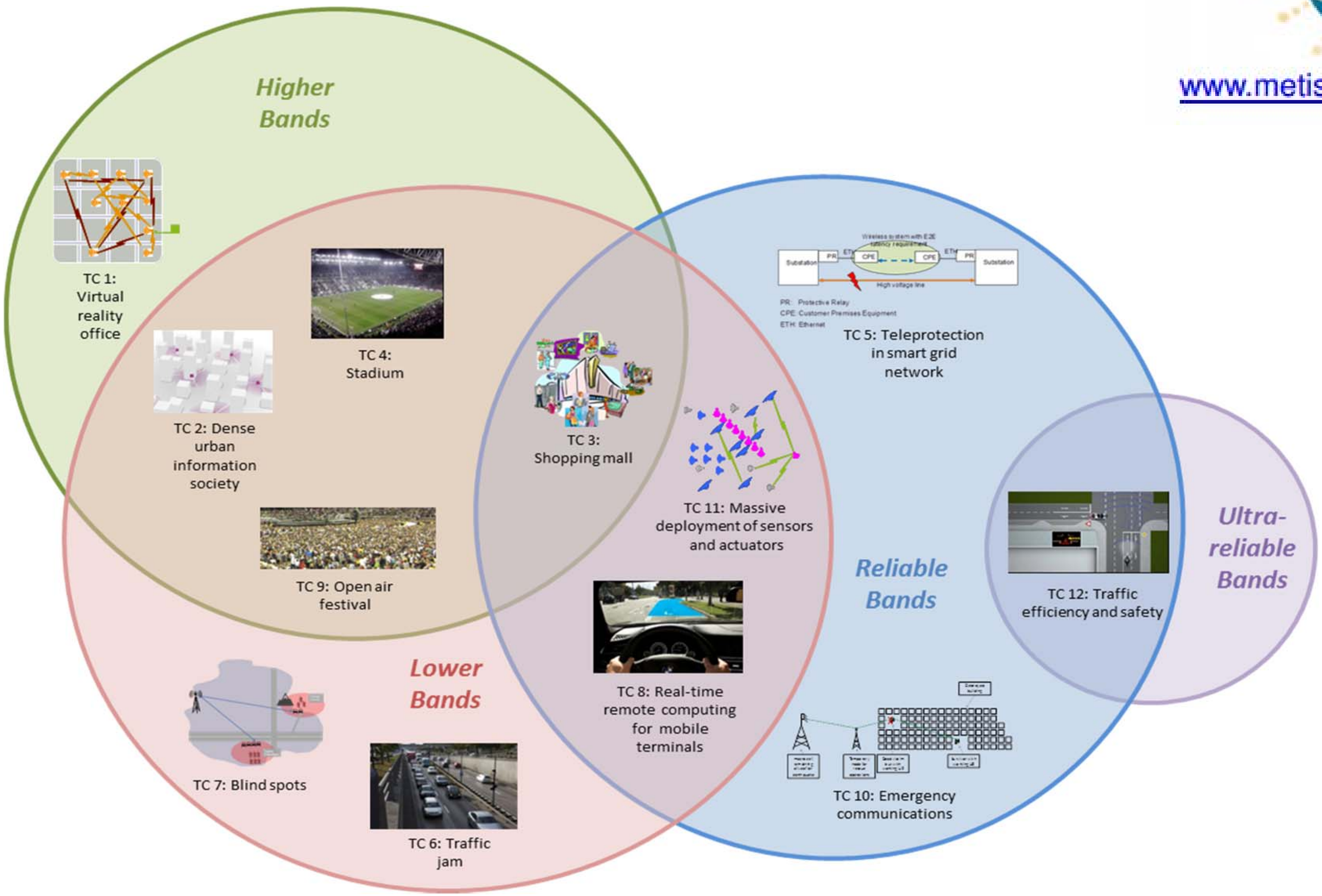
# What kind of spectrum ?

www.metis2020.com



# Spectrum options

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

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

# Spectrum sharing ?

# Criteria for successful (secondary) sharing

Different usage patterns

- If primary and secondary systems compete for the same frequency in the same time & space, this will be a competition the secondary will loose.

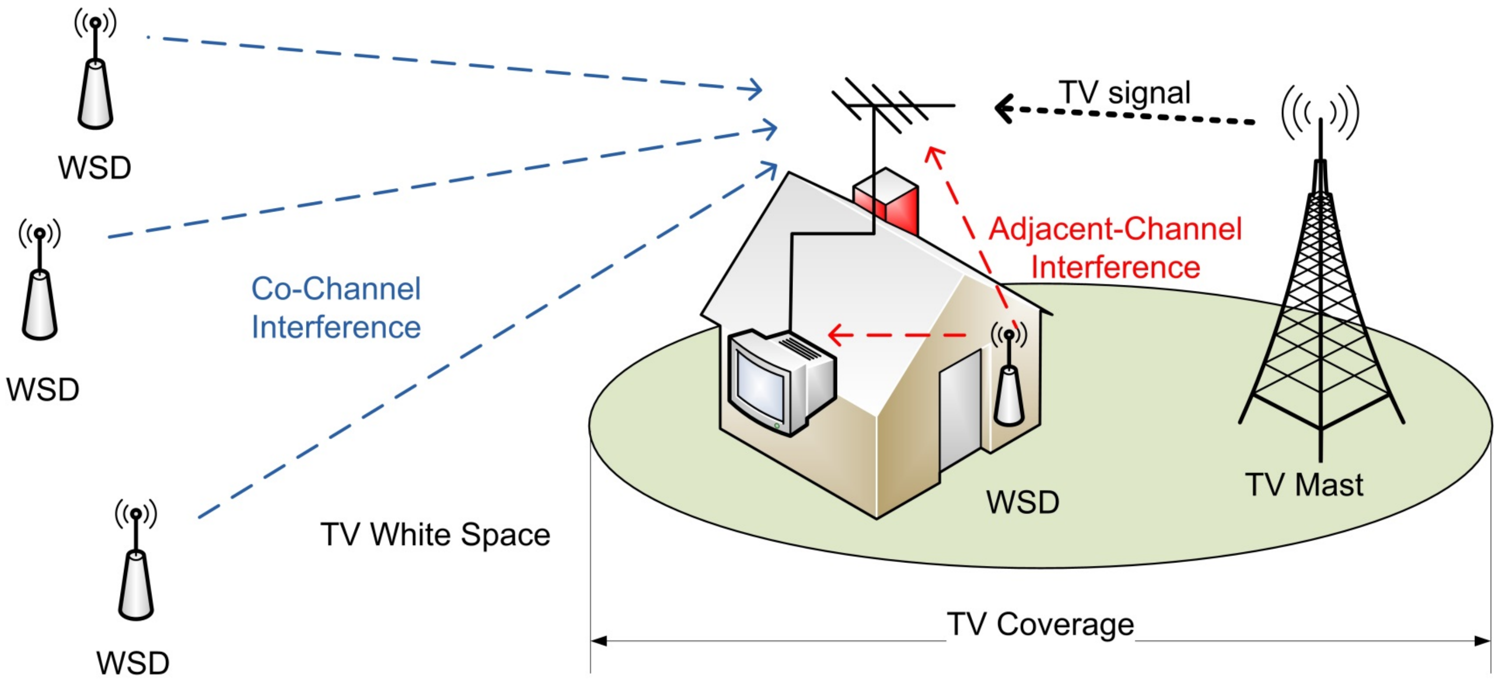
(Detailed) Knowledge about the primary system behavior

- where are the primary transmitters, when and on which frequencies will they transmit..
- where are the primary receivers and what interference will they tolerate ?

Inefficient spectrum utilization of the primary system spectrum

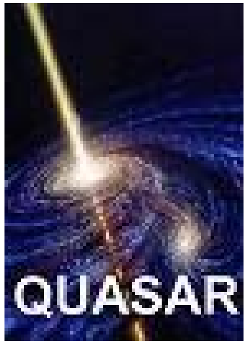
- e.g. the efficiency of the primary system is limited by legacy technology

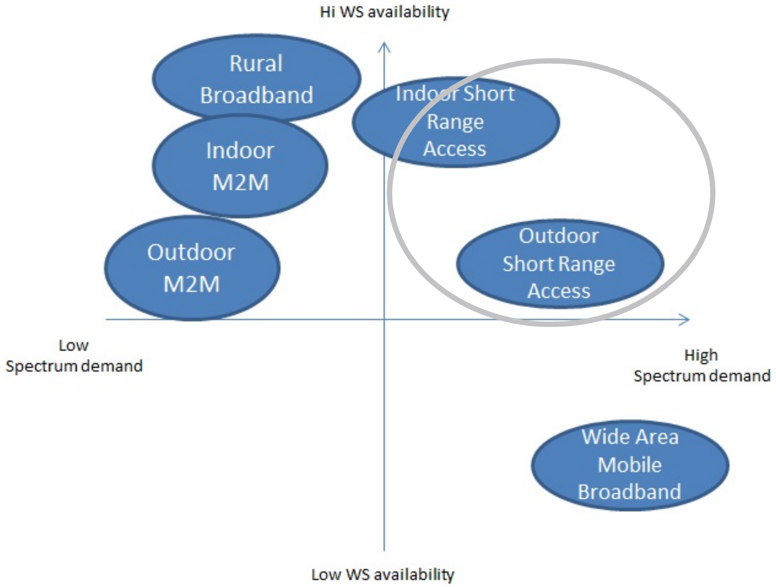
# Co-channel & Adjacent channel interference




Lei Shi, "Efficient Spectrum Utilization of UHF Broadcast Band"
Ph.D. Thesis, KTH June 2014

# The Commercial Sweetspot of spectrum use

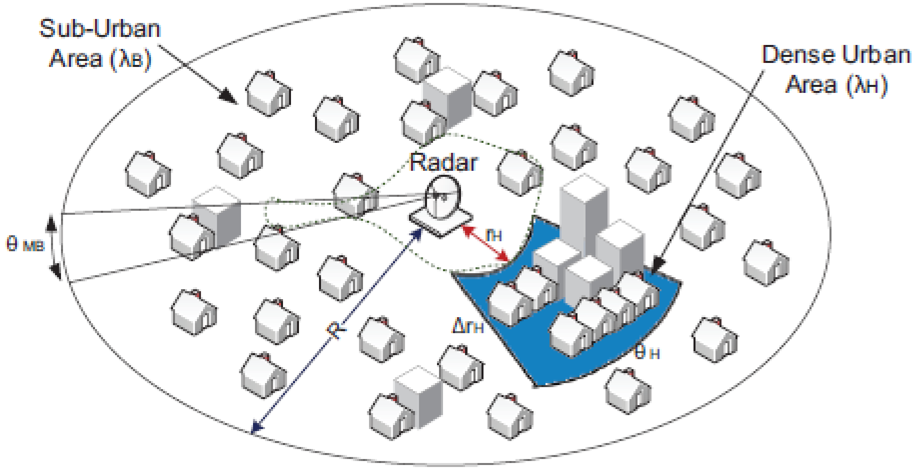


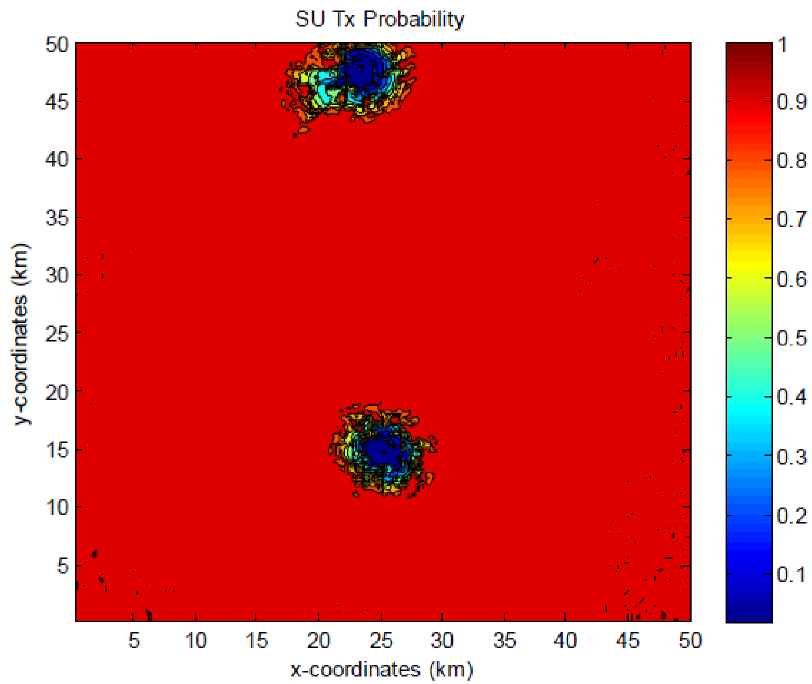




**Short range/indoor high capacity systems**

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

# Example:  ATC radar spectrum shared indoor




Different usage patterns

(Detailed) Knowledge about the primary system behavior

Inefficient spectrum utilization of the primary system spectrum

Stockholm case study

Co-channel, Outdoor, P=10dBm h=1,5m

600 users/sqkm, 15% activity

E Obregon et al "On the Sharing Opportunities for Ultra-Dense Networks in the Radar Bands"
IEEE International Symposium on Dynamic Spectrum Access Networks (DYSPAN), McLean, VA, USA, April 1-4, 2014

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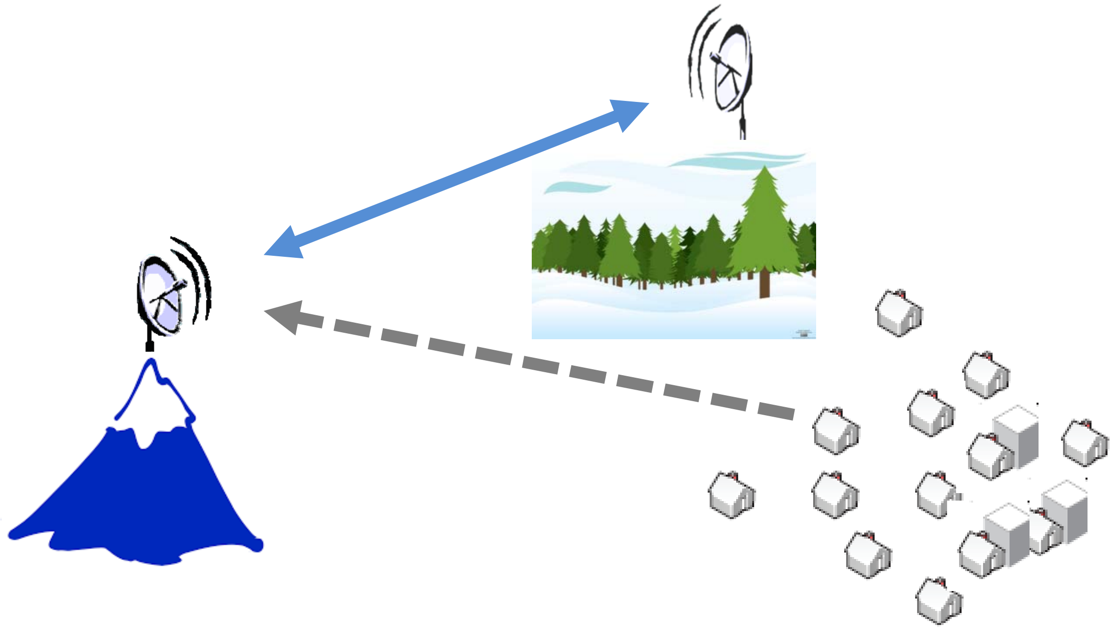
# Microwave link – Indoor sharing scenario



Different usage patterns (spatial separation)

(Detailed) Knowledge about the primary system behavior

Inefficient spectrum utilization of the primary system spectrum (very limited spatial region)

# Key Trends in spectrum sharing

| Today | Tomorrow |
|---|---|
| Transmitter specification | Receiver specification |
| Interference Limits | ”Pain Sharing |
| Secondary access | Sharing / Co-primary |

# Where are we heading - spectrumwise?

Millimeter-Wave, short range, indoor

- Low investment
- High frequencies (>30 GHz)
- Very short range → very limited interference with other services

Open Access

Mobile short range, indoor

- Low/moderate investment
- Moderate frequencies (3-30 GHz)
- Indoor Short range → limited interference with other services

Wide-Area outdoor

- Large, long-term infrastructure investments (>> spectrum cost)
- Low frequencies (<3 GHz)
- Wide coverage → interference with other services

?

Vertical / Horizontal sharing?

Exclusive – LSS – Open Access ?

Exclusive licensing

# Where are we heading - spectrumwise?

## Wide area access

Spectrum needed to lower infrastructure 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

Millimeter-waves to get exclusive spectrum?

## Short range access

Plenty of potential spectrum <10 GHz

Higher frequencies (>3 GHz) for high capacity (lower interference)

Local & temporal spectrum regimes (National Block-licensing inefficient)

Unlicensed, Secondary, LSA, ”Instant licensing”

Infrastructure vs Spectrum Sharing ?

# Some conclusions

- Wireless Cloud Access – the dominant design of future services !?
- Indoor ultra-dense deployment – a completely different ballgame
  - Systems constraints
  - Spectrum sharing feasible
- Spectrum not really a fundamental limiting factor for capacity
  - Matching to infrastructure investment life cycle