

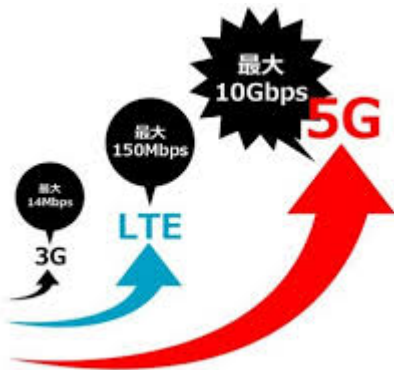
Is it a bird? .. a plane?



No, it's 5G!

Jens Zander

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KTH – The Royal Institute of Technology,
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Outline

- **Why do we need 5G ?**
 - Transparency & mobile data tsunami
 - Things that communicate & the Internet of Senses
- **Are there Scalable Infrastructure Solutions ?**
 - The two worlds – or are they three ?
 - The Resource Triangle: Cost, Energy, Spectrum
- **What are the technologies we should be looking for ?**



Key trend 1: Transparency eats efficiency for breakfast

Why do we have a Data Tsunami? Dominant designs

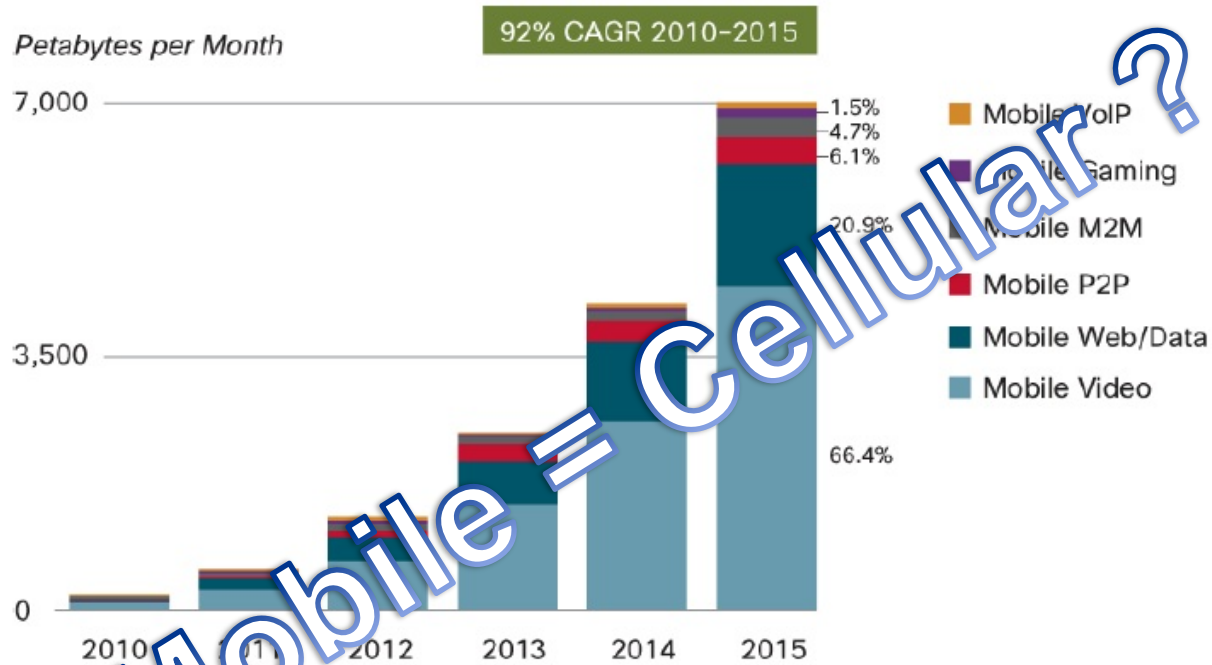
- **Internet access** + Cloud based solution = the Dominant Design for all application involving communication – since 2007 also on mobile
- Simple interface **IP** for all "apps" creates explosive growth – works on all platforms
- Inefficient for (almost) all applications: we buy flexibility at the 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 Mobile Data avalanche (as seen in 2010)



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

Source: Cisco, "N1 Mobile, 2011"

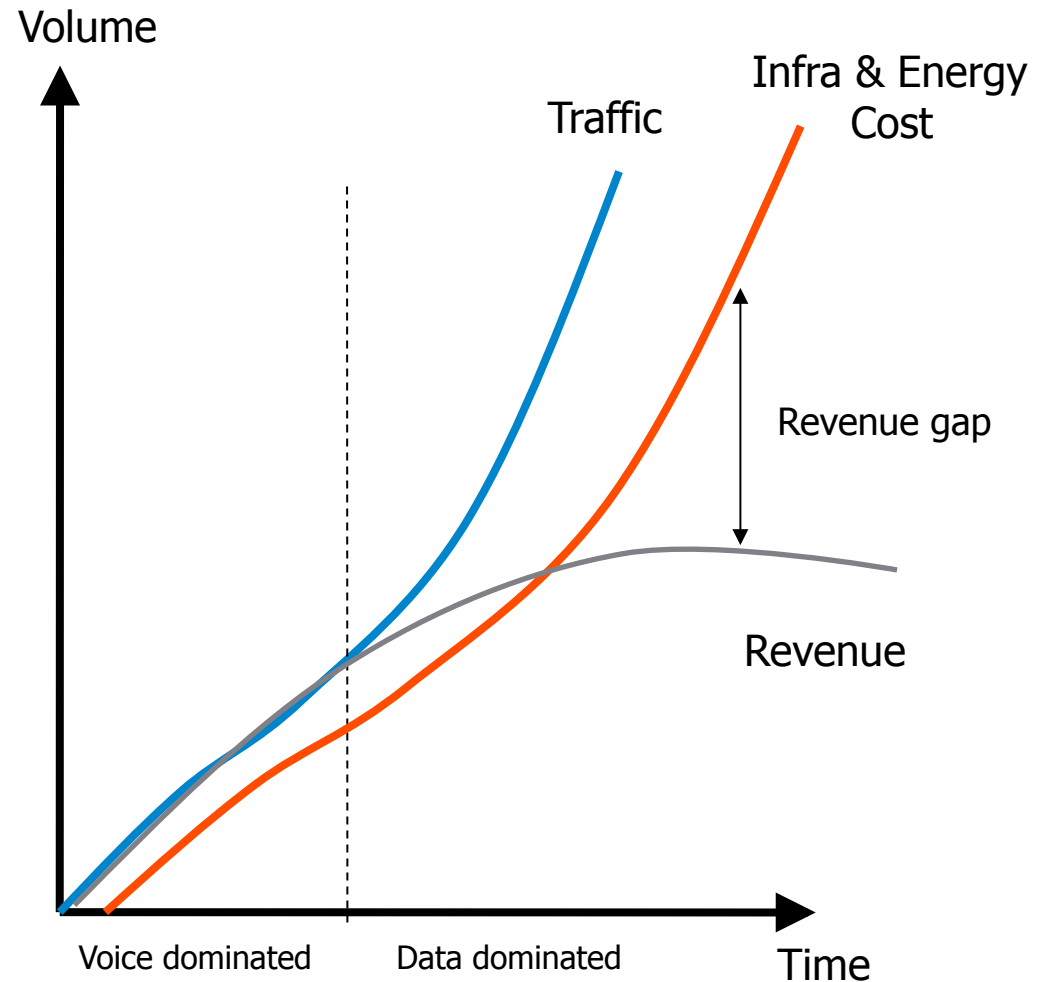
Exponential growth
Assumes **zero marginal cost** for access
How long can this be sustained ?

Operator dilemma: More for less money

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

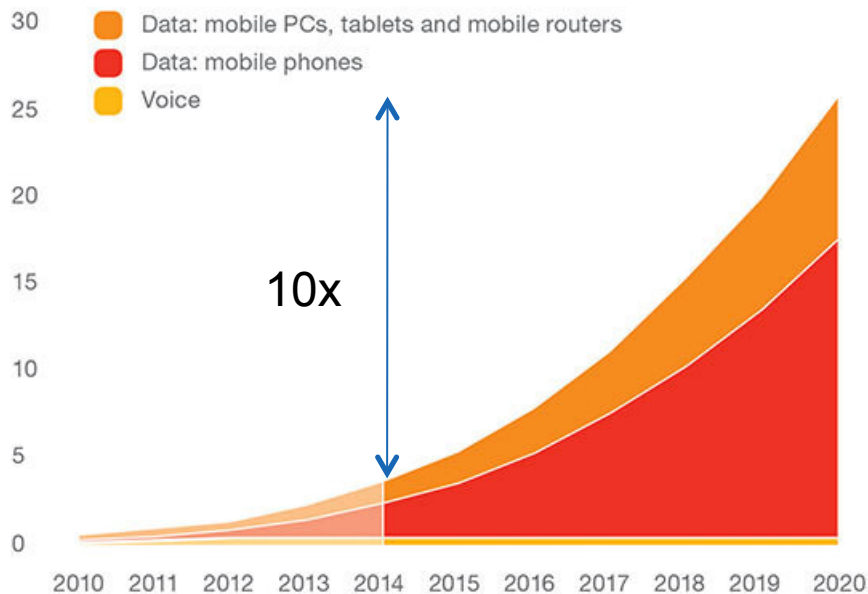
$$C_{SYS} = c_{BS} N_{BS}$$

Challenge:
 1000x lower cost/bit



Cellular traffic estimates now more modest

Global mobile traffic (monthly ExaBytes)



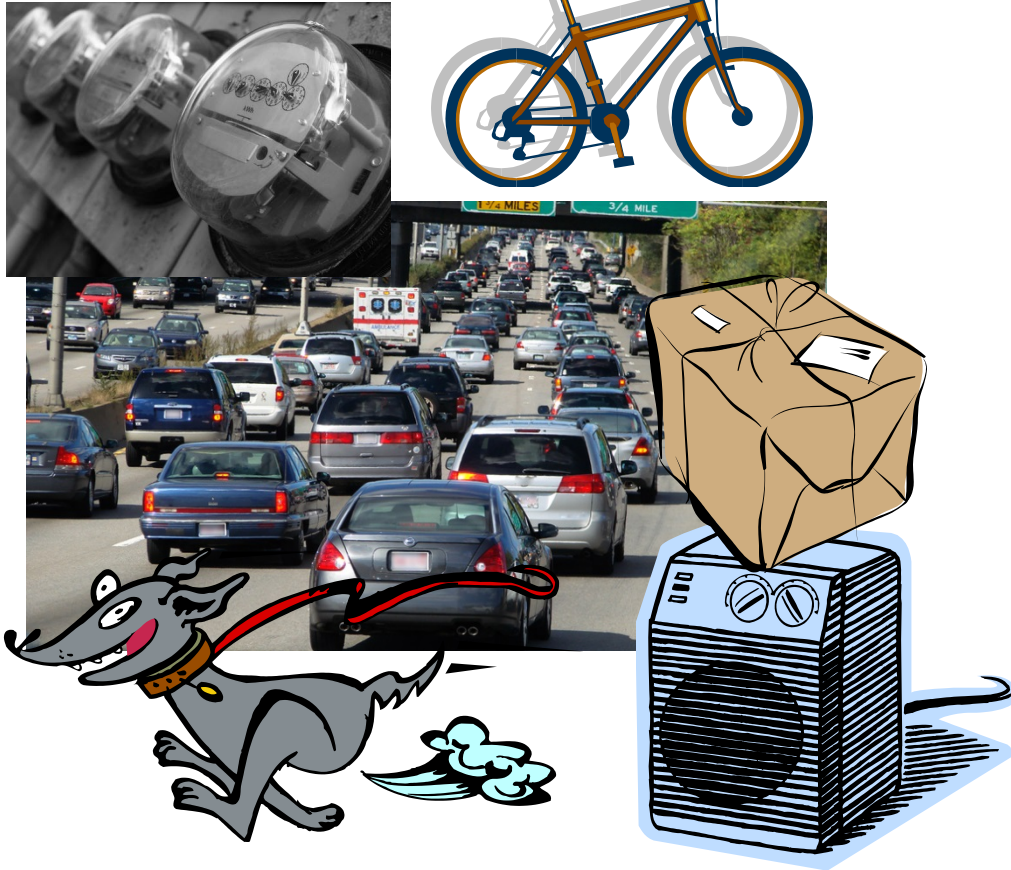
- Market saturation ?
 - Everyone has a smartphone?
- Volume based charging ?
 - "Buckets" instead of "all-you-can-eat"
- Bulk of the traffic off-loaded elsewhere ?
 - WiFi

Source: Ericsson Mobility Report, Nov 2014



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

Things that communicate

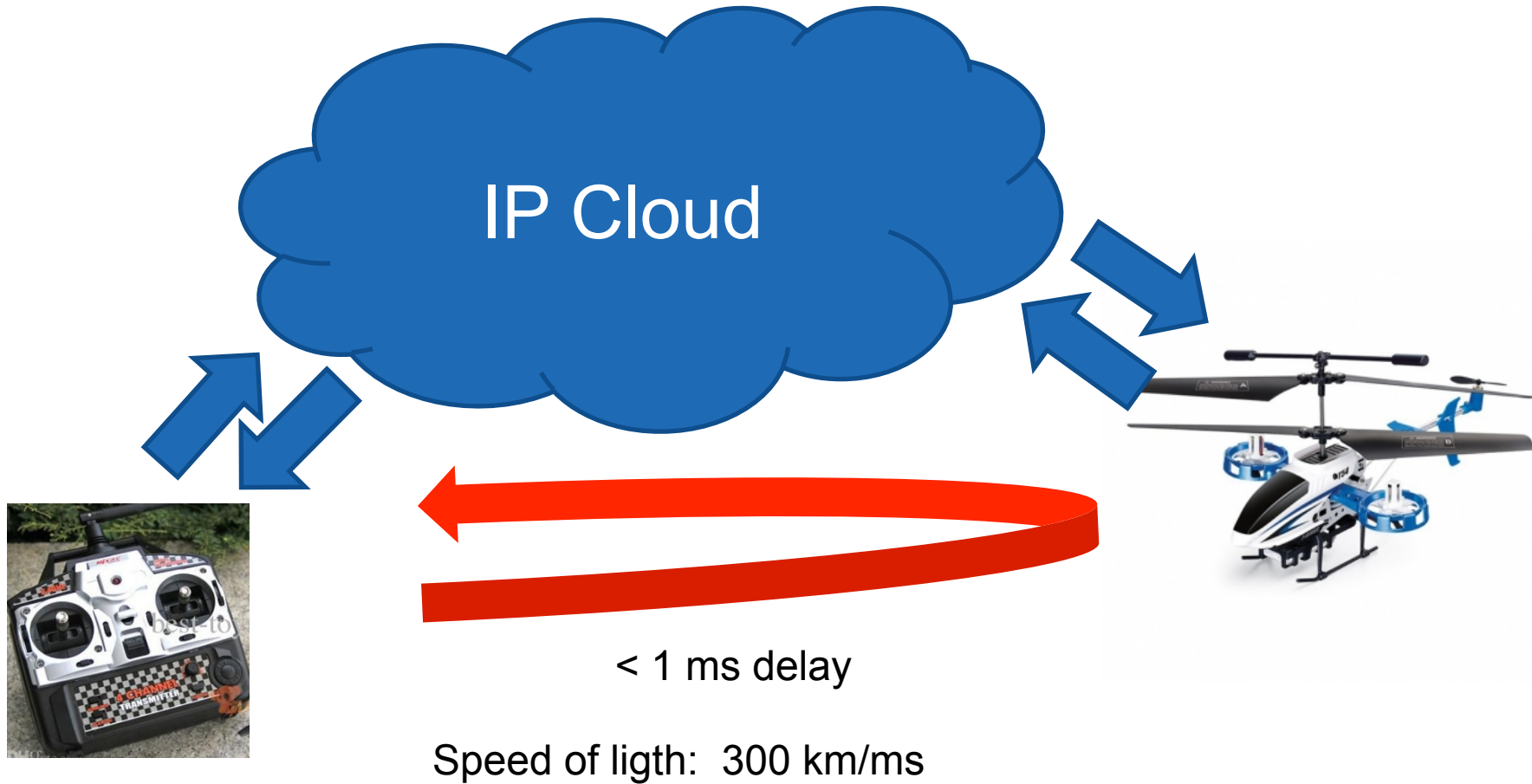


Internet of Things

- 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")

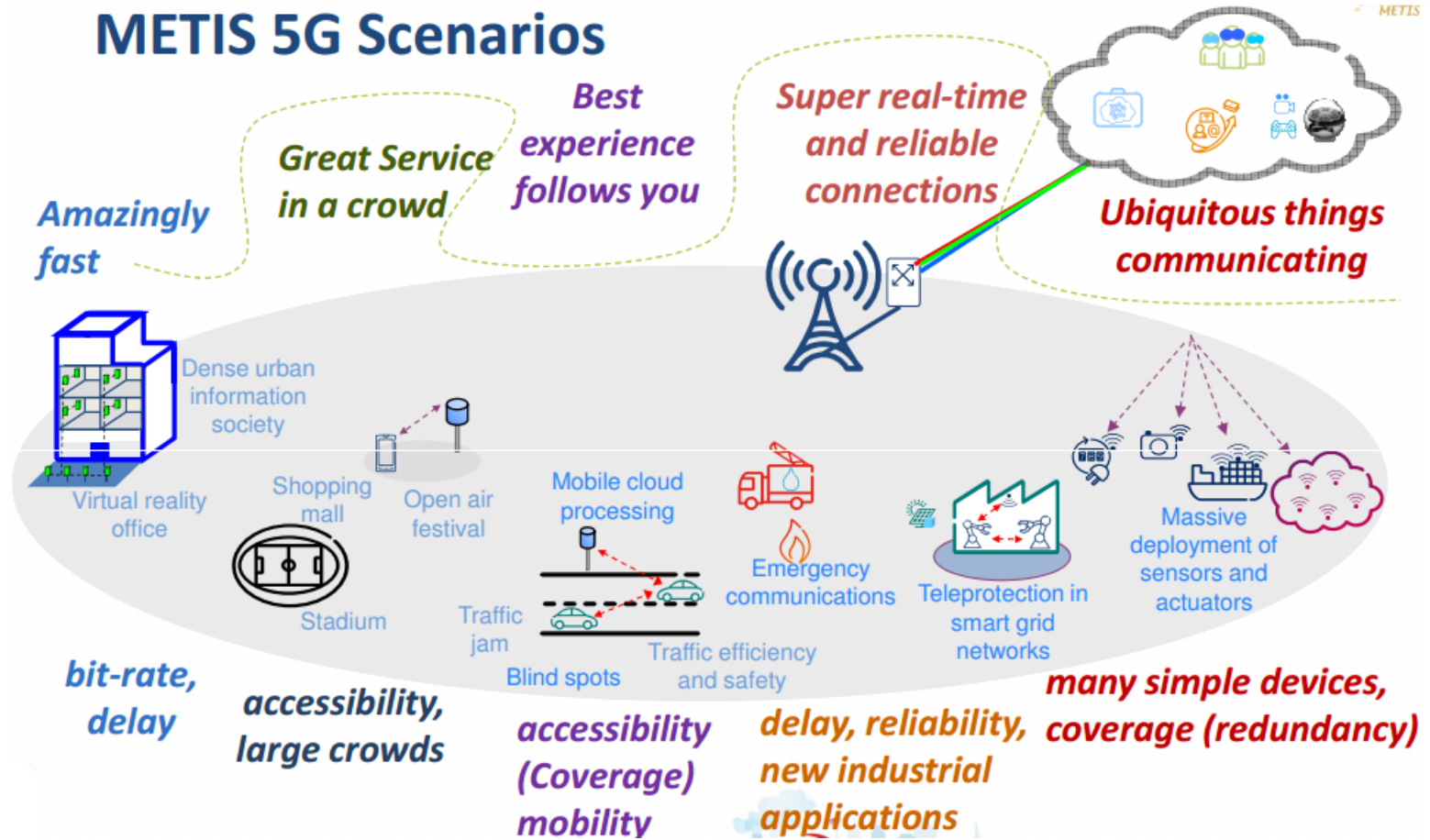


Mission critical communication (Super real-time, super reliable...)



Source: The Economist, April 20th, 2013

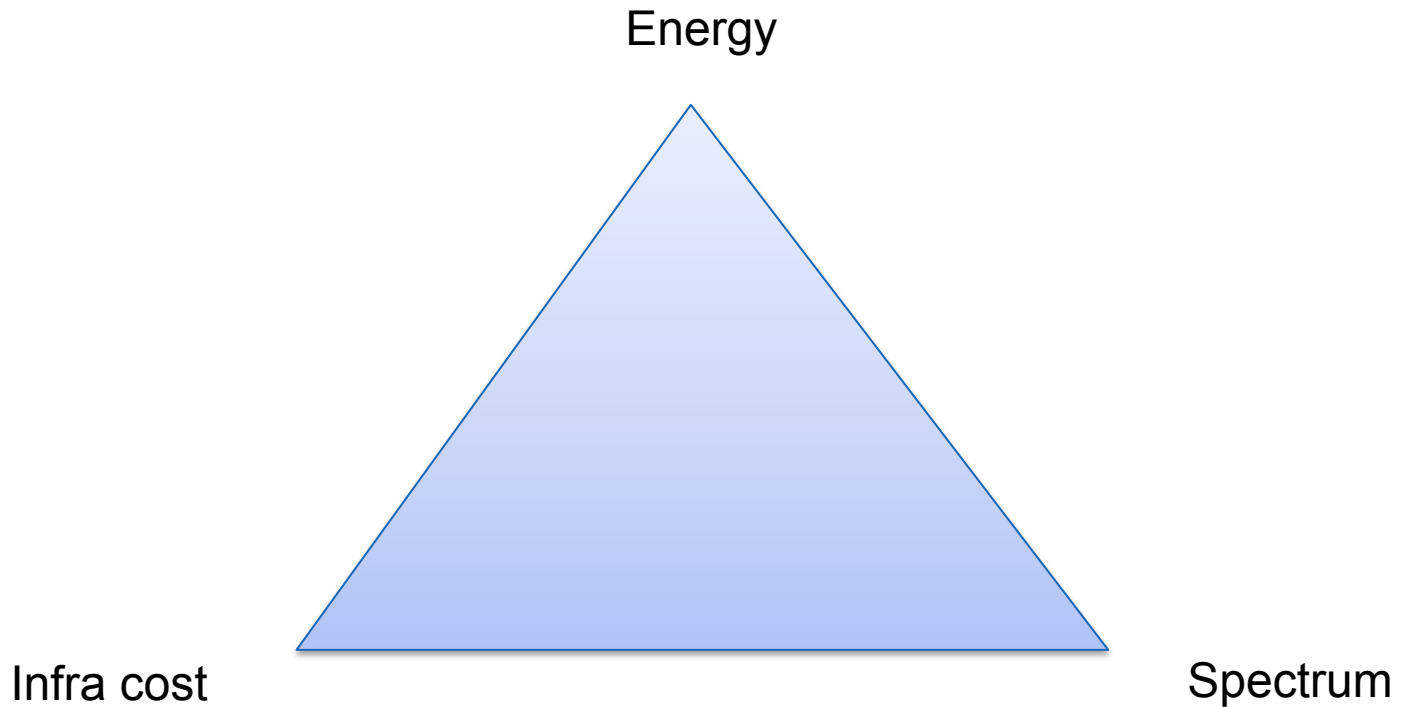
METIS 5G Scenarios



Is there (one) Scalable Infrastructure Solution ?



The Resource Triangle



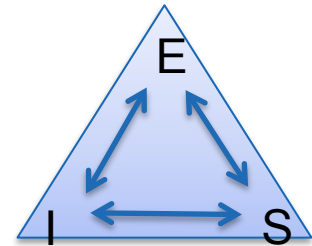
$$C_{tot} = C_{spectrum} + C_{infra} + C_{energy}$$

How to increase capacity ?

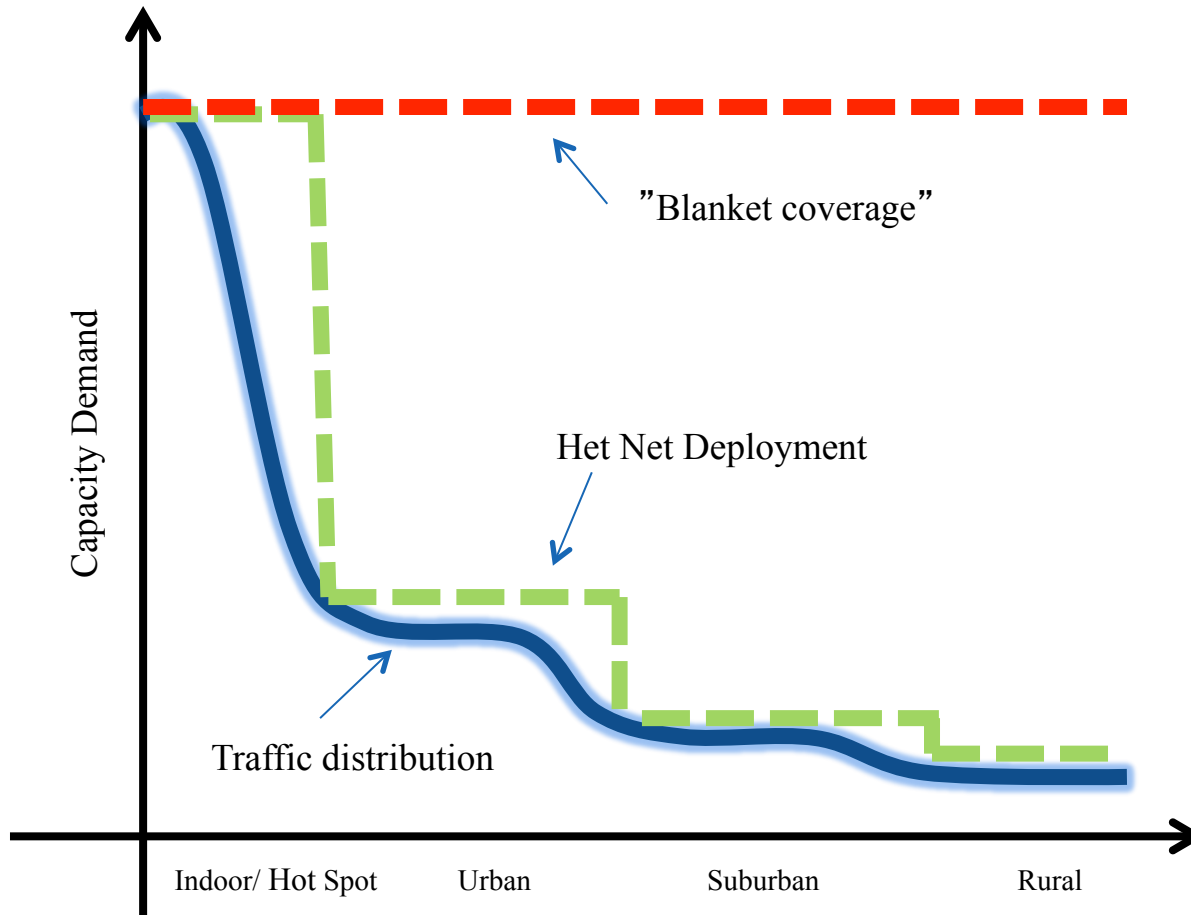
$$R_{tot} \approx \frac{\eta}{A} N_{BS} W_{sys} \text{ Gbit/s/m}$$

$$C_{SYS} = c_{BS} N_{BS} + c_{sp} W_{sys} + c_E E_{sys} (\eta, N_{BS}, W_{sys})$$

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



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



The Light Analogy I : HET NETS



Outdoor – Wide Area

- Indoor – Short Range



A World Divided

The coverage world



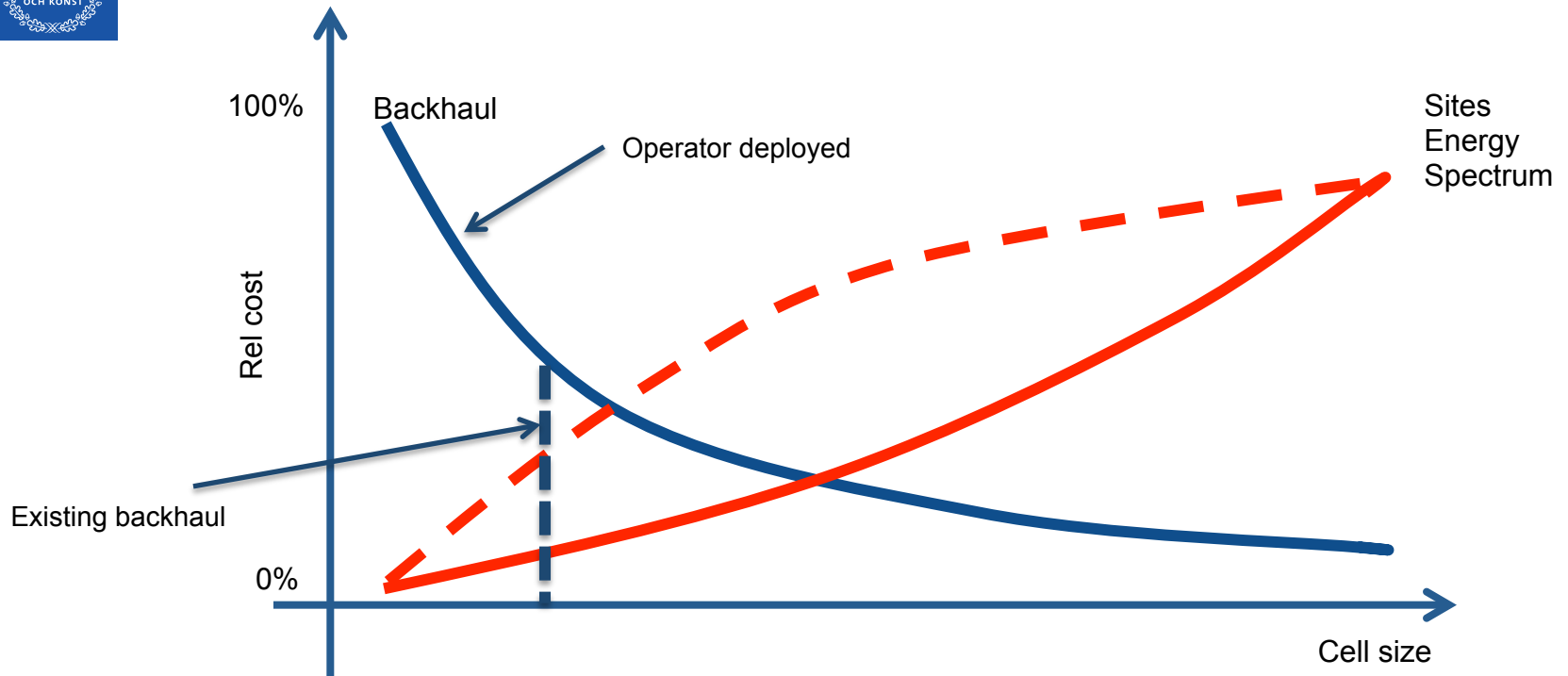
Industry grade equipment
High power/Wide area
24-7 availability
High **system** complexity

The capacity world

Consumer grade equipment
Low power/Short range
Reliability through redundancy
Low **system** complexity

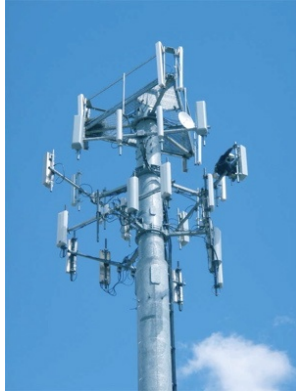


Cost factors



A World Divided

The coverage world



Public operators

- **Access any-time, anywhere**
- "Insurance" – guaranteed access at moderate data rates (<10Mbit/s)
- Monthly fee
- Power/Site/Backhaul
- Exclusive spectrum licensing – spectrum sharing

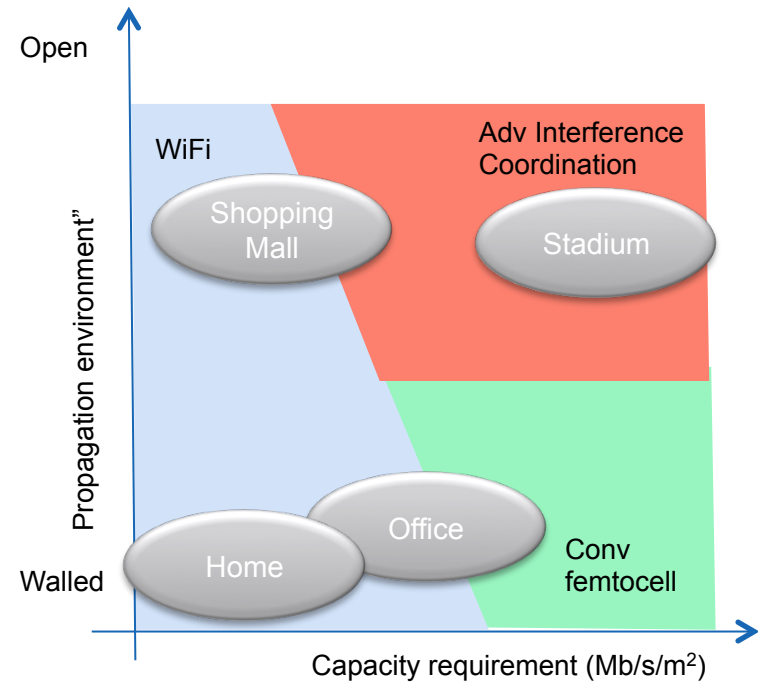
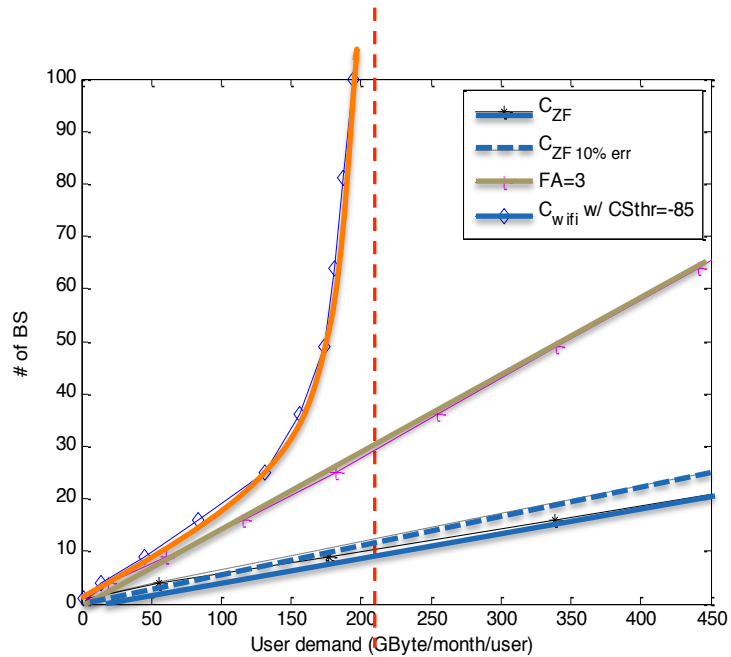
The capacity world

Facility owners

- Local access - "off-loading"
- Sanitary requirement / no charge
- User experience – high data rates
- Ultra dense deployment – Interference
- Low power, "no" site cost, existing backhaul
- Post-code licensing – infrastructure sharing



Capacity and Economic feasibility



More access points - or more expensive backhaul (for coordination) ?

Is there enough capacity ?

| | Intersite | Spectrum | No BS | Cap/Site | Area cap |
|--------------|-----------|----------|----------------------|----------|-----------------------------------|
| Macro | 300 m | 500 MHz | 10 /km ² | 1Gb/s | 10 Gb/s/km ² (outdoor) |
| WiFi - today | 30m | 500 MHz | 1000/km ² | 1 Gb/s | 1 Tb/s/km ² |
| WiFi -ideal | 1/room | 2 GHz | 50K/km ² | 4 Gb/s | 200 Tb/s/km ² |

Simple area-based calculation – outdoor/indoor wall penetration not included

Where are we heading - spectrumwise?



Wide-Area outdoor

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

Exclusive licensing



Mobile short range, indoor

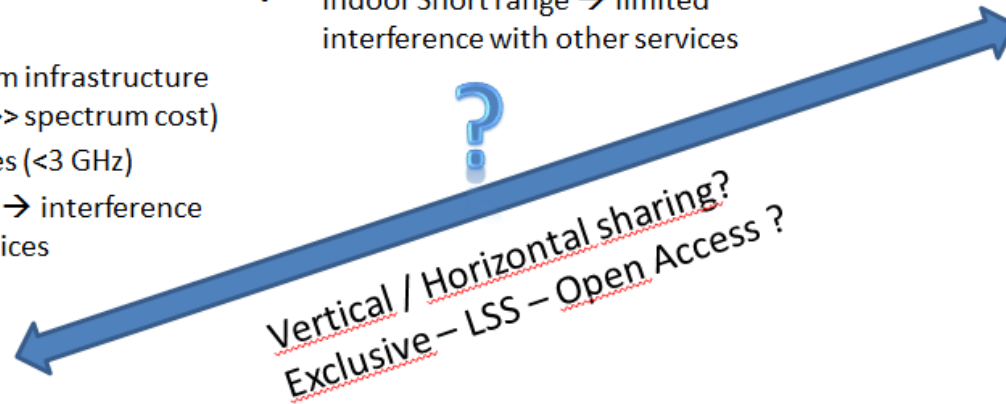
- Low/moderate investment
- Moderate frequencies (3-30 GHz)
- Indoor Short range → limited interference with other services



Millimeter-Wave, short range, indoor

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

Open Access



Where are we heading - spectrumwise?

Wide area access

- Spectrum need 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



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 ?

Key Trends in spectrum sharing

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



Can the Things use the same infrastructure ?

Very diverse requirements



| Requirement | Human centric | Machine Type |
|--------------------|---------------|-----------------------|
| Capacity | Very Large | Small |
| Number of devices | Moderate | Very large |
| Wide area coverage | Important | (Sometimes) Important |
| Reliability | Moderate | (Sometimes) High |
| Cost | Moderate | (Sometimes) Very low |
| Power consumption | Moderate | Sometimes) Very low |
| Delay | Moderate | Sometimes) Very low |

Everything under one roof ?

Transparency vs Efficiency



The IP-access world

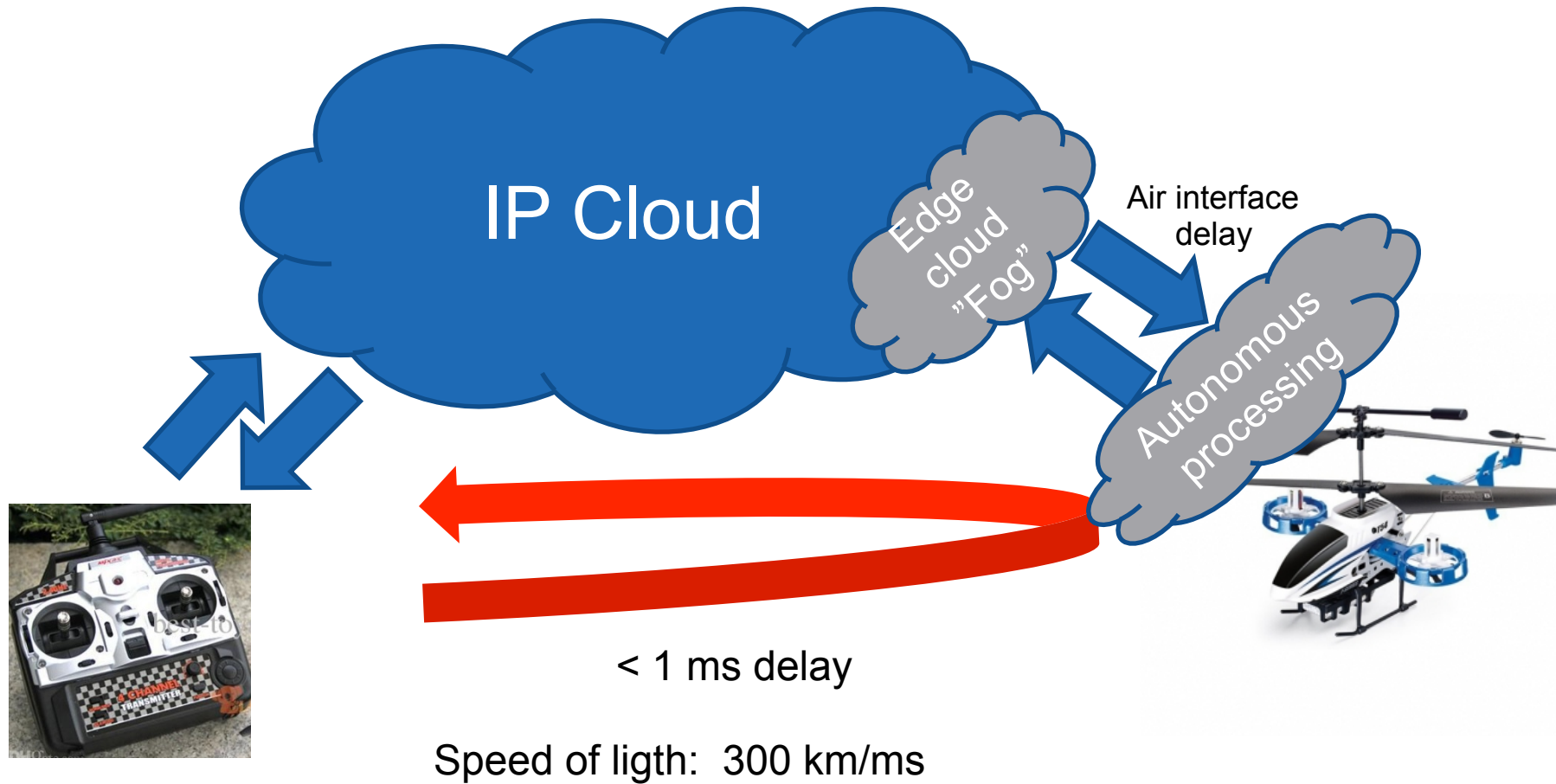
- Large volumes of standardized equipment, unified platforms
- Low efficiency, overprovisioning of resources
- Willingness to pay for flexibility



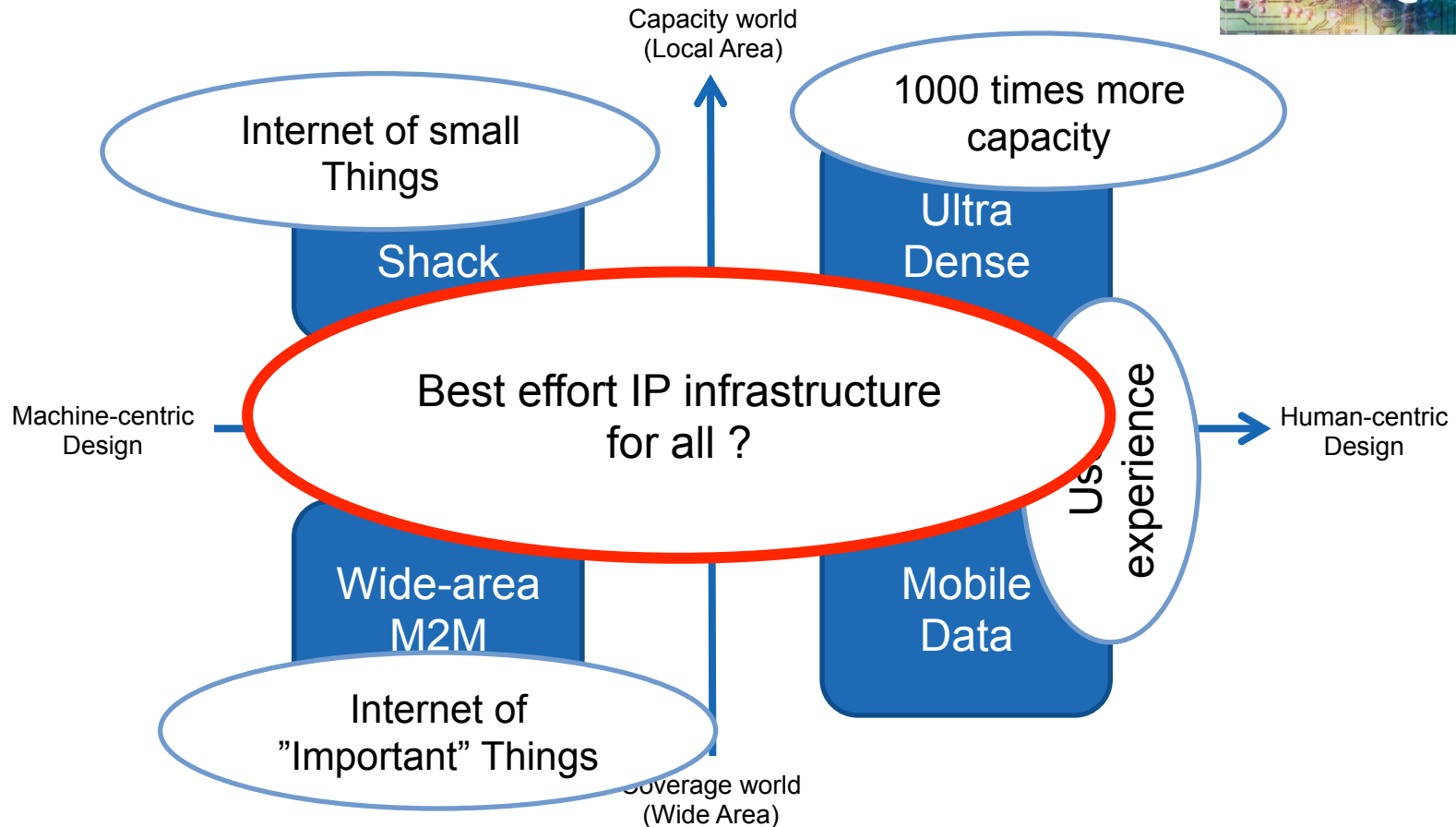
The MTC world

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

Distribution of resources critical

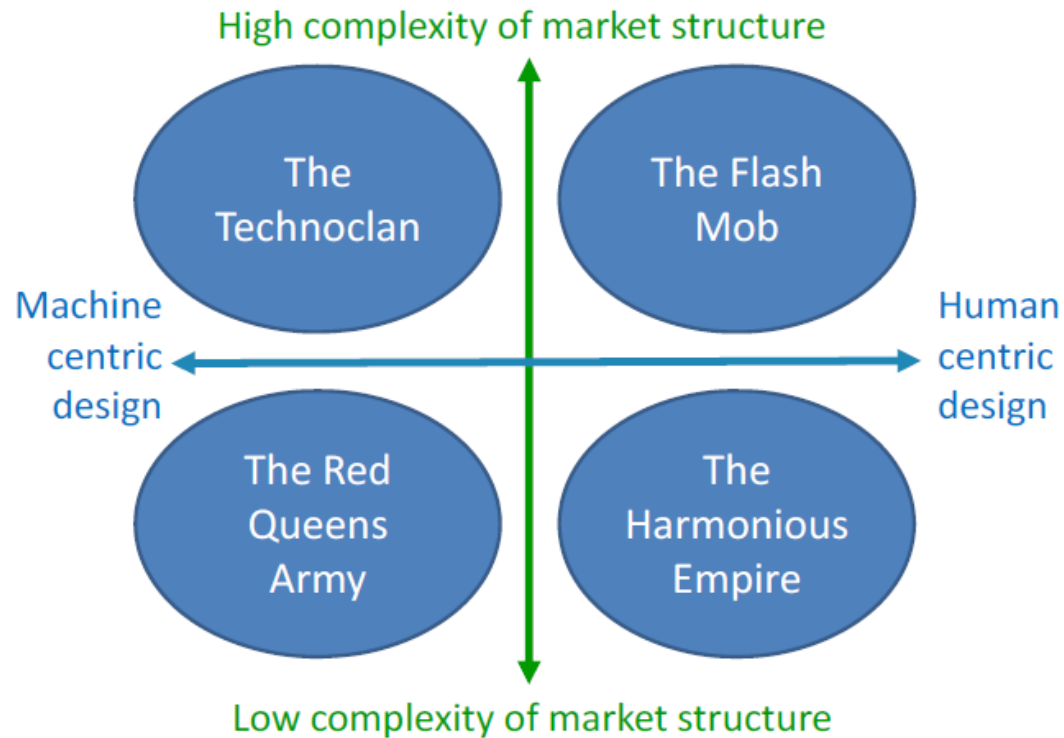


Mobility Foresight – Alternative (Technical) Mapping



Single infrastructure = traditional operator model ?

Mobility Foresight



In Summary: Fundamental/revolutional 5G challenges



- **Addressing the Internet-of-Important Things:**
 - Scalable, low power, low-cost super-reliable wide-area
 - Extreme low latency
 - Distribution of computational resources

- **Spectrum/Infrastructure sharing concepts**
- **"Plug-and-play" ultra-dense**



In Summary

5G is

- **Not technically needed to contain most of the "Data Tsunami"** (can be managed by evolved 4G +WiFi)
- Addressing new challenges in **large scale, wide-area infrastructure for M2M** applications
- Not only about connectivity but a **computational platform** to manage generic resources like processing and storage
- Important to the incumbent industry to show renewal and claim (exclusive) spectrum **to sustain current business modell**





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Upcoming

| | | | | | |
|-------------|--|-------------|--|-------------|--|
| 08 MAR 2014 | Thursday Tea Time Talk with Lars Östrow from King Candy Couch (Sage) | 19 MAR 2014 | Wireless Thursday seminar with Peter Karlsson, Sony Mobile | 19 MAR 2014 | Lunch meeting KTHW on wireless: high speed network for small and medium sized enterprises, KTHW (KTH Technology Network) |
|-------------|--|-------------|--|-------------|--|

Highlights


- The Games Industry: Present & Future. Why is it important to Network
- Video: Jens Zander on the revenue gap for 100km operators
- The 2014 Johannesberg Summit is set to take place on May 10-12

What's new? / View all updates

| | | | | | | | |
|-------------|--|-------------|---|-------------|---|-------------|---|
| 26 FEB 2014 | Interview with Andrés Laya on new project M2-H2020 | 17 FEB 2014 | Call for workshop papers - Workshop on M2M solutions and services | 17 FEB 2014 | 2 PhD position in Wireless Techno-Economics | 04 FEB 2014 | DN news article on Media project with Jens Zander |
|-------------|--|-------------|---|-------------|---|-------------|---|



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LTE'S BROTHER WIRELESS THE UNWIRED PEOPLE

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

Posted on September 19, 2011 by [Jens Zander](#)

Recommendations: 11 All den första bland dina vännare eller rekommenderade.

We learn from Economics theory that, if you want to trade goods effectively, these shall be as general as possible, suitable by anyone or 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 40) 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. "LITE/LTE2") is to provide a "black 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 catch ? Well, its what in the business is called "Legacy Equipment", i.e. anything that is out there before these new regulations are put into place. We have already numerous examples of interference problems. Airport radars, GSM-R (railway) systems, TV-receivers are facing interference from new LTE/LMDS systems that are put into operation in neighboring bands. Is something wrong with these systems ? No. Are they violating the spectrum mask rules ? Not likely. Would the problems go away with perfect new equipment ? Unfortunately not.

You see, most of this equipments was not designed to have a LTE or LMDS base station next door. The wire 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 users, the television set manufacturers or railways modify their systems ? Not likely. There seems to be "squatters rights" in the spectrum domain – the guns 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 LMDS in the 900 MHz band is OK as long as you stay a kilometer away from the nearest airport (i.e. where the highest population 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.

Filed in: [Spectrum-Systems](#) | [2 Comments](#) and [1 Pingback](#)

Recent Posts

- Technology Neutral Spectrum Assignment – a nice concept but is it realistic ?
- Chesson 2011-Some notes
- URSI General Assembly 2011, Politics and Spectrum usage
- LightSquared – even more money down the drain?
- "Big Brother" says streaming more than 100 times is illegal

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- Business
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Comments

Recent Comments

Jander 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 Faisal Yousaf H, 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

wireless@kth