Perspectives on 5G

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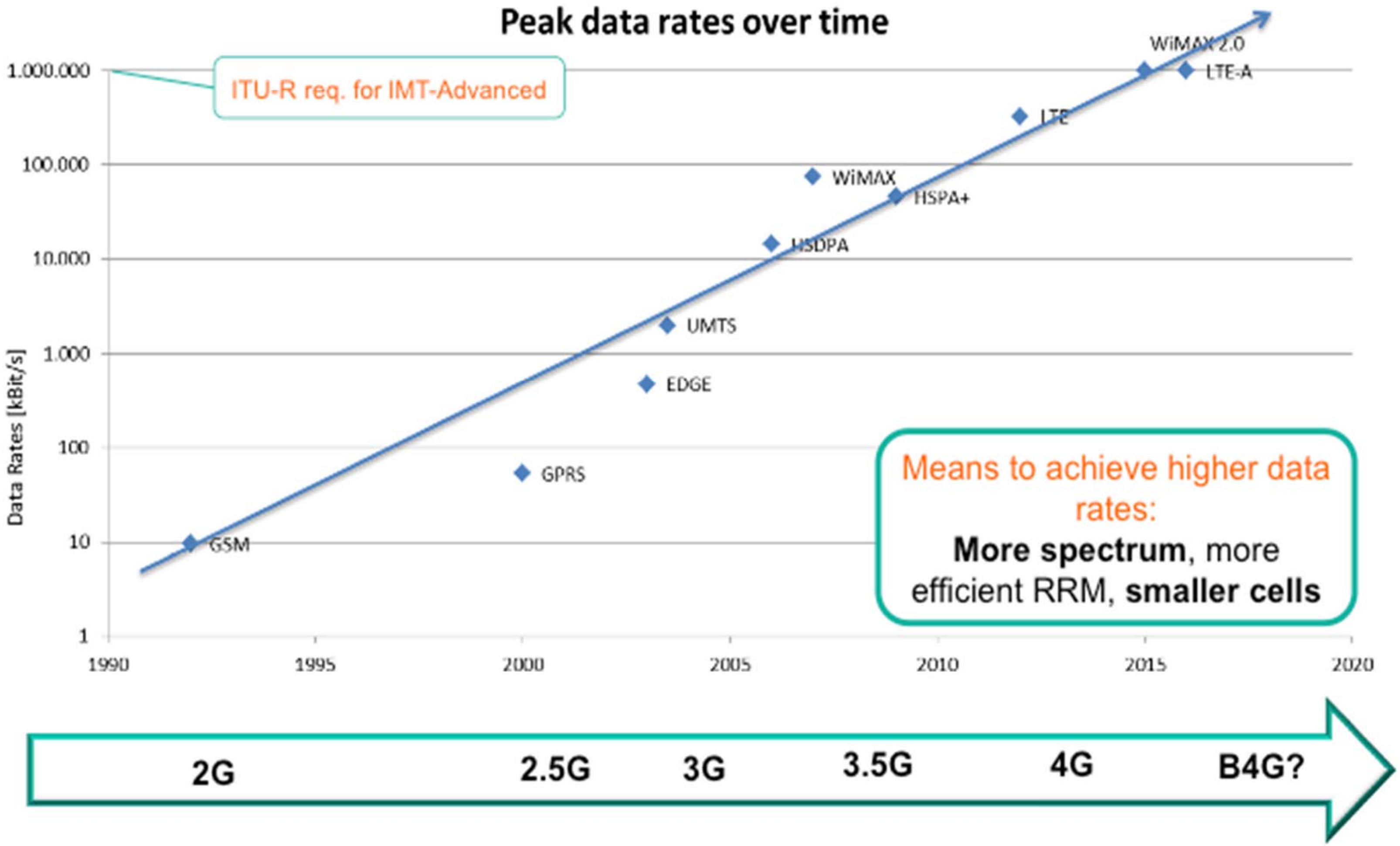
Where innovation starts

Overview

- Introduction
- What drives “5G”?
- Challenges: what is required by 2020?
- What are the solutions and the questions?
- 5GPPP program
- Conclusion

Cellular Evolution



Source: NEC – Andreas Maeder, Feb 2012

What drives “5G”?

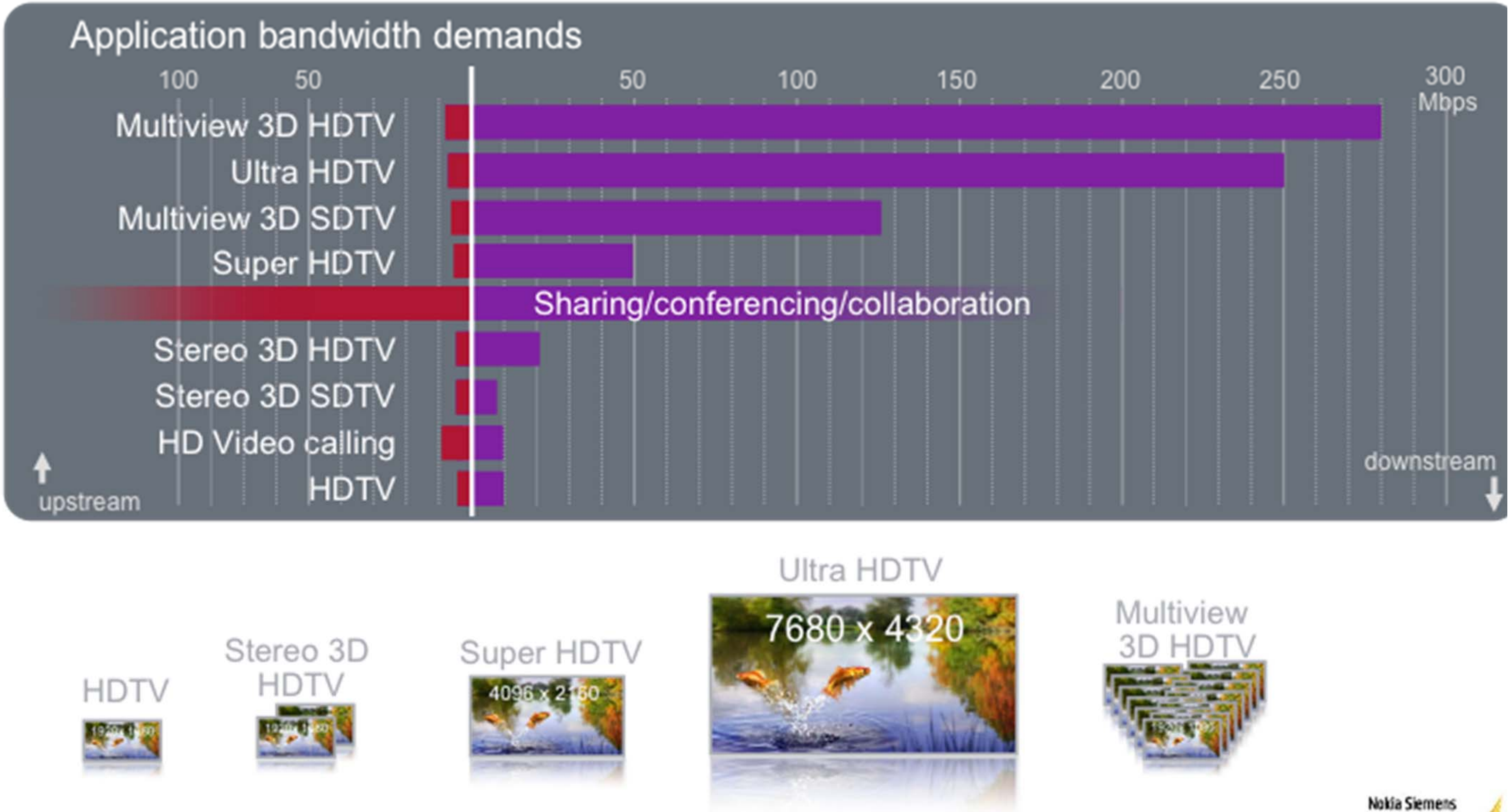
- Growth of existing applications
- New applications and new ways of doing things
- Main actors: the IT industry, read Google, Apple, Facetime, Amazon, IBM etc and their Chinese equivalents

Existing Applications

- Email, file transfer, etc.
- Real-time audio (VoIP)
- Video*:
  - 2013: 66% of IP traffic, excluding P2P filesharing
  - 2018: 79%
  - More and higher data rates

**** Cisco Visual Networking Index: Forecast and Methodology, 2013–2018***

Bandwidth hunger is ever increasing
Video & TV drive needs



Source: Nokia Siemens Networks

  29th Wireless World Research Forum Meeting, Berlin, Germany, October 23 to 25, 2012

Nokia Siemens Networks

New Applications

- Instant Messaging (IM) … with big files: lots of short connections, high data rates
- Internet-of-Things (IoT) and Machine-to-Machine (M2M): massive numbers of devices and connections, little data

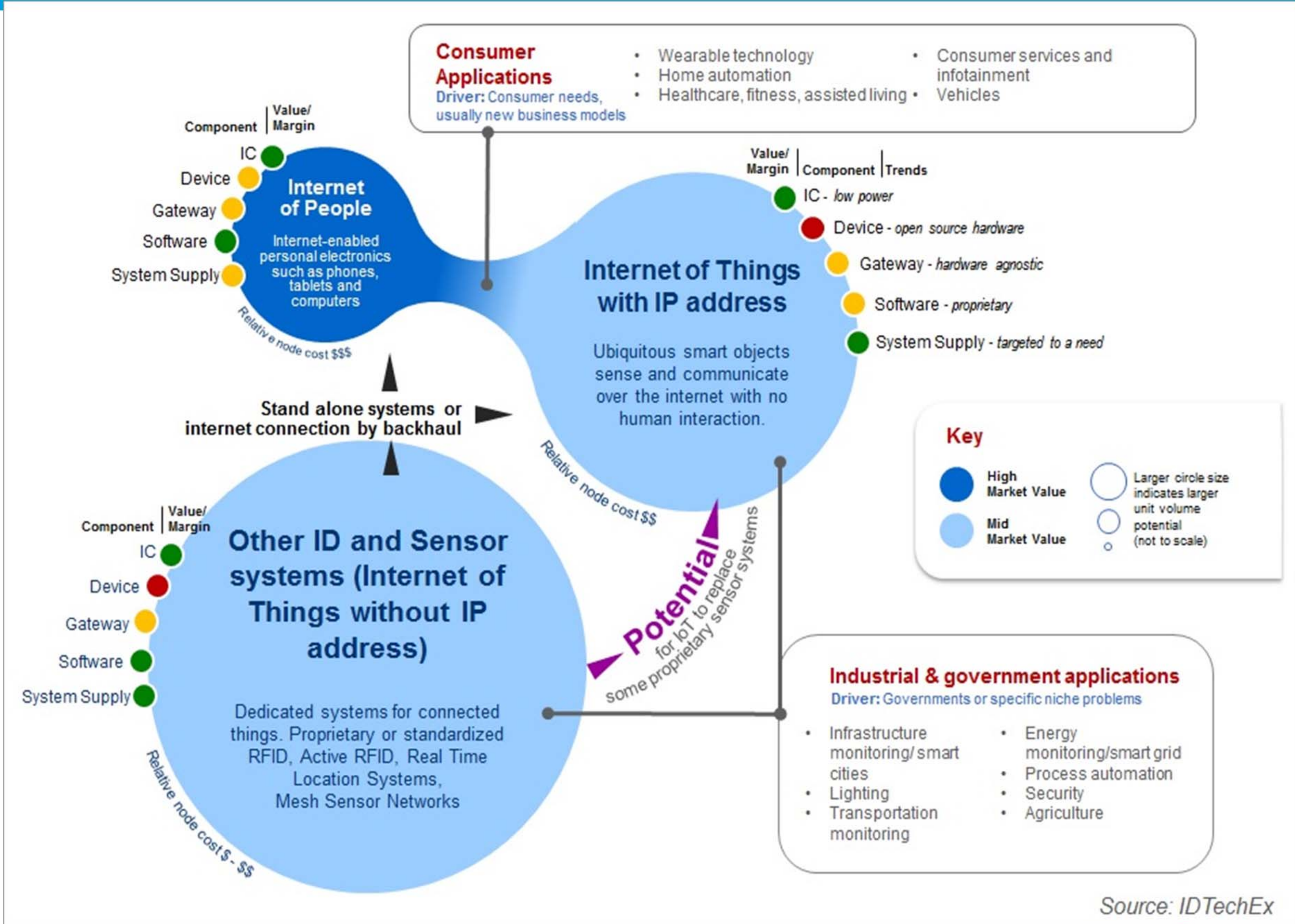
  > 50 billions of connected devices in 2020*

Inefficiency and

heavy load on Control and Management plane

***** *http://www.ericsson.com/res/doc/whitepaper/wp-50-billions.pdf***

Internet of Things (IoT)



Source: IDTechEx

New Applications

- Cloud based services: frequent fast connectivity everywhere and low latency
- Critical applications, e.g., health, safety and security, traffic systems: guaranteed QoS
- Some vehicle-to-X communication ITS: critical and time-constrained (Check poster Chetan Math)
- Tactile internet (Fettweis): human in the loop control of sensing-actuating systems, e.g., remote robot control, remote surgery, remote vehicle control, drones. etc

Challenges: what is required by 2020?

- Traffic/capacity and performance
- Deployment challenges.
- Spectrum challenges.
- Energy challenges.
- Health challenges?
- Business challenges.

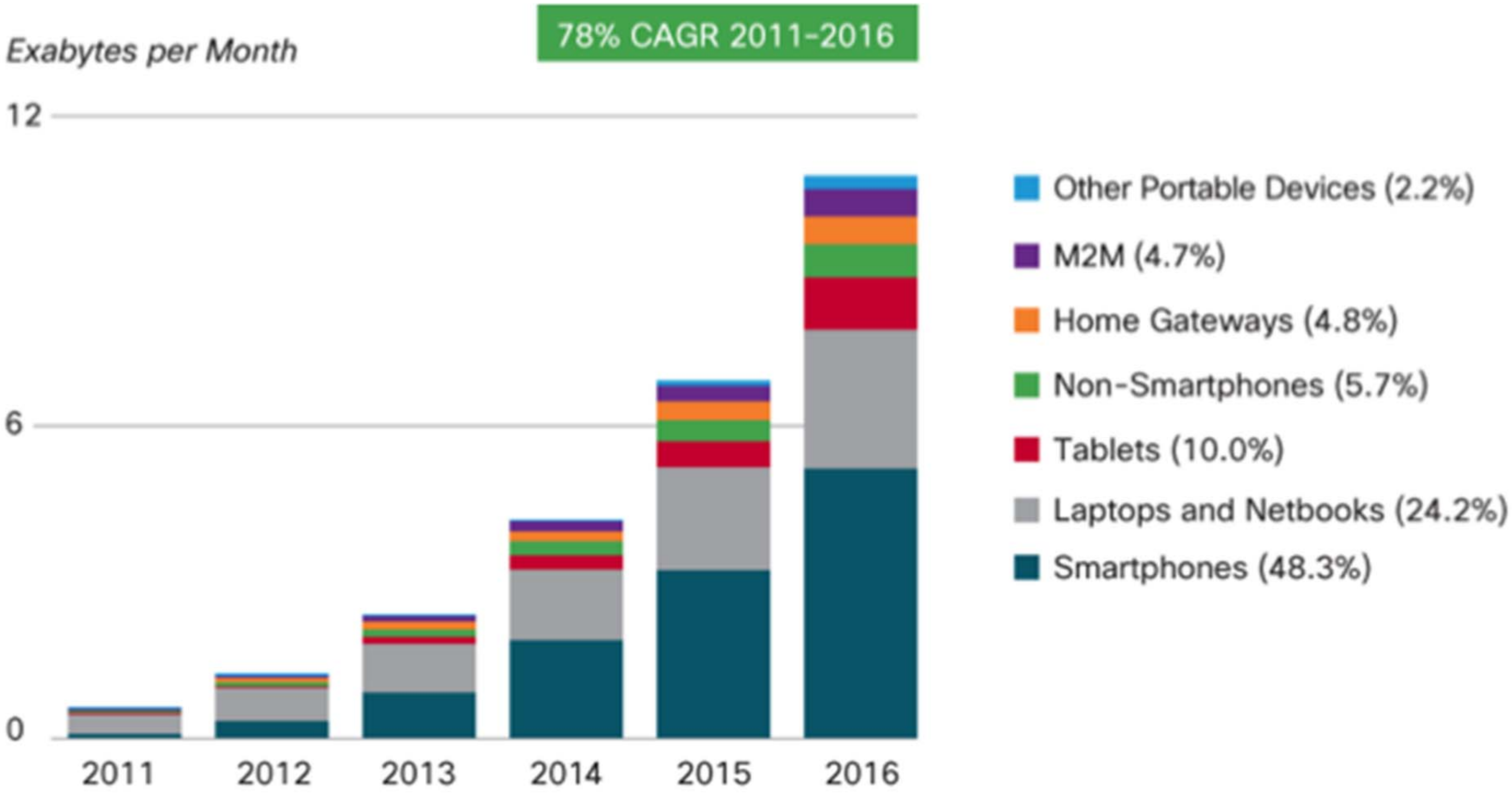
Traffic challenges

- Volume of traffic
  - IP traffic will grow at a compound annual growth rate of 21 percent from 2013 to 2018, i.e., it will triple by 2018*
  - Traffic from wireless and mobile devices will exceed traffic from wired devices by 2018*
- Huge amount of short data exchanges
- Change in traffic balance: uplink, downlink and “crosslink”
- User expects same services indoor and outdoor

Target: traffic capacity x 1000

**** Cisco Visual Networking Index: Forecast and Methodology, 2013–2018***

Cisco's traffic prediction



Figures in legend refer to traffic share in 2016.
Source: Cisco VNI Mobile, 2012

Round-trip delay

- Driven by new use cases, e.g., tactile internet
- Cloud computing
- Involves many components, not just the access network

Target roundtrip delay < 1 ms

Performance goals

- Radically higher data rates in the wireless domain (2 to 3 orders of magnitude)
- Radically lower round-trip delays (< 1 ms)
- Very high dependability for critical applications

Deployment challenges

- Small cell deployment
- Increasing installation complexity of antennas on rooftops
- Backhaul

Spectrum challenges

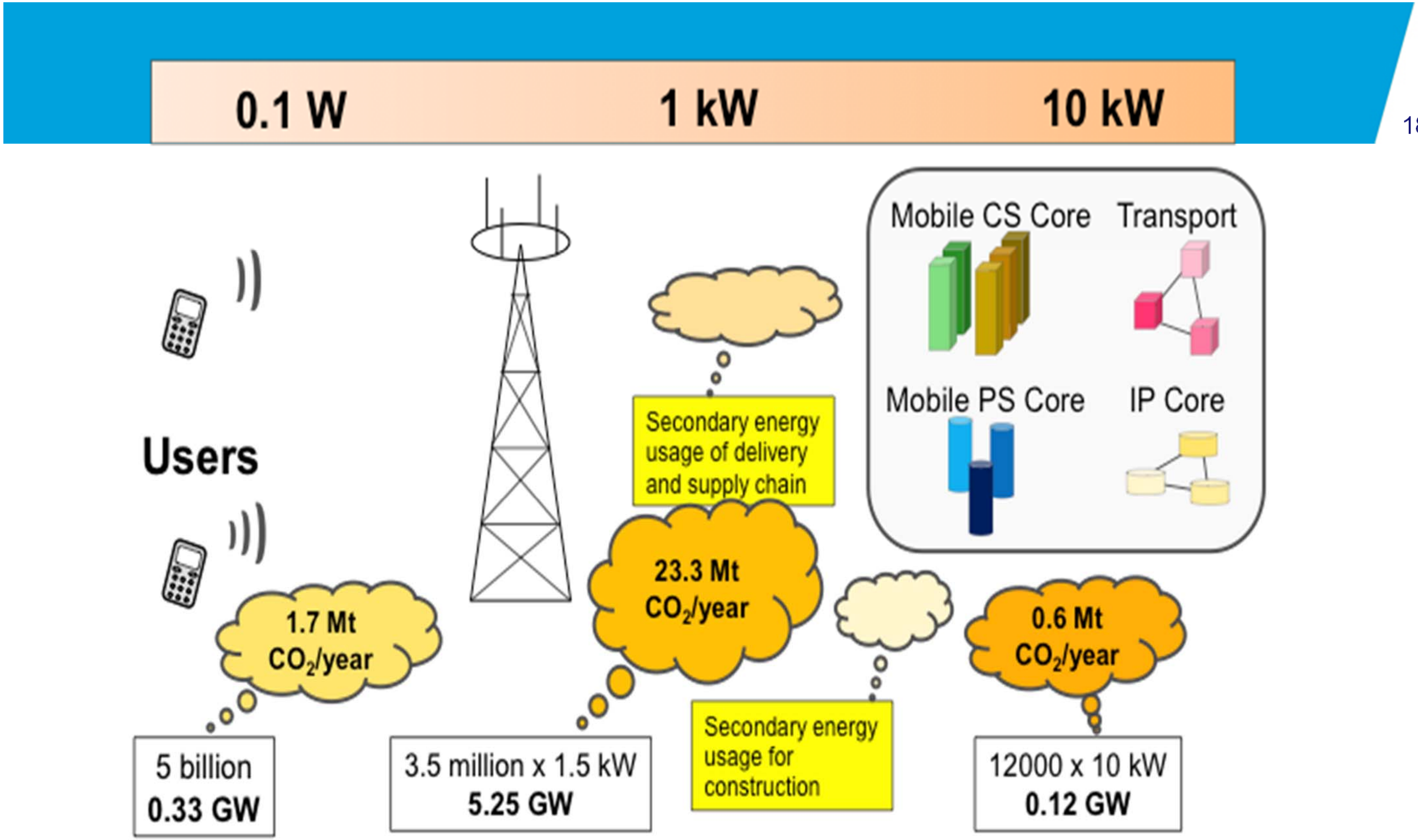
- Extra spectrum needed
- Opportunities:
  - mmWave spectrum: 30-300 GHz
  - Cognitive use of licensed spectrum (“cognitive radio”)

- Issues:
  - Spectrum fragmentation
  - Higher frequency bands have worse propagation

Energy and (perceived) health challenges

- Energy consumption: energy bill of the RAN has a large share of the operator's OPEX
- CO_2 production

- Reduction of EMF exposure: some cities set very low thresholds -> difficult to deploy new carriers, new technologies and small cells



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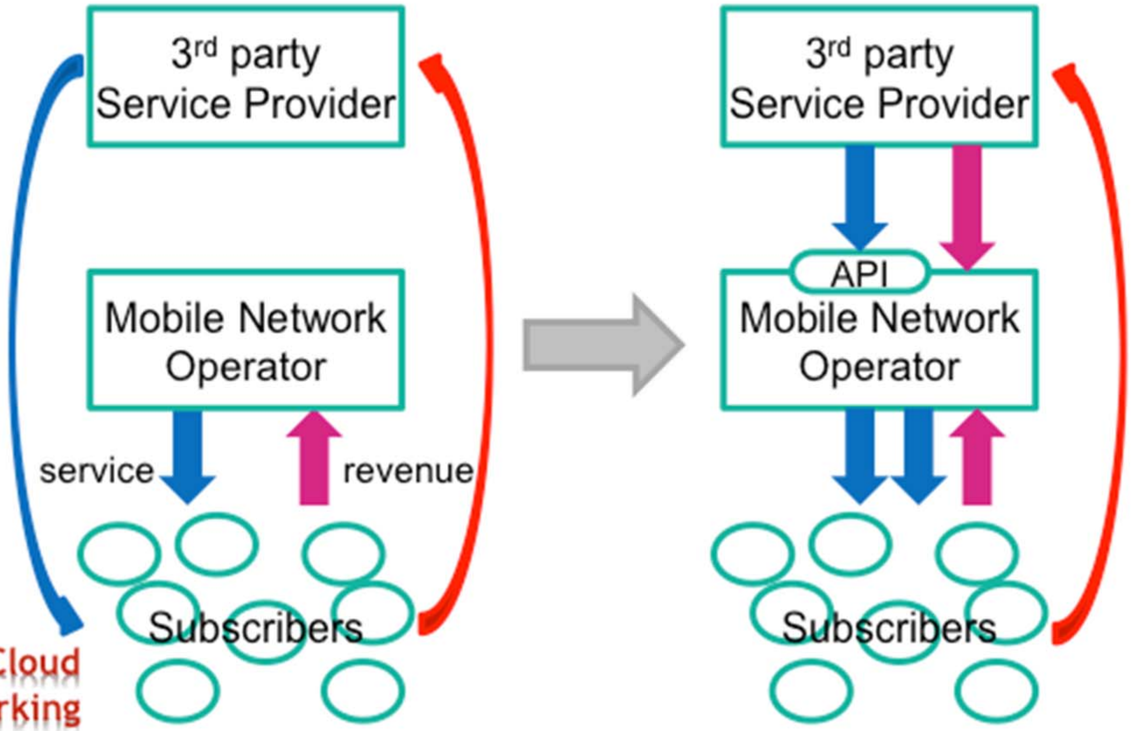
Business challenge

Mobile operators are suffering…. 3/3

- **Excluded from the revenue value chain** of the Internet ecosystem

  → **Operators are considered mere 'bit-pipe' providers**



MobileCloud Networking

What are the solutions?

Finding solutions for

- Capacity and performance challenges
- Deployment challenges
- Spectrum challenges
- Energy and health challenges
- Business challenges

Solutions will be across multiple domains:

- technology, architecture, components
- regulatory
- business

Solution to the capacity problem

In descending order of their contribution

- Spatial densification
- Radio spectrum
- Link efficiency

with appropriate backhaul (base stations to core) and accompanying architectural changes can achieve **1000 x increase in capacity**

Addressing Capacity Needs in the Past

❑ Increase in capacity over past decades:

- ❑ Martin Cooper: doubled every 30 months over past 100 years
- ❑ overall: million-fold increase in capacity since 1957

❑ Breakdown of these gains:

- ❑ 5 x PHY; 25 x spectrum; 1600 x reduced cells, 5 x rest

❑ Breakdown of (estimated) cost:

[**HOT - TOP 3 IEEE DOWNLOAD IN APRIL 2011**] Mischa Dohler, R.W. Heath Jr., A. Lozano, C. Papadias, R.A. Valenzuela, "Is the PHY Layer Dead?," IEEE Communications Magazine, vol 49, issue 4, April 2011, pp 159-165.

Spatial densification

- Heterogeneous networks:
  - macrocells,
  - picocells

  Plus
  - neighborhood small cells (NSC) = offloading to user-premises nodes
  - device-to-device (D2D)

Small cells: shorter distances, lower power, frequency reuse

Spatial densification issues

- Interference
- Handovers more frequent
- Requires coordination
- Potential for dynamic infrastructure, depending on traffic dynamics, QoS demands, etc.
- Backhaul

Requires architectural tools:

- Cloud-RAN
- ROF
- Virtualization and SDN
- SON

Device-to-device (D2D)

- Direct communication between devices in a cell
- Reduced latency and higher data rates
- Reduced energy consumption
- Spectrum reuse
- Offloads BS
- Enables proximity services
- Relay services

- Controlled by a BS or autonomous
- Creates a dynamic environment

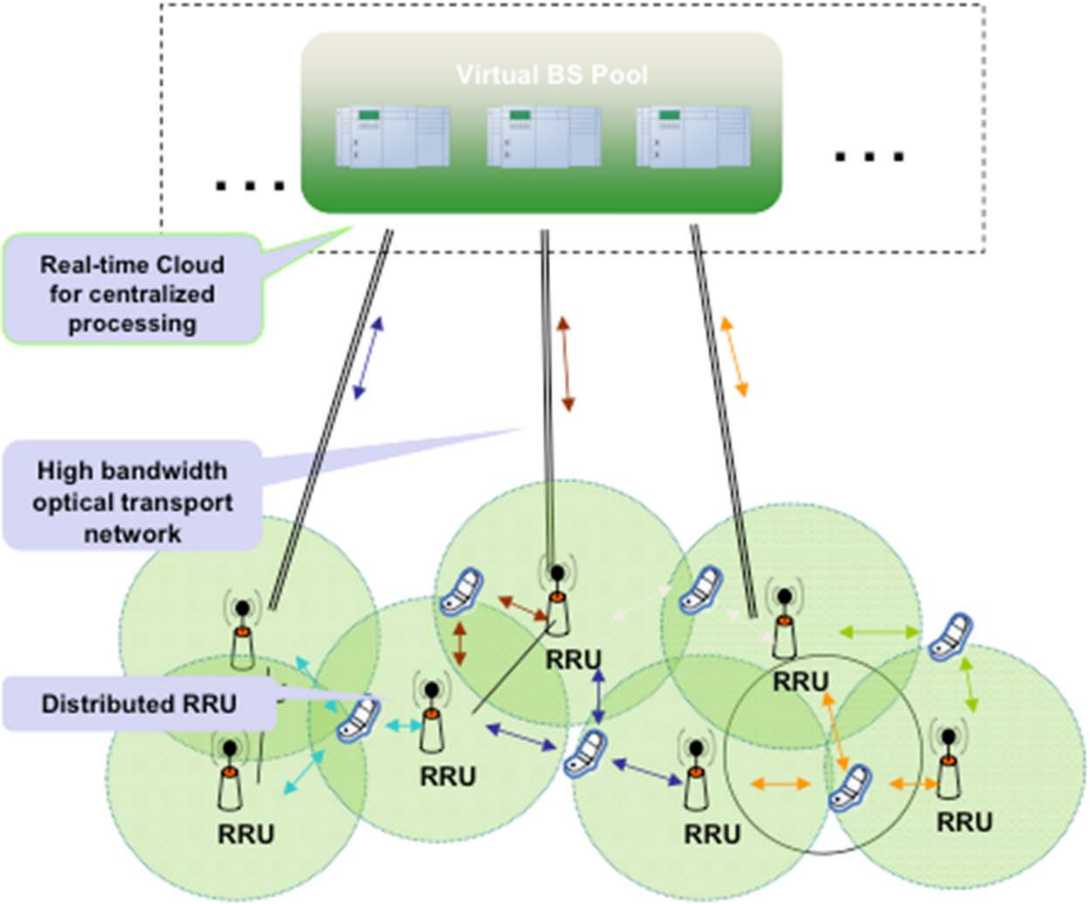
Architectural tools to make densification work

- Cloud-RAN (C-RAN)
- Virtualization and Software Defined Networking (SDN)
- Self-organized Networks (SON)
- Radio-over-Fiber (ROF)*

Reduce cost, support dynamics and flexibilty, facilitate optimizations

* Several projects at ECO Group, including 60 GHz

C-RAN Concept



Centralized Control and/or Processing

- Centralized processing resource pool that can support 10~1000 cells

Collaborative Radio

- Multi-cell Joint scheduling and processing

Real-Time Cloud

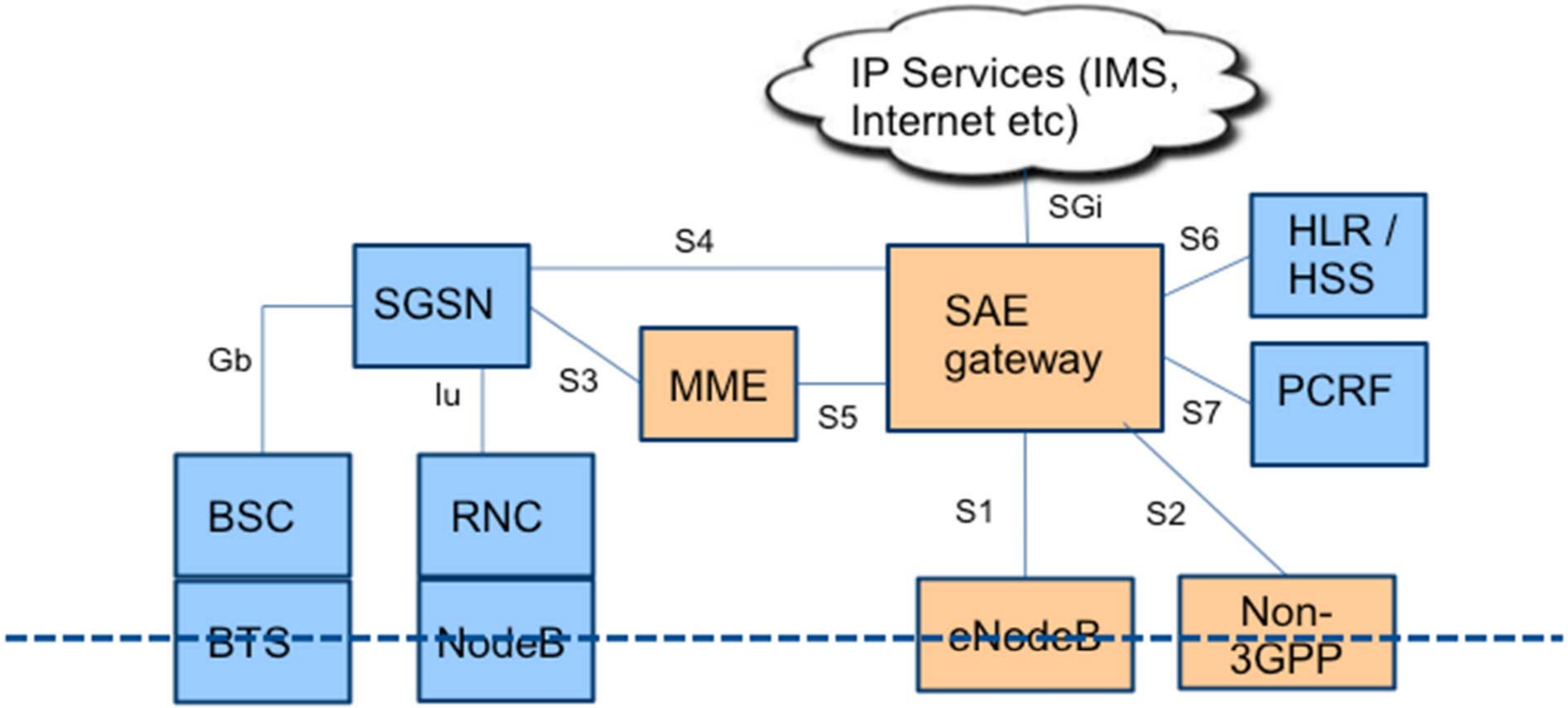
- Target to Open IT platform
- Consolidate the processing resource into a Cloud
- Flexible multi-standard operation and migration

Clean System Target

- Less power consuming
- Lower OPEX
- Fast system roll-out

Soft base-station – seamlessly scalable and upgradable

Virtualising the mobile network - how far ?



MobileCloud Networking

BBU, antenna processing, radio resource allocation can be moved to a cloud processor

BT

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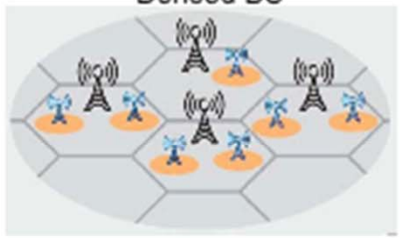
Beyond Cellular Generation

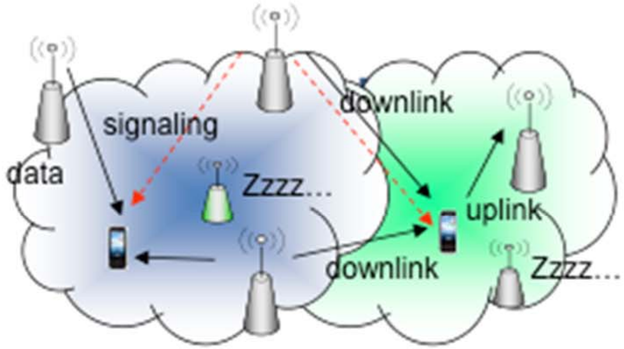
- Traditional Cellular Network is coverage-based and is not energy efficient, especially when traffic is low
- Data traffic growth densifies BS
- Beyond cellular generation
  - On-off small cells (AP)
  - Signaling and data decoupling
  - Uplink and downlink decoupling

Enhanced Macro BS

Densed BS

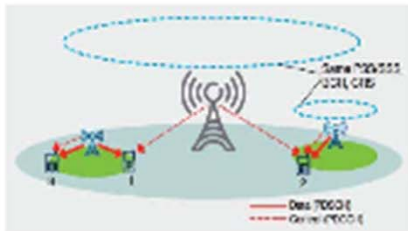


Hetnet



BCG structure

GreenTouch BCG2



Ericsson soft-cell

Self Organizing Networks (SON)

- Operational activities: planning, dimensioning, configurations, tuning, maintenance, etc. rely on intensive manual work
- Saving of OPEX is expected with SON, via reducing human interventions
- SON needed for small cells where the number of deployed nodes could be very high

Deals with the deployment challenge and the traffic dynamics

SON functions

- Reducing/eliminating RF planning and plug-and-play deployment by end users
- Self-configuration: neighbor self-discovery , coordinated selection of parameters, e.g., cell identity, Tx-power, time-frequency resource sharing, based on UE feedback and network-listening
- Mobility management: optimized hand-over parameters
- Backhaul load balancing

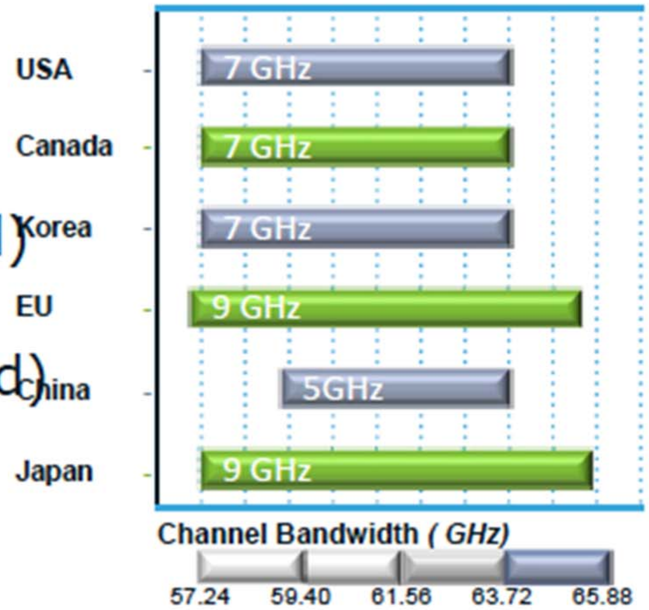
= sophisticated distributed control system (sensing, acting, algorithms)

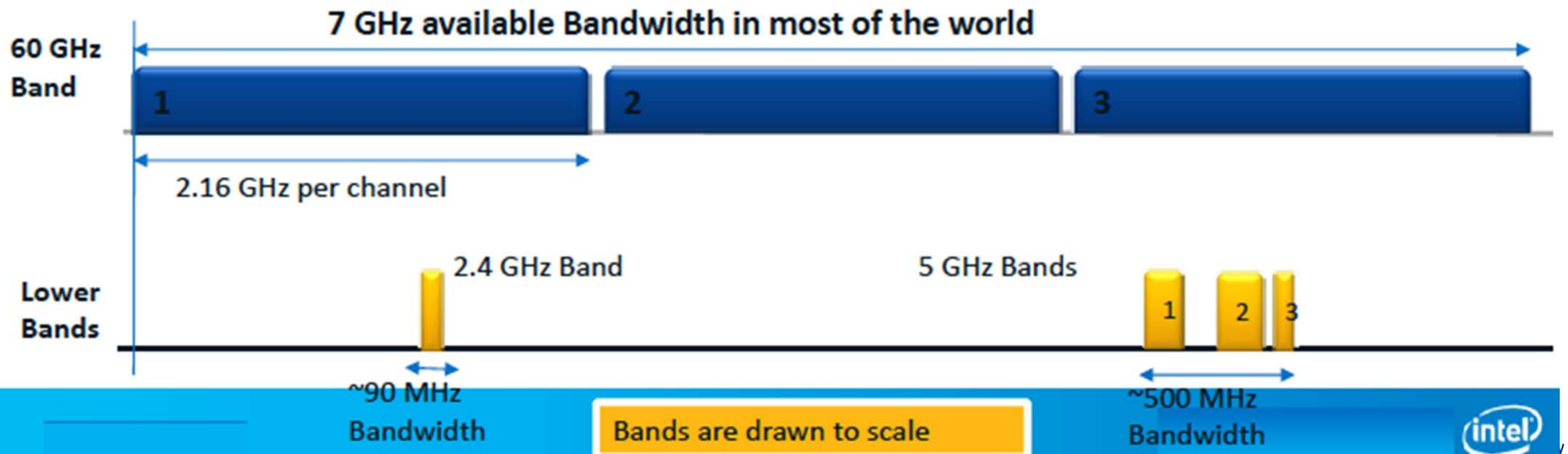
Spectrum opportunities

- mmWave: 30-300 GHz
- Cognitive radio (in the narrow sense): use of underutilized licensed spectrum
- THz? A bridge too far for 5G

Available Unlicensed Frequency Bands

- The 60GHz band offers 5 – 9 GHz of unlicensed bandwidth across most Geographies.
  - 2.16GHz Bandwidth per channel
- Compared with:
  - ~90 MHz in ISM band (2.4GHz band)
    - 20Mhz – 40MHz per channel
  - ~500 MHz in UNII band (5 GHz band)
    - 20Mhz – 160MHz per channel



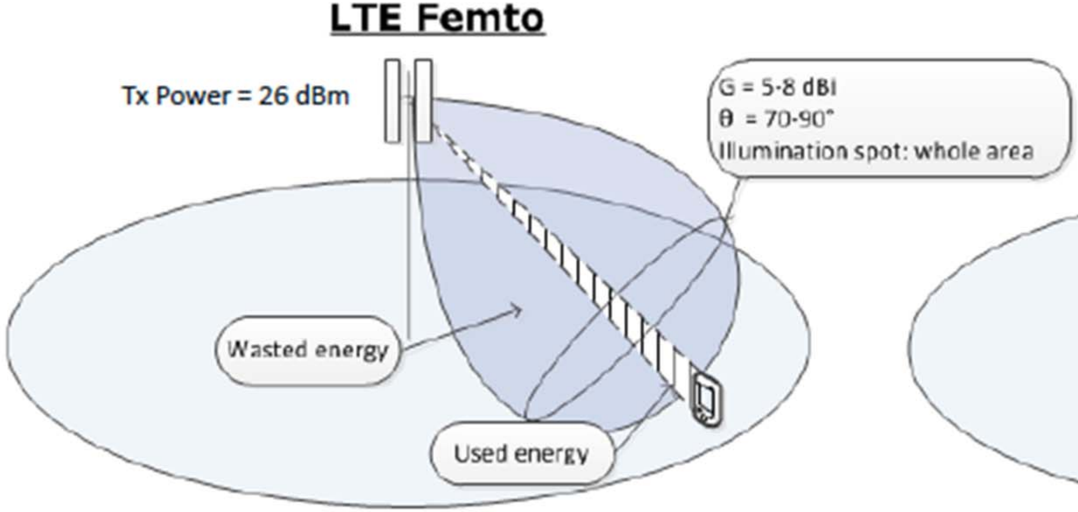


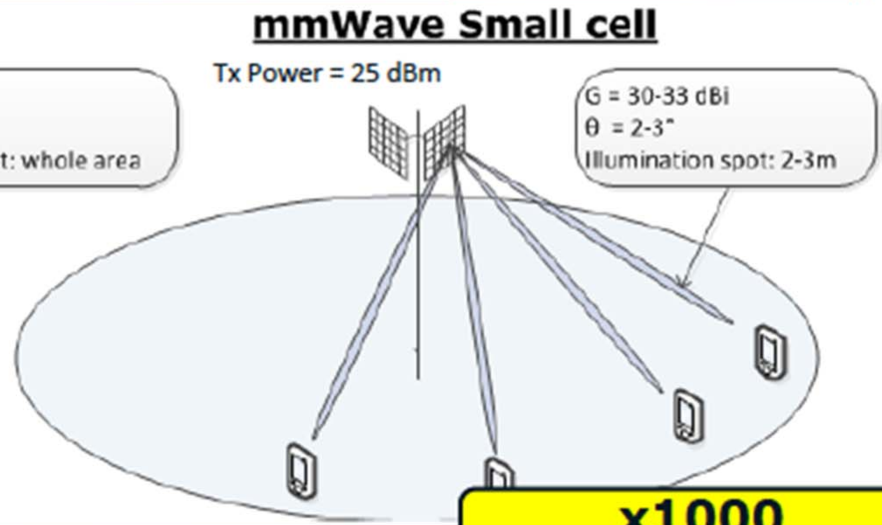
mmWave

- Frequency range 30 to 300 GHz
- High bandwidth per channel, data rate up to 7 Gbit/s
- Short range/ propagation characteristics and blocking
- Beamforming in BS and user devices
- Small cells (~ 10m radius) and backhaul
- Need for sophisticated algorithms and implementations to exploit the capabilities, e.g., discovery, beamforming, tracking, deal with blocking, etc.
- Existing solutions, e.g., IEEE 802.11ad, WiGig alliance, Wireless HD and 802.15.3c

Huge increase in data rates and cell capacity.

mmWave Small Cell vs. Modern LTE Femto





x1000
throughput increase

Cell throughput comparison

LTE average : **50 Mbps/cell** MU   mmWave Small Cell: Up to **4 Gbps** SU, **50 Gbps** MU

Energy efficiency / beamwidth comparison (green radio)

LTE Femto antenna HPBW: **70-90°**   mmWave Small Cell antenna HPBW: **2-3°**

New feature: Intelligent beam control

x30
Energy efficiency increase

- Per-beam power control to meet QoS and FCC requirements
- Beam steering / Beam tracking and Precise user positioning

Massive MIMO

- Multiuser MIMO with number of antennas at BS >> number of devices (e.g., 100 antennas)
- Energy focused into small regions of space
- Eliminate inter-cell interference through highly directional beamforming, no cell-to-cell coordination
- Modular low cost hardware
- Centralized or distributed

Capacity increase: 10

Energy efficiency improvement: 100 *

* leaving out the signal processing

Massive MIMO Research Topics

At the “testbed” stage, e.g., Lund and Rice universities

Many research topics, e.g.

- Fast and distributed coherent signal processing
- Power consumption, e.g., baseband signal processing
- Channel characterization methods
- Synchronization of antenna units

Check poster of Qing Wang, TU/e

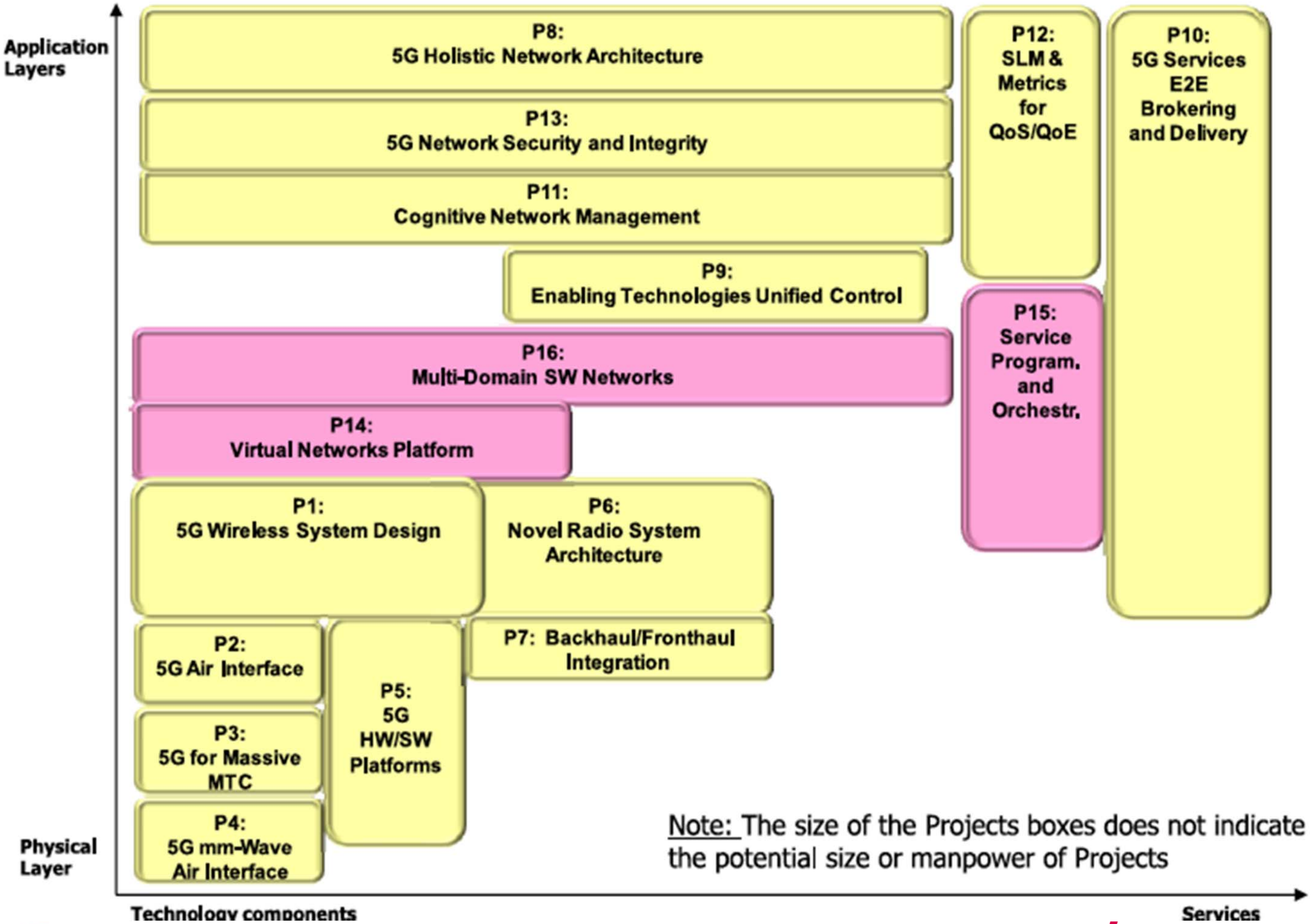
Lund University Massive MIMO Testbed

- 4-500kg
- 5kW@start-up
- Lots of cables!

5GPPP Program

5G PPP Program Ambitions

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
- Saving up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network
- Reducing the average service creation time cycle from 90 hours to 90 minutes
- Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision
- Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
- Enabling advanced user-controlled privacy



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Conclusion

- 5G driven by evolution of present use cases and disruptive new use cases, imposing requirements that cannot be met by evolving the present infrastructure
- Consensus on 5G goals:
  - capacity x 1000
  - round-trip delay < 1ms
  - energy consumption up to 90% less
- Requires evolutions and revolutions across multiple domains: technology, architecture, business, regulatory

Rich research environment!

Check IEEE Communications Magazine special issues on 5G (February 2014 and upcoming November 2014)