Green Wireless Networks

Dr. Gee Rittenhouse

Chairman of the Board, GreenTouch

Alcatel·Lucent

OUTLINE

1. GreenTouch Introduction

2. Research Directions for Green Wireless Networks

3. Initial Research Results and Ongoing Activities

A NEW WIRELESS WORLD / INTERNET

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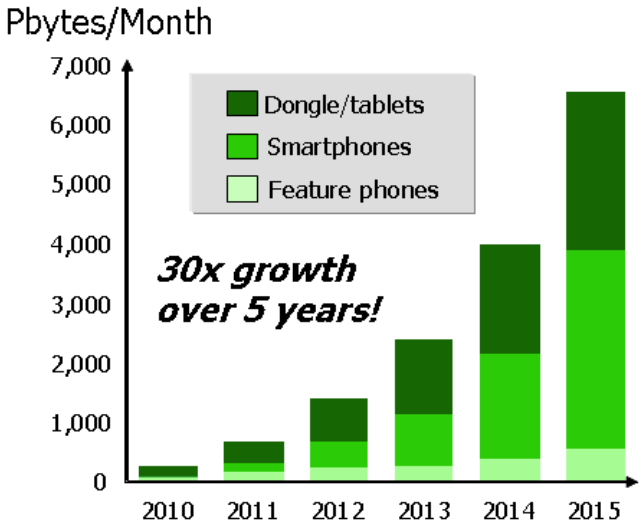
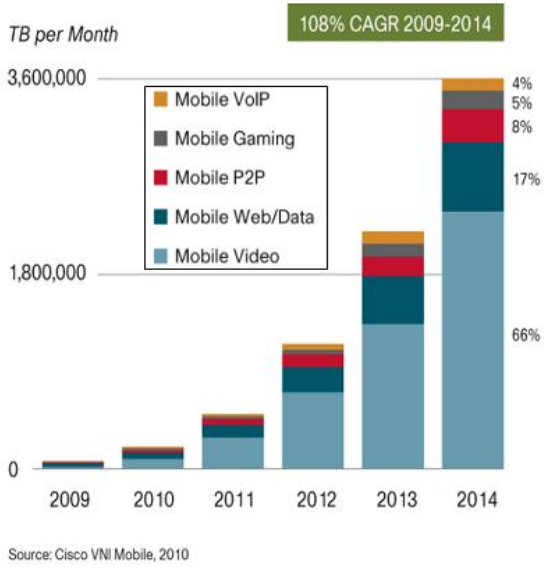
MASSIVE DATA TRAFFIC GROWTH



MORE DATA MEANS MORE POWER



Today

=

- 17.5 GigaWatts
- ~ 9 Hoover Dams
- ~ 15 nuclear power plants

- ~ 15M car emissions a year
- ~ 150,000 Paris to New York round-trip flights

Future

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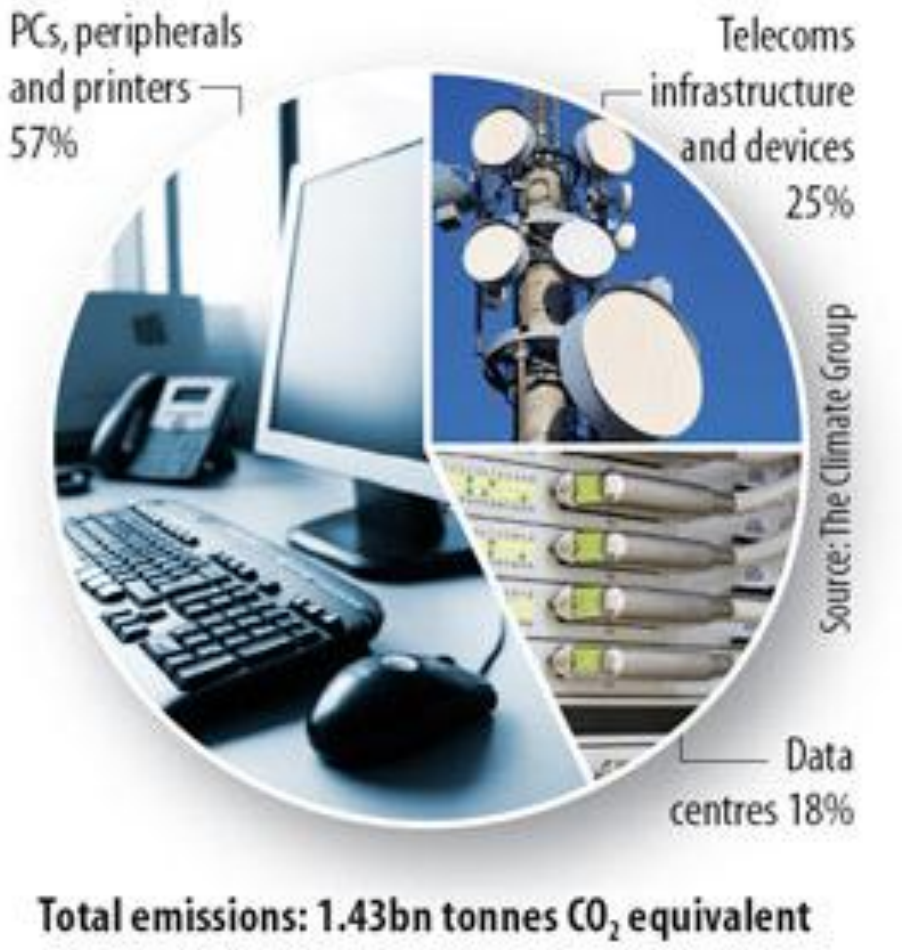
2020 ICT CARBON FOOTPRINT

820m tons CO_2



360m tons CO_2

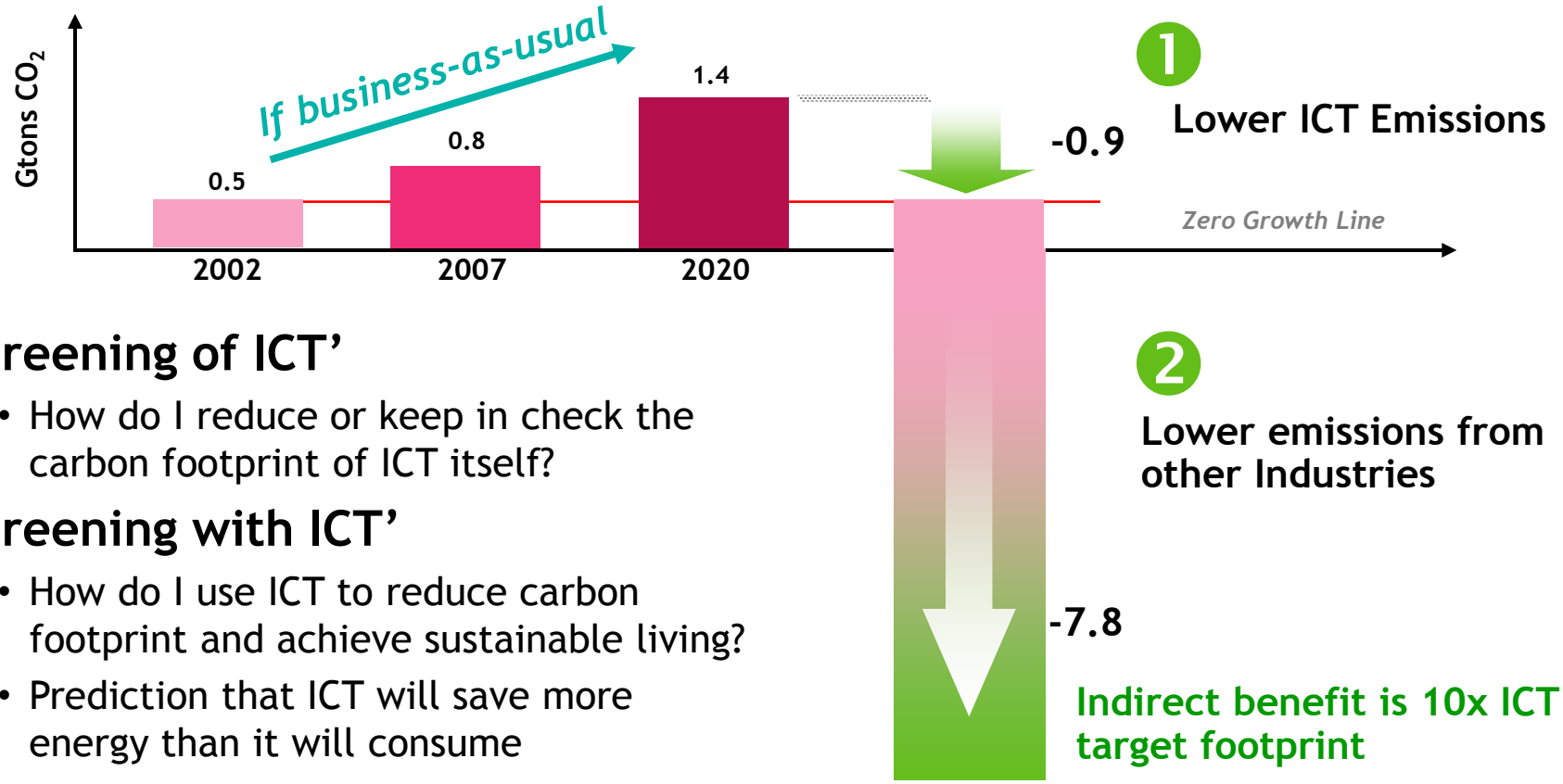
260m tons CO_2

- 2007 Worldwide ICT carbon footprint: 2% = 830 m tons CO_2
- Comparable to the global aviation industry
- Expected to grow to 4% by 2020

The Climate Group, GeSI report "Smart 2020", 2008

ICT: A PROBLEM AND THE SOLUTION

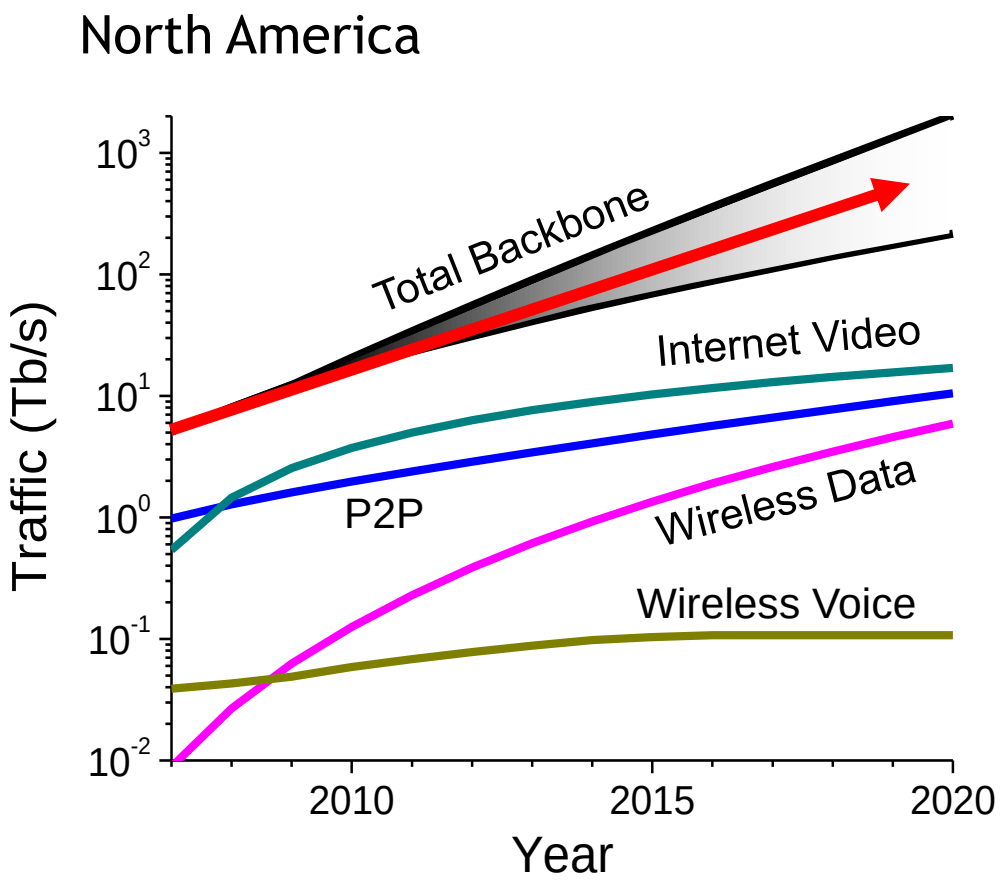
ICT today: 2% of global emissions…
with an opportunity to make tremendous impact on the remaining 98%



- **'Greening of ICT'**
  - How do I reduce or keep in check the carbon footprint of ICT itself?
- **'Greening with ICT'**
  - How do I use ICT to reduce carbon footprint and achieve sustainable living?
  - Prediction that ICT will save more energy than it will consume

Source: GeSI – SMART 2020: Enabling the Low Carbon Economy in the Information Age

CONTINUED EXPONENTIAL TOTAL TRAFFIC GROWTH IN THE INTERNET

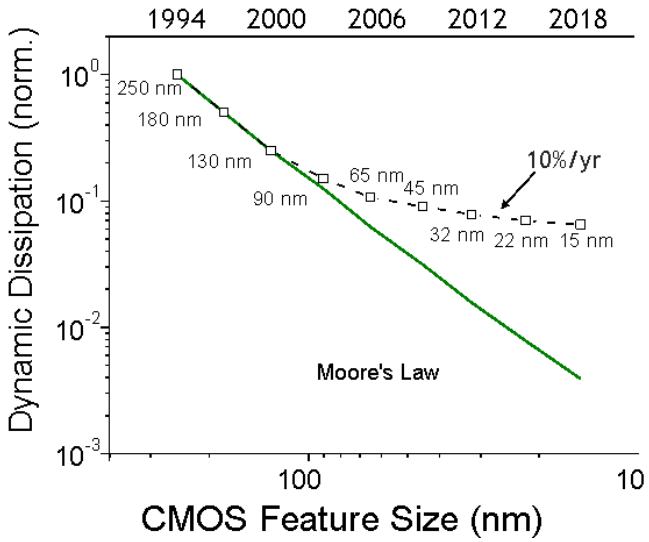


Traffic doubling every 2 years

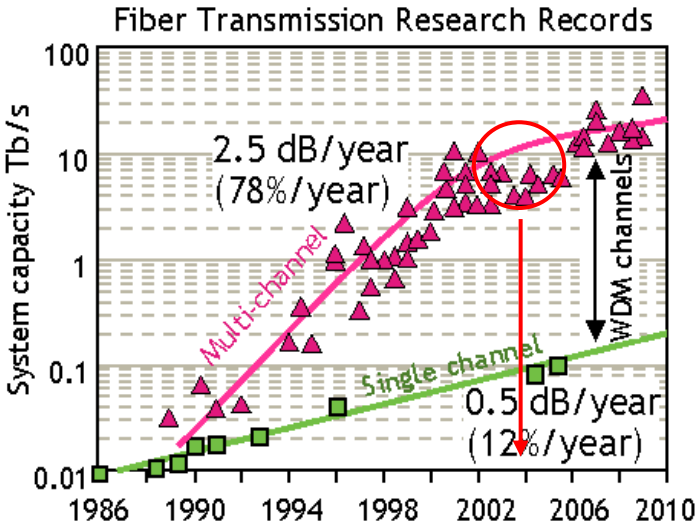
- 40% per year
- 30x in 10 years
- 1000x in 20 years

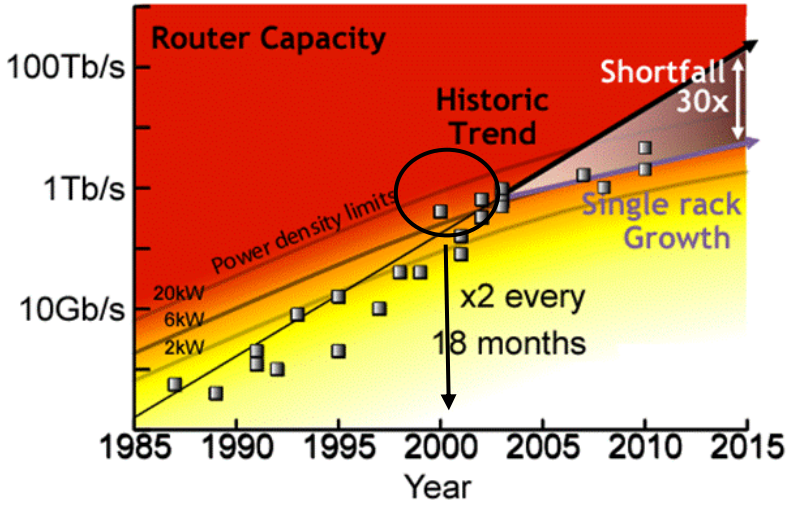
Data from: RHK, McKinsey-JPMorgan, AT&T, MINTS, Arbor, ALU, and Bell Labs Analysis: Linear regression on log(traffic growth rate) versus log(time) with Bayesian learning to compute uncertainty

SLOW-DOWN IN TECHNOLOGY



Network energy efficiency only increasing at 10-15% per year





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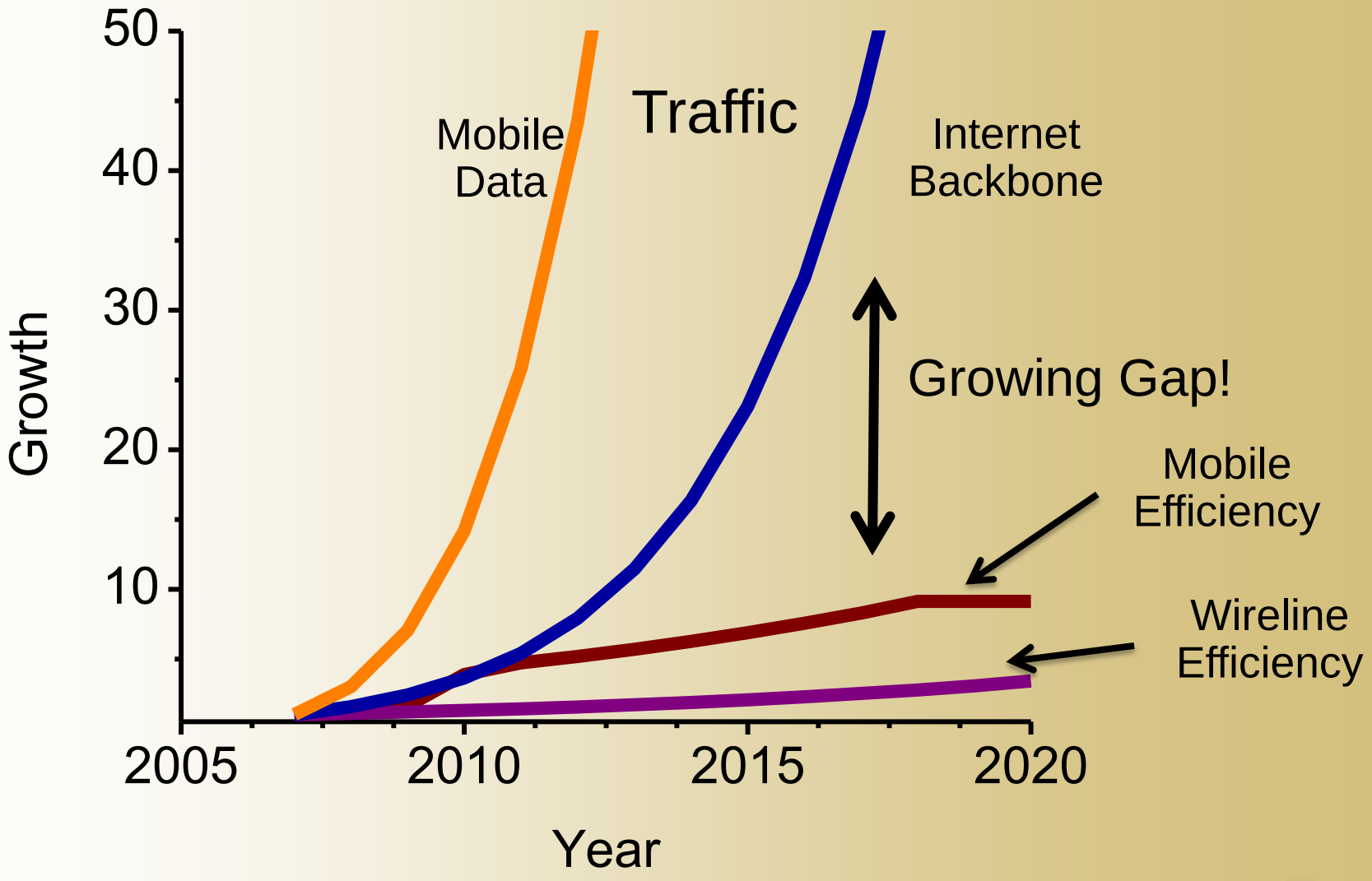
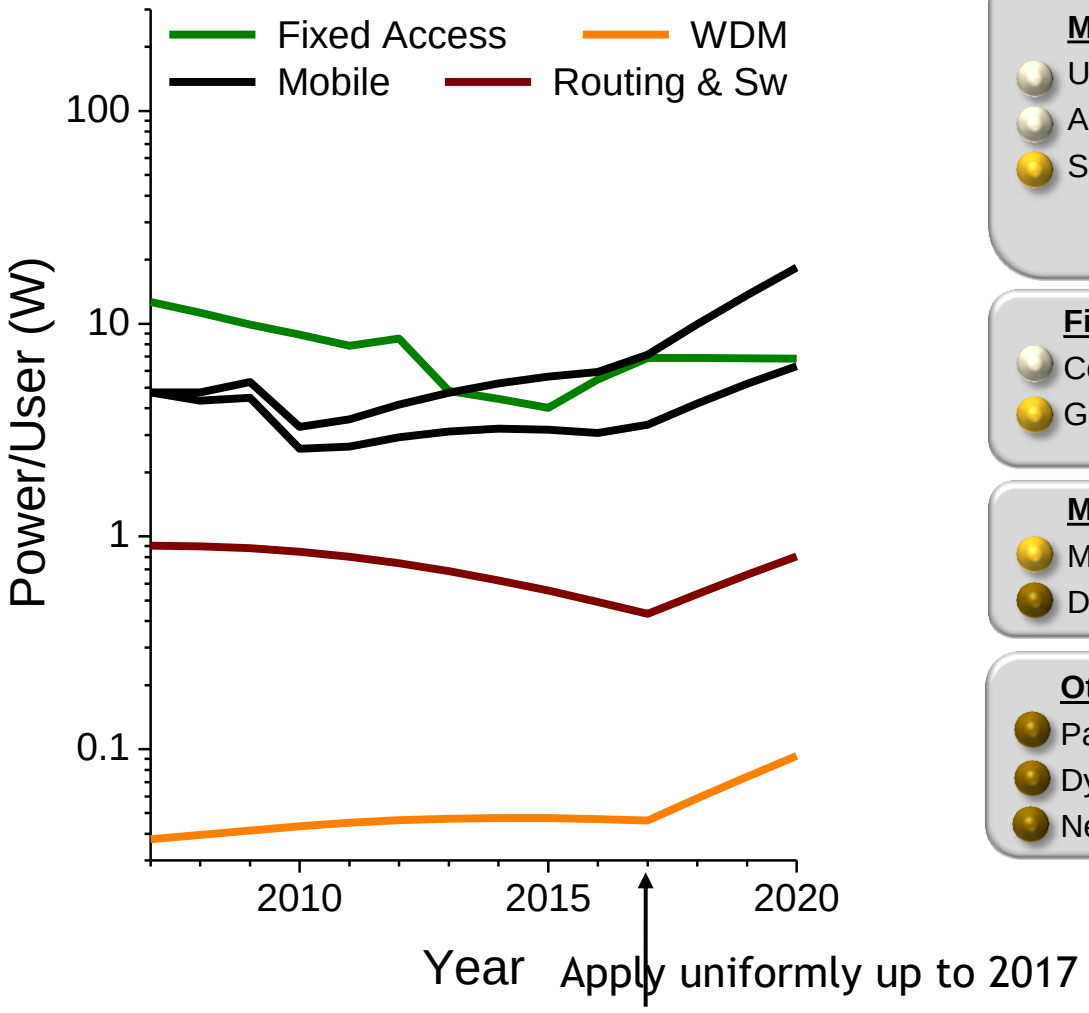
THE NETWORK ENERGY GAP



BEST CASE EFFICIENCY IMPROVEMENTS



Mobile Access:
- Ultra-efficient power amplifiers (70%)
- Active antennas
- Self organizing networks

Fixed Access:
- Cost-reduced FTTH/N
- Green PON (from ~16W/user to ~5W/user)

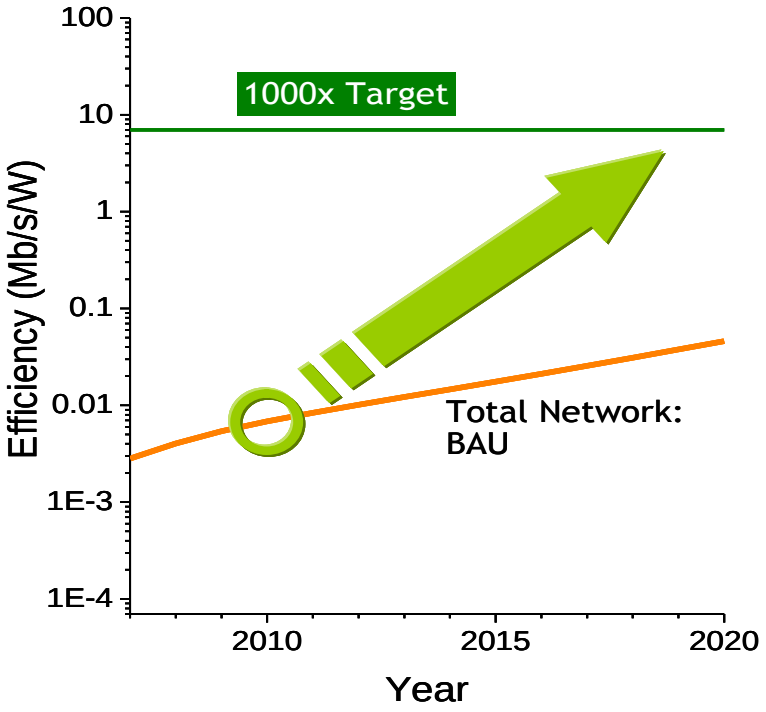
Metro/Core:
- Mesh protection / fast restoration
- Dynamic Optical Bypass

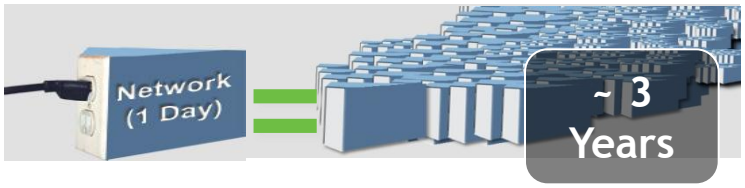
Other:
- Passive cooling everywhere
- Dynamic energy usage (proportional to load)
- Network Virtualization

Degree of Difficulty: Lower ↕ Higher

GREENTOUCH MISSION (www.greentouch.org)

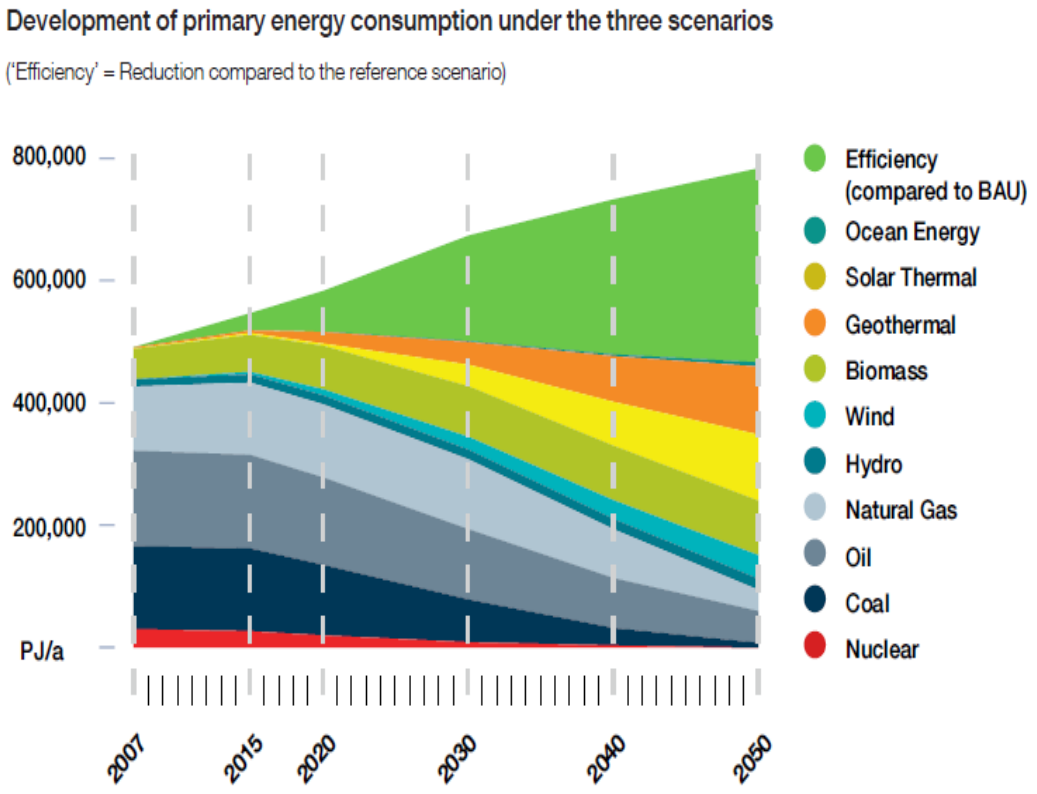
By 2015, our goal is to deliver the architecture, specifications and roadmap — and demonstrate key components and technologies —needed to increase network energy efficiency by a factor of 1000 from current levels.





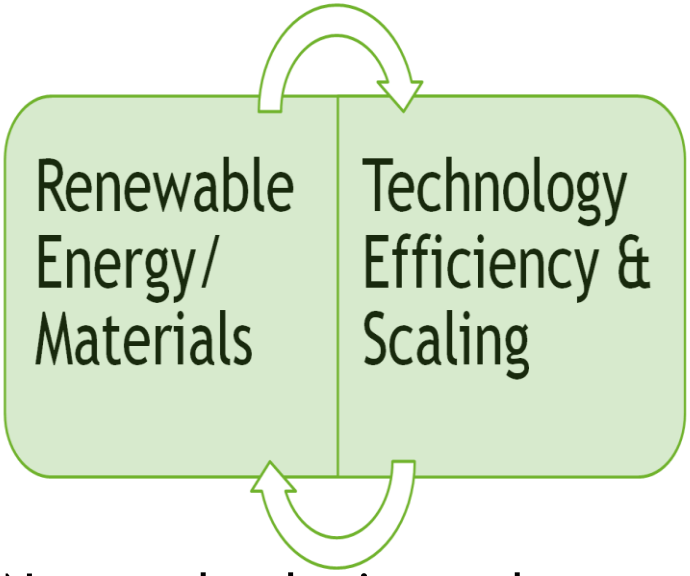
- Global research consortium representing industry, government and academic organizations
- Launched in May 2010
- 52 member organizations
- 300 individual participants from 19 countries
- 25+ projects across wireless, wireline, routing, networking and optical transmission

EFFICIENCY AND RENEWABLE ENERGY SOURCES



Greenpeace, G. Cook, J.V. Horn, 'How dirty is your data' 2011 Greenpeace, EREC 'Energy (R)evolution' 2010

Directions and requirements



New technologies and capabilities

SOME RESEARCH PROJECTS…

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- Beyond Cellular – Green Mobile Networks — Fondazione Politecnico di Milano
- Virtual Home Gateway — swisscom
- Optimal End-to-End Resource Allocation — University of Leeds
- Service Energy Aware Optical Networks — Columbia University in the City of New York
- Green Transmission Technologies — Huawei
- Minimum Energy Access Architectures — ceet; Bell Labs
- Single-Chip Linecards — imec
- Large-Scale Antenna Systems — Bell Labs
- Highly-Adaptive Layer Mesh Networks — Samsung Advanced Institute of Technology
- Massive MIMO — Samsung Advanced Institute of Technology

25+ Projects

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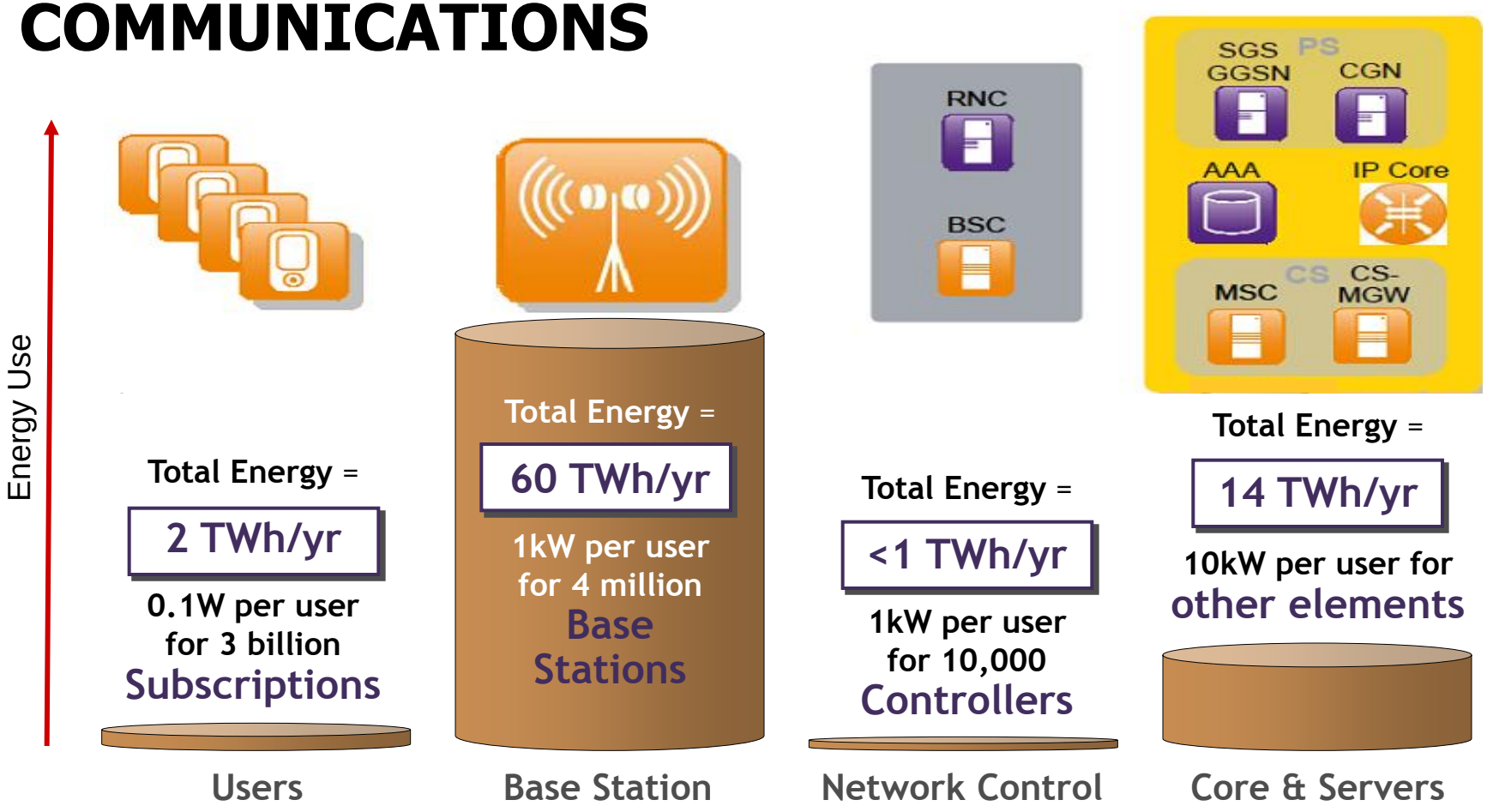
Research Directions for Green Wireless Networks

POWER CONSUMPTION OF MOBILE COMMUNICATIONS



The greatest opportunity to reduce energy consumption is to improve base stations

Based on: ETSI RRS05_024, NSN

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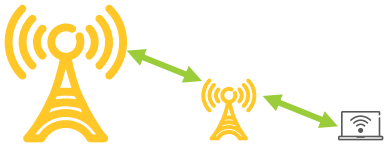
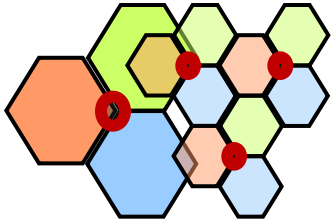
GREEN NETWORK OPPORTUNITIES (I)

Deployment:

Relays Nodes



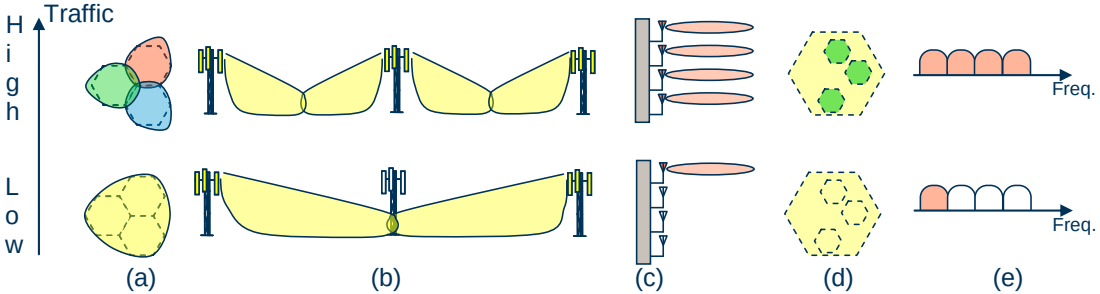
Multi RAT



Heterogeneous Networks

Network Management:

BS cooperation, Adaptive NW configuration



Multi-Antenna Techniques:

Reconfigurable antennas, Beam forming, Spatial multiplexing

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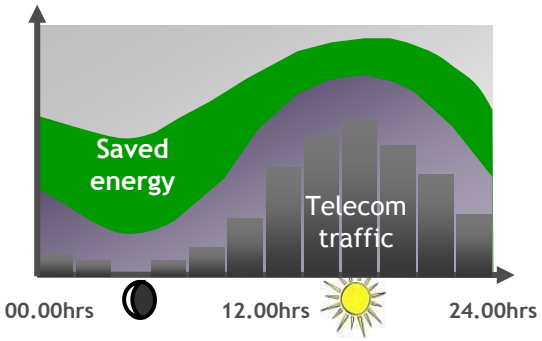
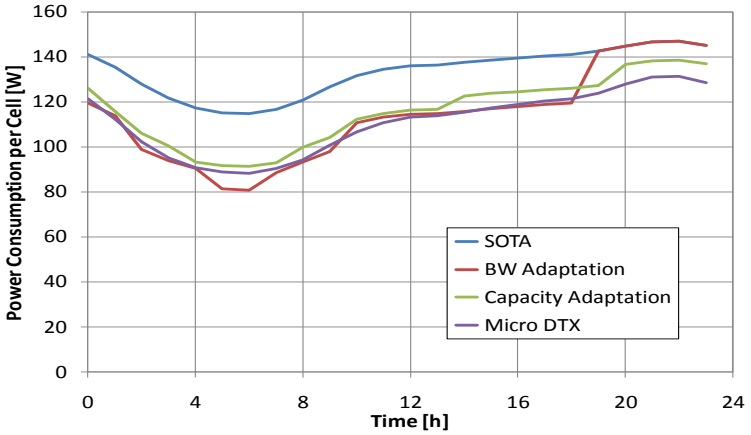
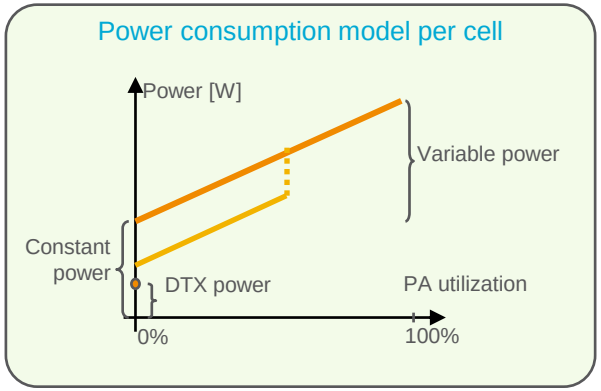
GREEN NETWORK OPPORTUNITIES (II)

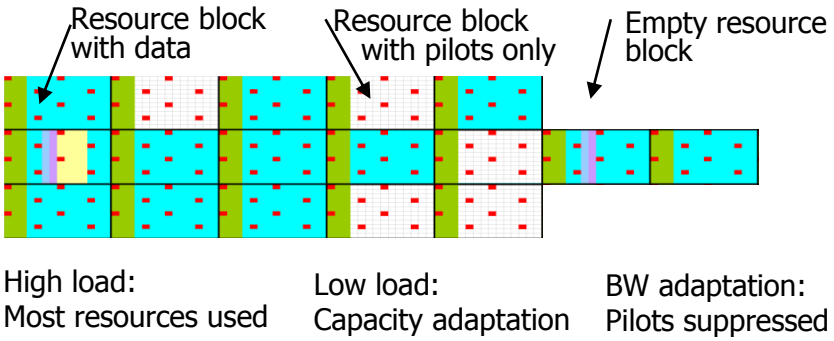
Radio Resource Management:

Energy efficient scheduling, Sleep modes, Bandwidth Adaptation









Recent Results and Ongoing Projects

SOME SPECIFIC RESEARCH ACTIVITIES

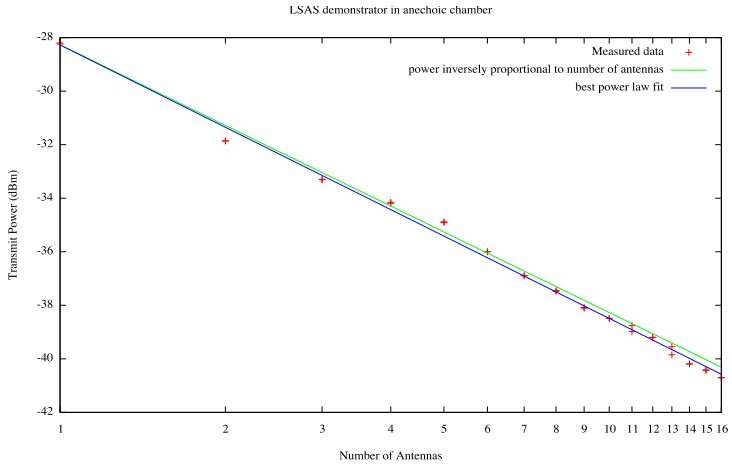
1. Large Scale Antenna Systems
   - Massive MIMO
   - Distributed Antenna Systems

2. EARTH (Energy Aware Radio and neTwork tecHnologies)
   - Small cells and heterogeneous network deployment
   - Network management

3. BCG^2 (Beyond Cellular Green Generation)
   - Green network management / intelligent power management
   - Independent network configuration for data and signaling

LARGE SCALE ANTENNA SYSTEM

Measured transmit power is inversely proportional to the number of antennas:

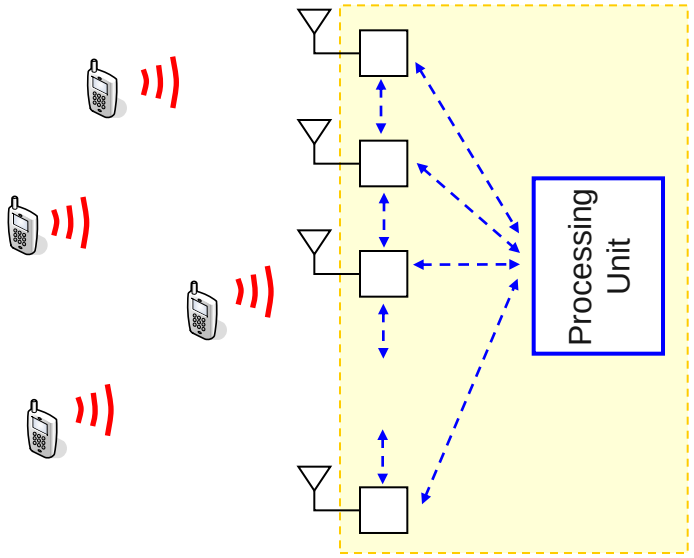


- ***Beam-forming for energy efficiency, not capacity***
- ***First GreenTouch technology demonstration***

APPLICATION SCENARIOS

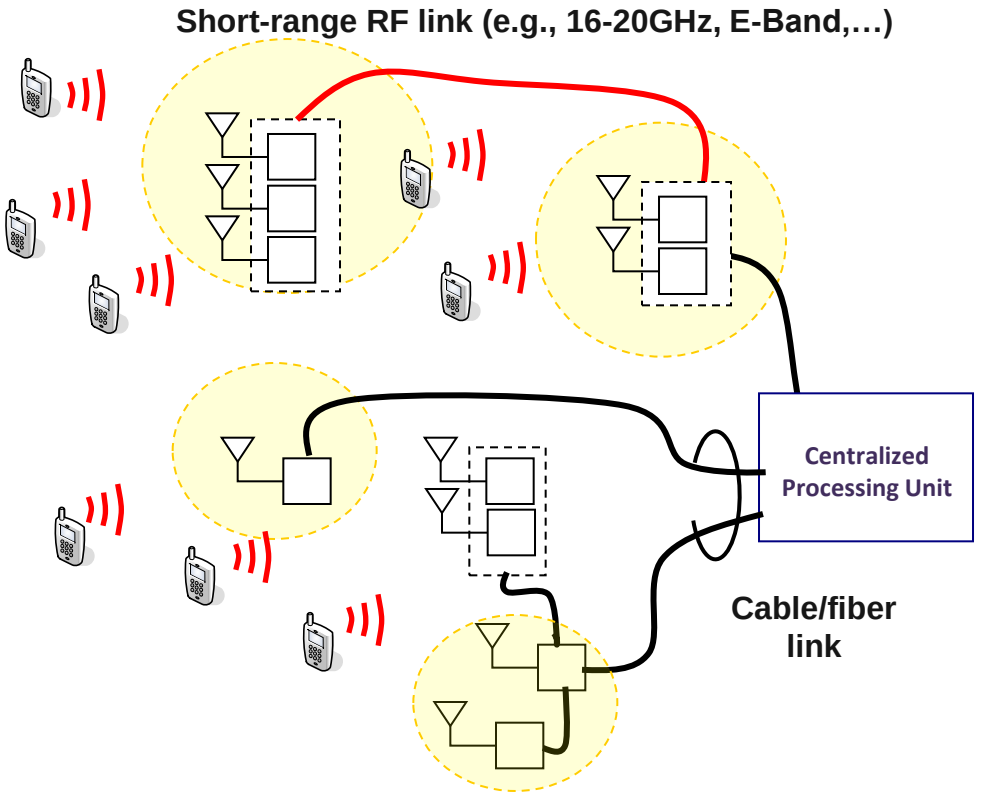
GreenTouch

Massive Co-located Antennas



Marzetta, T. L., IEEE Trans Wireless Communications, Nov 2010

Spatially Distributed Antennas



- ***100's or 1000's of antenna elements***
- ***'Power amplifiers' operating at micro-Watt levels***

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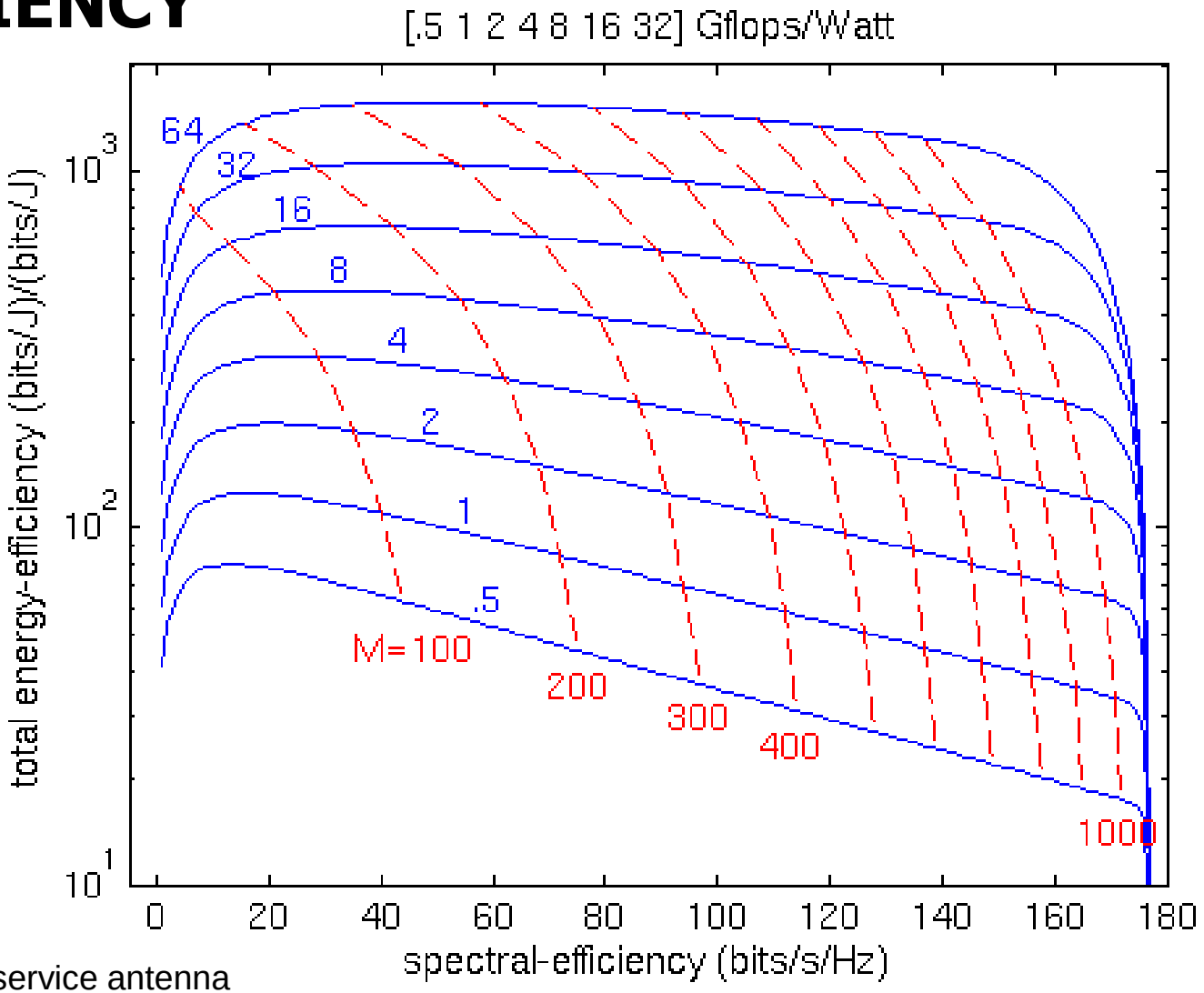
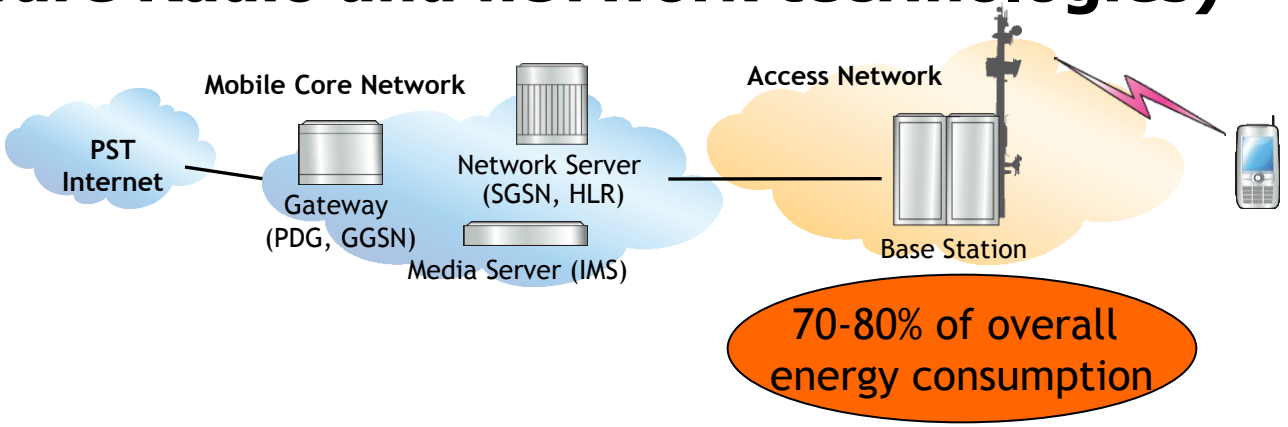
TOTAL ENERGY VS. COMPUTATIONAL ENERGY EFFICIENCY & SPECTRAL EFFICIENCY



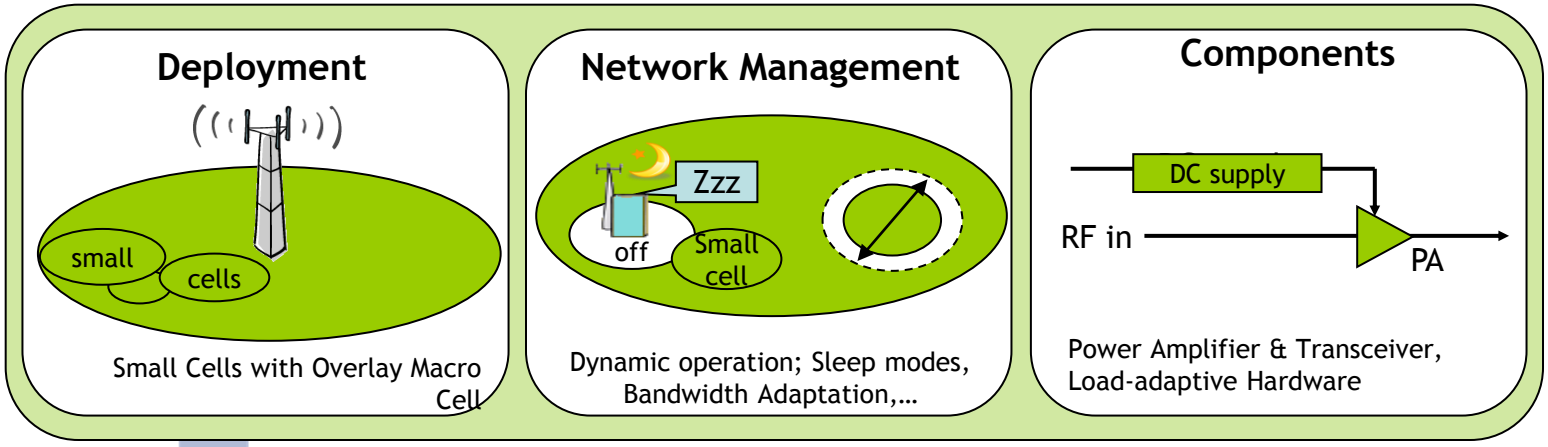
M: number of service antenna

EU FP 7 PROJECT EARTH
(Energy Aware Radio and neTwork tecHnologies)

earth
Energy Aware Radio and neTwork tecHnologies



GOAL: SAVE 50% POWER IN LTE-BASED ACCESS NETWORKS



https://www.ict-earth.eu

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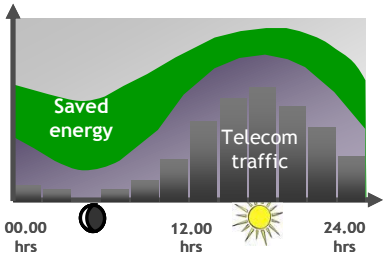
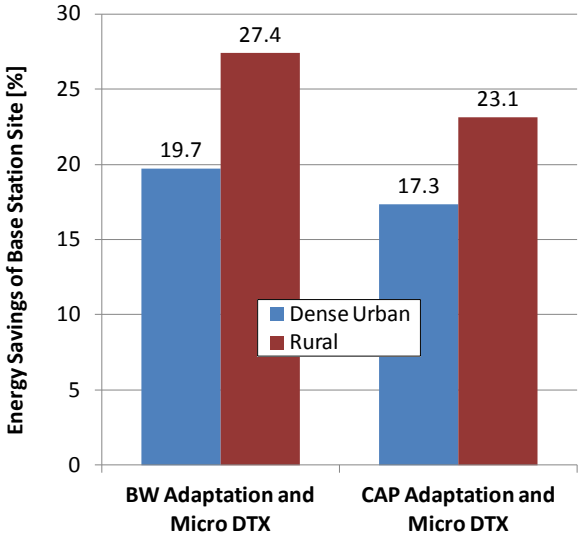
GREEN MANAGEMENT SOLUTIONS

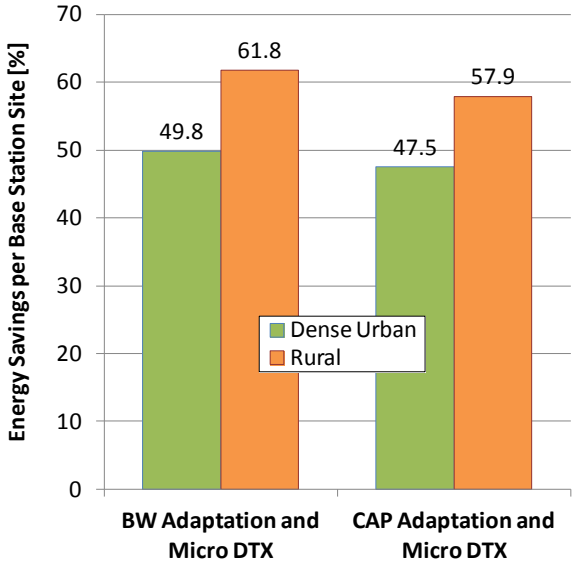
earth
Energy Aware Radio and neTwork tecHnologies



- Energy saving potential for Green LTE calculated over daily traffic cycle
- Highest gains by combination of BW adaptation and micro DTX
- High energy savings for combination of CAP adaptation and micro DTX
- Complemented by improvements in baseband hardware and other components
- **Overall a 50% saving is reached**



20% improvements by new PA and management



Complemented by EE baseband components

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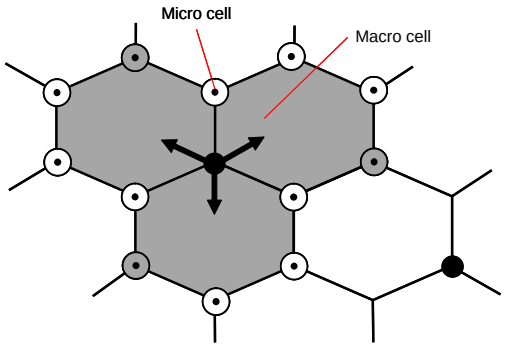
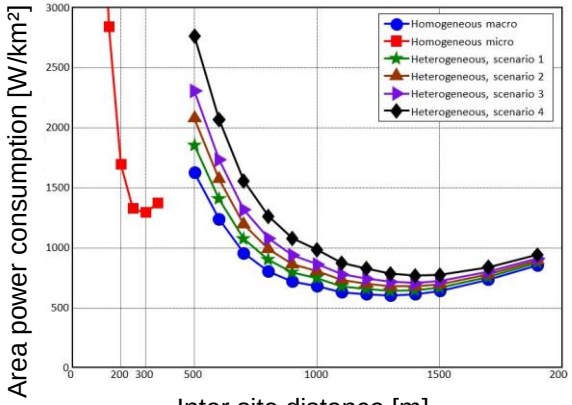
HETEROGENEOUS DEPLOYMENT
with adapted Macro Cells and Micro Cells at Cell Edges



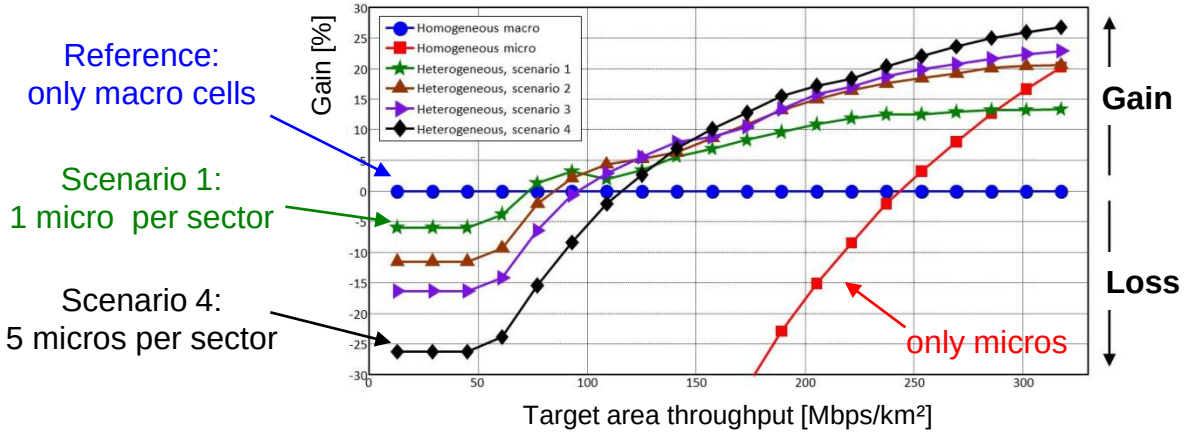
Approach: System Level study on best cell size and optimum deployment strategy depending on traffic demand

- Indoor user with uniform distribution
- Hexagonal macro network, Tx power density **adapted to cell size**
- One or more micro cells at cell edge

Area Power [W/m²]



Relative gain in Area Power consumption [%]



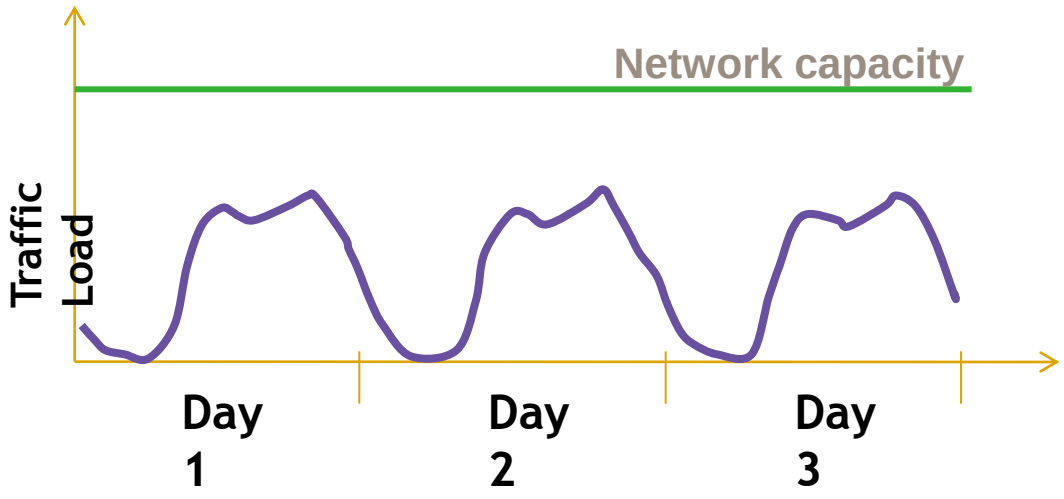
see O. Blume, F. Richter in section 2.1 of EARTH D3.1 "Most Promising Tracks of Green Network Technologies". https://bscw.ict-earth.eu/pub/bscw.cgi/d31509/EARTH_WP3_D3.1.pdf

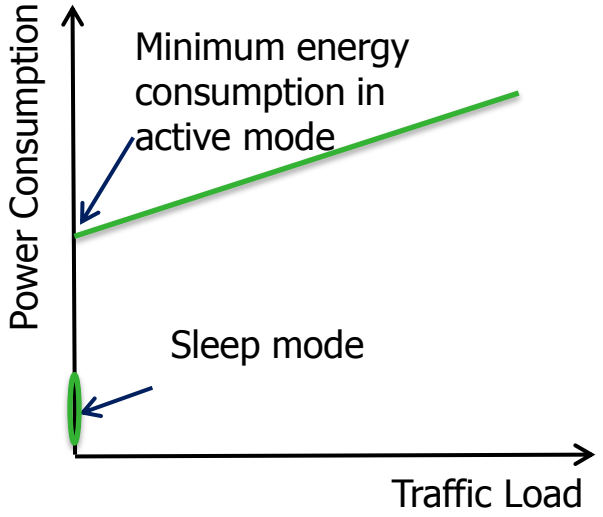
Results:

- There is an optimum urban macro InterSiteDistance (ISD), depending on traffic density.
- Small cells help to reduce the system power consumption only in case **when the offered extra capacity is required**.

BEYOND CELLULAR GREEN GENERATION (BCG²)

GreenTouch





- Wireless access networks are dimensioned for estimated peak demand using dense layers of cell coverage
- Traffic varies during the day
- Energy consumption is almost constant – Due to the power consumed by signaling

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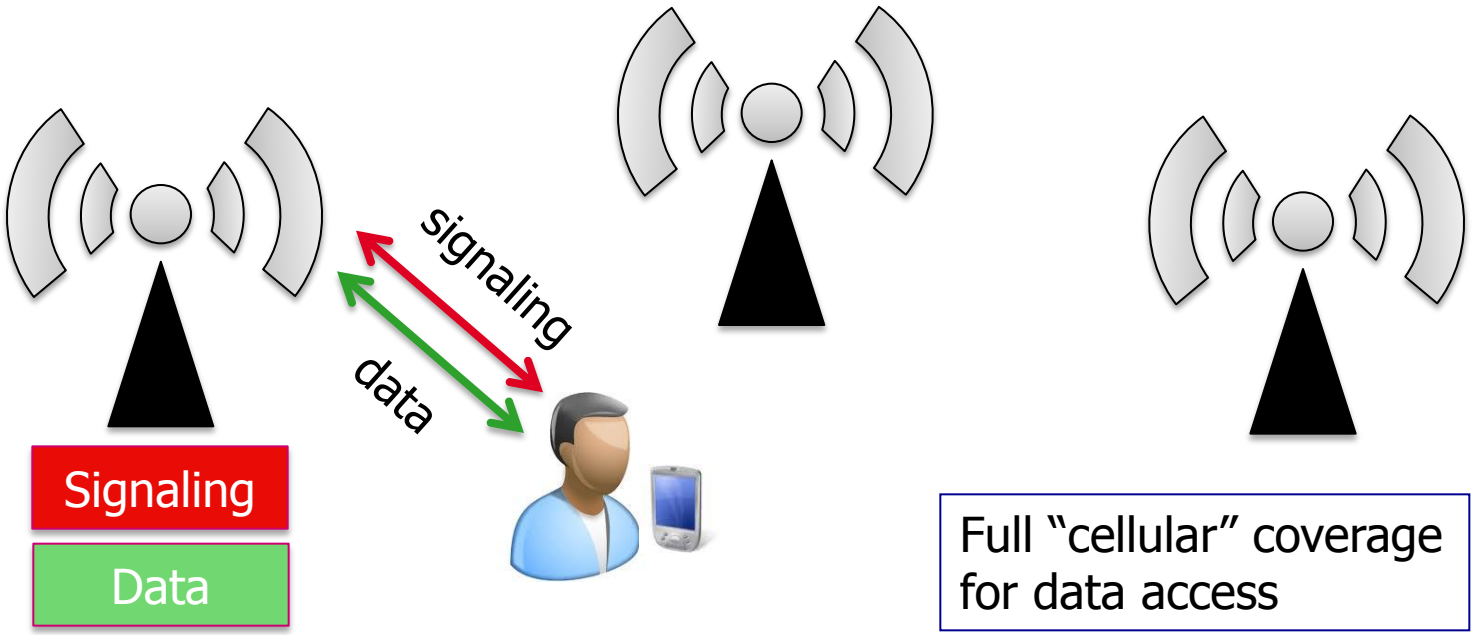
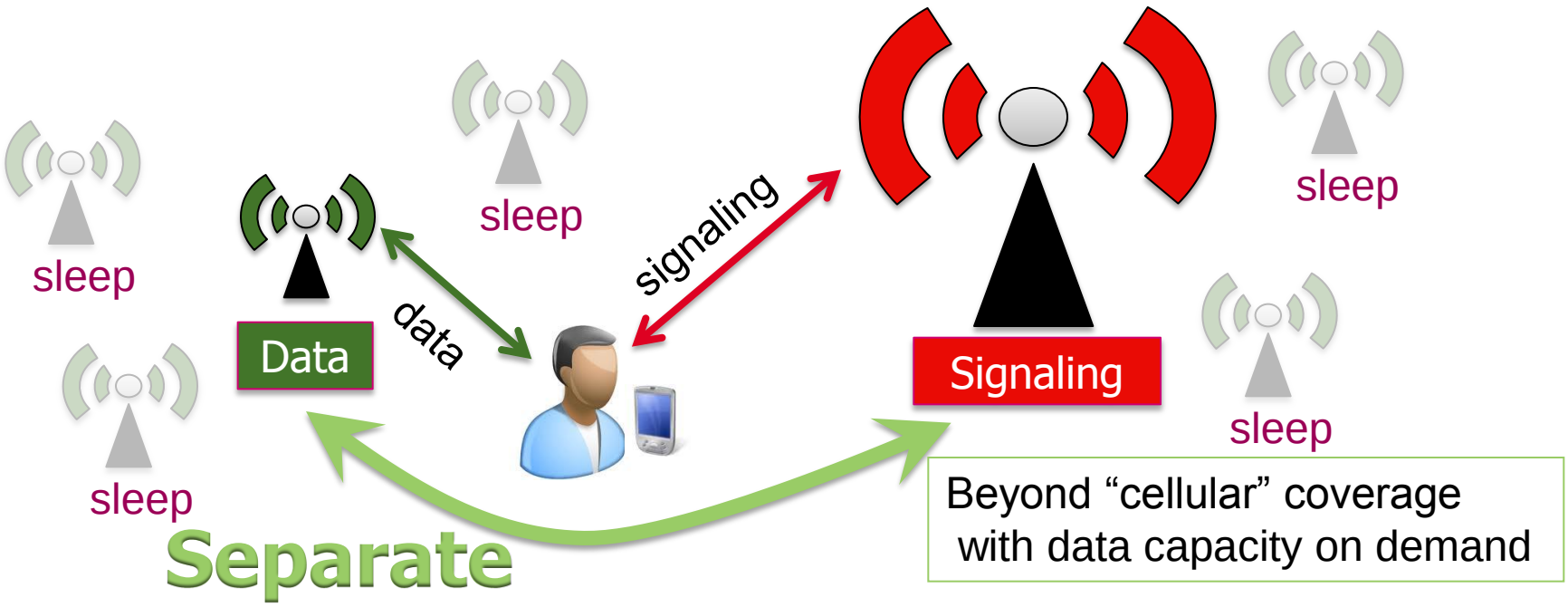
TRADITIONAL CELLULAR ARCHITECTURE



Limitation of traditional cellular architecture:

- Continuous and full coverage for data access
- Limited flexibility for energy management
- High energy consumption also at low traffic load

BCG² ARCHITECTURE



Beyond "cellular" coverage with data capacity on demand

Opportunities for sustainability:

- System designed for energy efficiency
  - Separate capacity from coverage
  - Optimise signalling transmission
  - Lean access to system
- Cope with massive amount of low data rate services

Challenges:

- New system architecture
- Re-invent mobility management
- Agile management, context aware, network with memory
- Hardware for fast reconfiguration

THEORETICAL UPPER BOUNDS ON POTENTIAL GAINS

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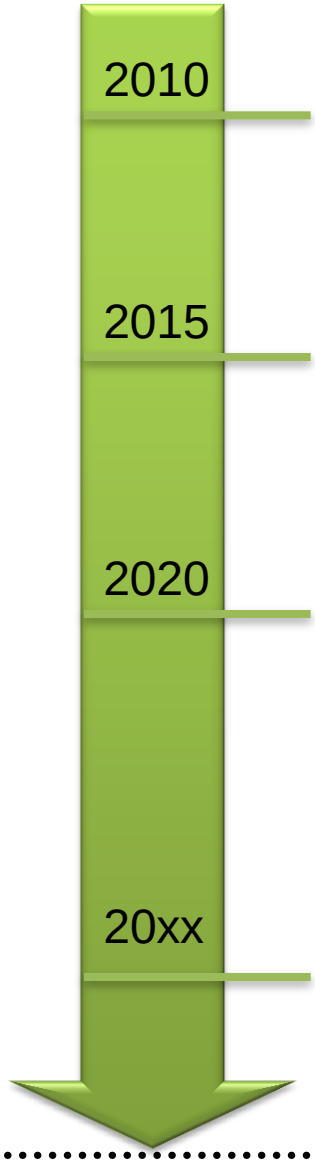
2010
Reference scenario:
Macro BSs only (SCENARIO 1)
Always-on
Low traffic level

2015
Mixed scenario with BCG
60% micro, 40 macro BSs (SCENARIO 2)
BCG energy management
Medium traffic level

2020
Micro/pico cellular scenario
10% macro, 60% micro, 30% pico BSs (SCENARIO 3)
BCG energy management
High traffic level

Long term scenario
Atto cellular scenario
100% atto BSs
BCG energy management
Any traffic level



Urban: 3887
Dense U: 1296
[10^{-3} J/kbit]

Urban: 38X
Dense U: 16X

Urban: 76X
Dense U: 36X

Urban: 1555X
Dense U: 518X

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CONCLUSIONS

- ICT networks are growing rapidly
  - Scaling networks is becoming more difficult
  - Bringing focus to energy efficiency
- ICT and research communities are organizing to address challenges
  - Dramatic, holistic change, but over long term evolution
  - Cooperative organizations such as GreenTouch guiding evolution
- Several promising research directions and initial results have been obtained
- More work remains!

Thank you!

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AT THE SPEED OF IDEAS