



# GreenTouch and Green Wireless Networks



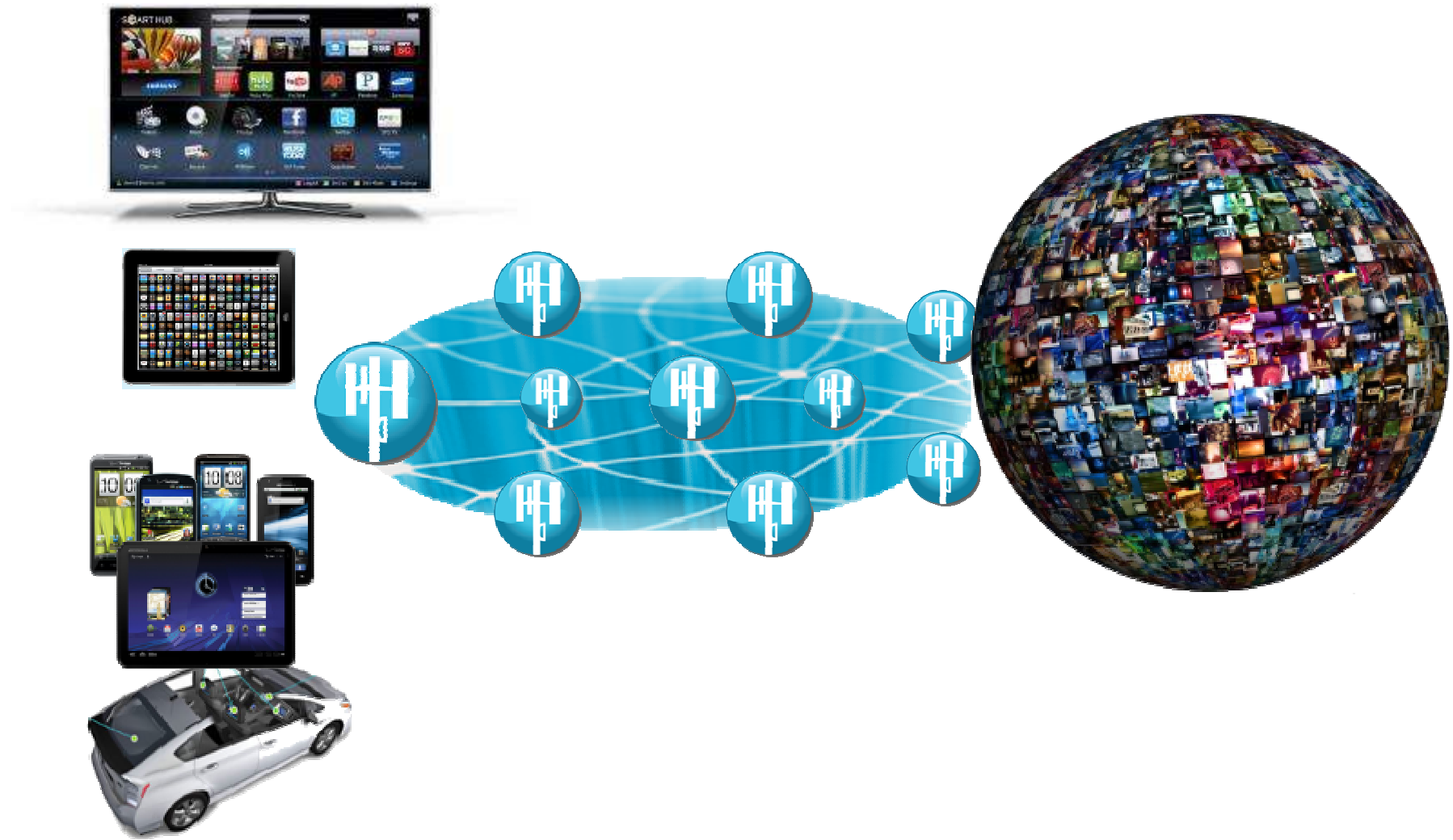
Alberto CONTE  
Alcatel-Lucent Bell Labs

GDR ISIS  
Methodological foundations of Green Radio  
15.06.2012

# OUTLINE

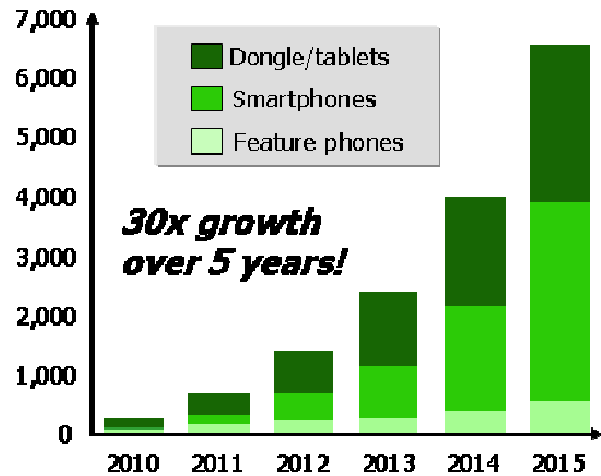
1. Energy Challenges on ICT
2. GreenTouch Initiative
3. Research Directions for Green Wireless Networks
4. Initial Research Results and Ongoing Activities

# A NEW WIRELESS WORLD / INTERNET

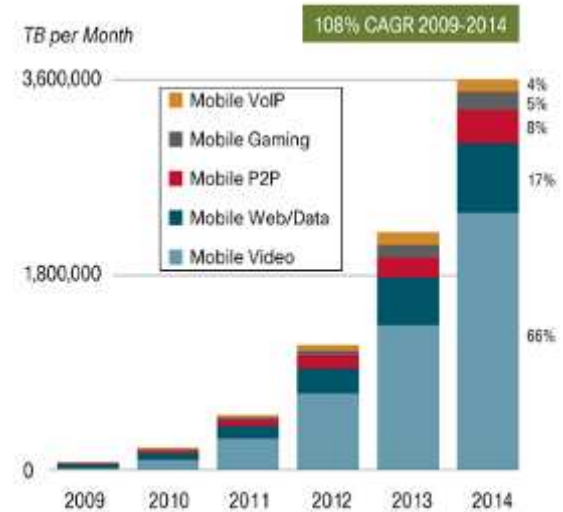


# MASSIVE DATA TRAFFIC GROWTH

Pbytes/Month



**MORE DATA  
MEANS MORE  
POWER**



**Today**

**Future**



=



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

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

# 2020 ICT CARBON FOOTPRINT

820m tons CO<sub>2</sub>

PCs, peripherals  
and printers  
57%

Telecoms  
infrastructure  
and devices  
25%

360m tons CO<sub>2</sub>



Source: The Climate Group

Data  
centres 18%

260m tons CO<sub>2</sub>

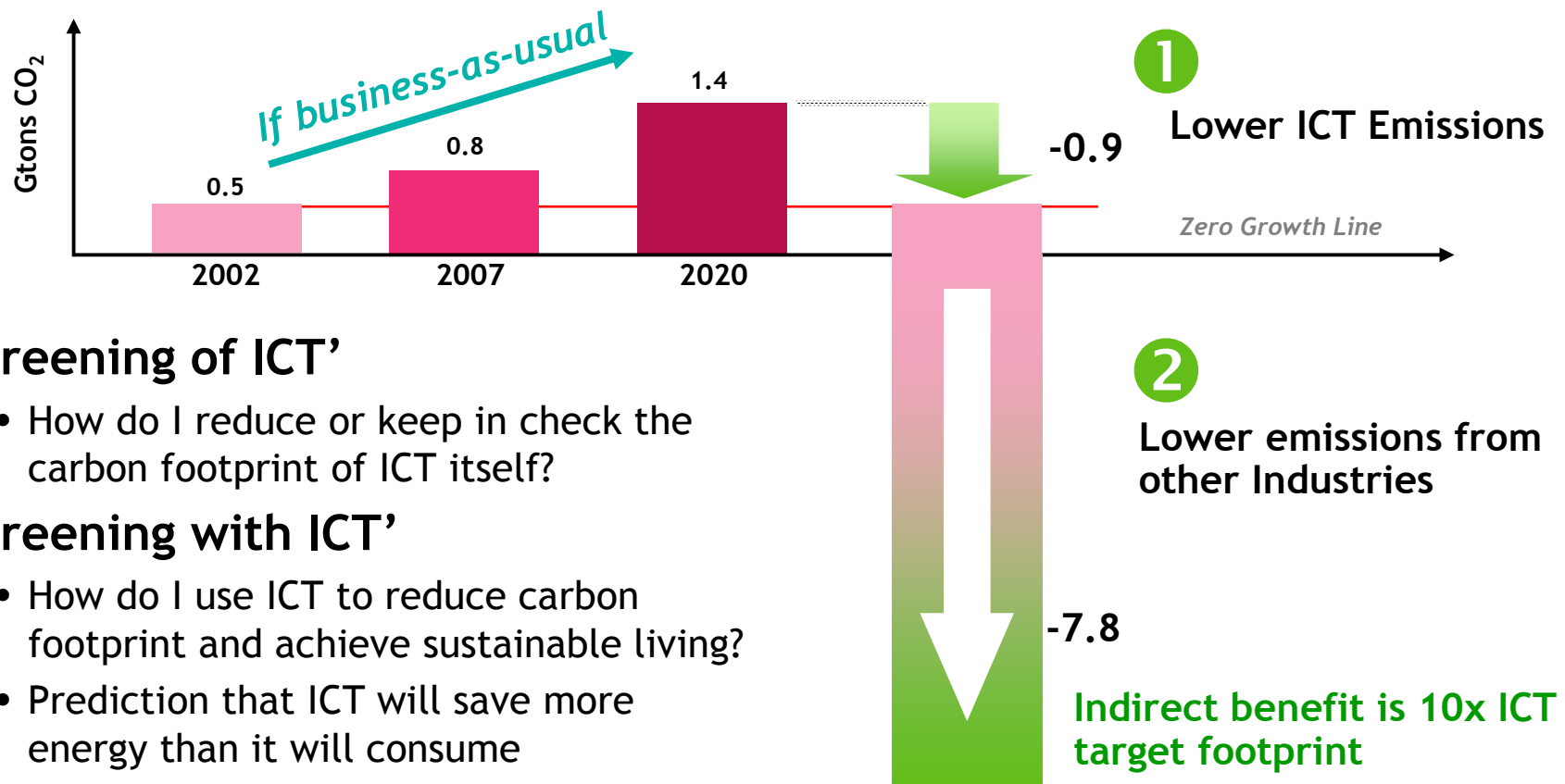
- 2007 Worldwide ICT carbon footprint: 2% = 830 m tons CO<sub>2</sub>
- Comparable to the global aviation industry
- Expected to grow to 4% by 2020

**Total emissions: 1.43bn tonnes CO<sub>2</sub> equivalent**

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%

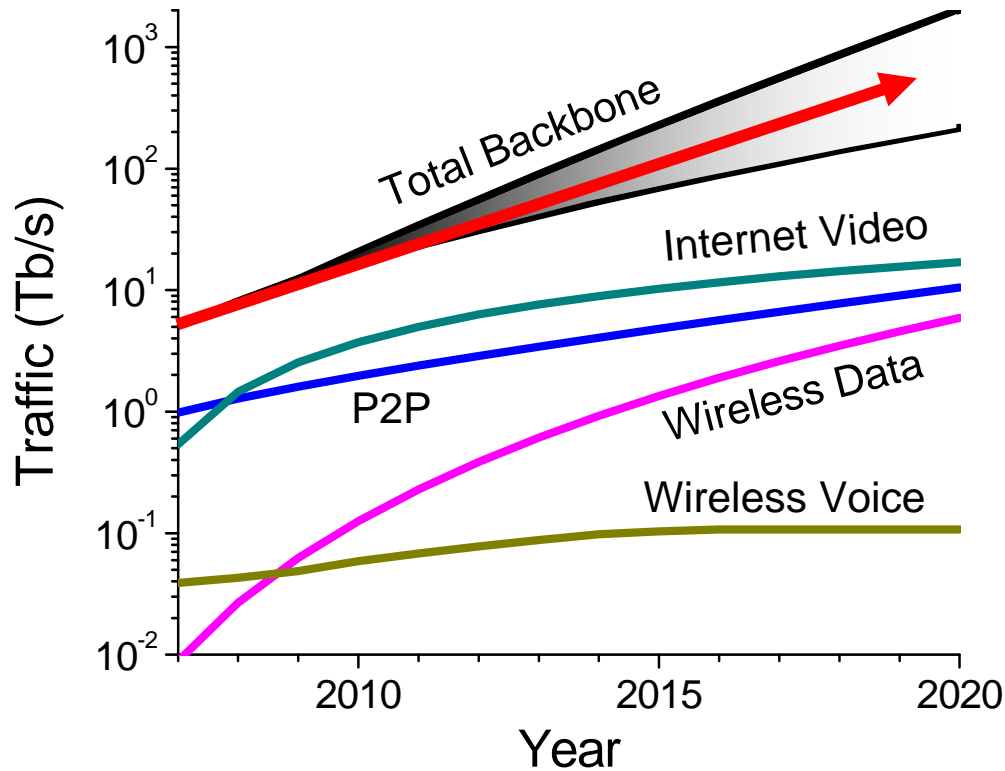


- ‘Greening of ICT’
  - How do I reduce or keep in check the carbon footprint of ICT itself?
- ‘Greening with ICT’
  - How do I use ICT to reduce carbon footprint and achieve sustainable living?
  - Prediction that ICT will save more energy than it will consume

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

# CONTINUED EXPONENTIAL TOTAL TRAFFIC GROWTH IN THE INTERNET

North America

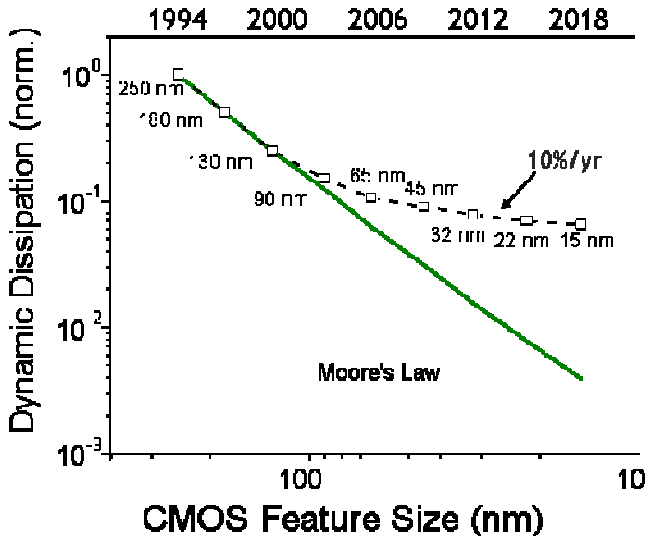


**Traffic doubling every 2 years**

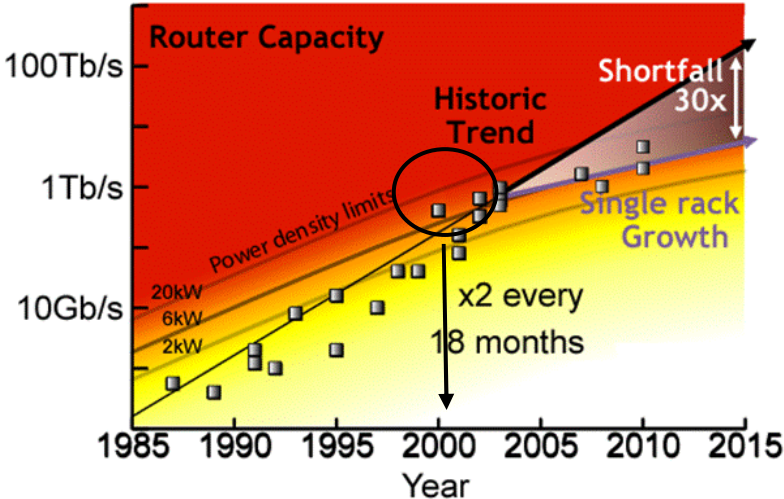
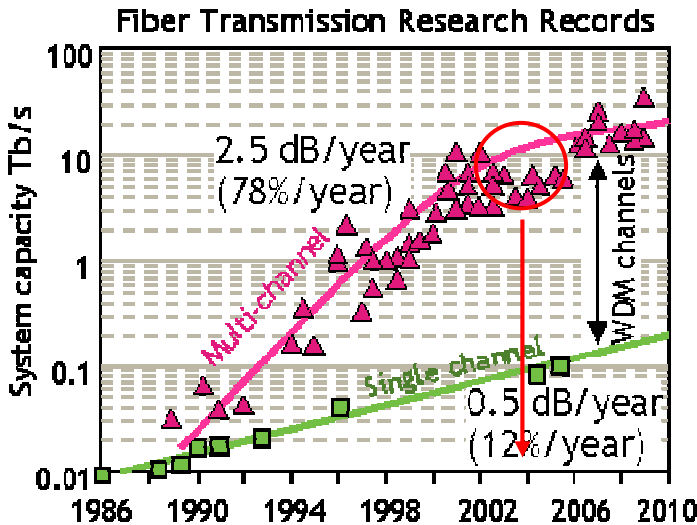
- 40% per year
- 30x in 10 years
- 1000x in 20 years

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

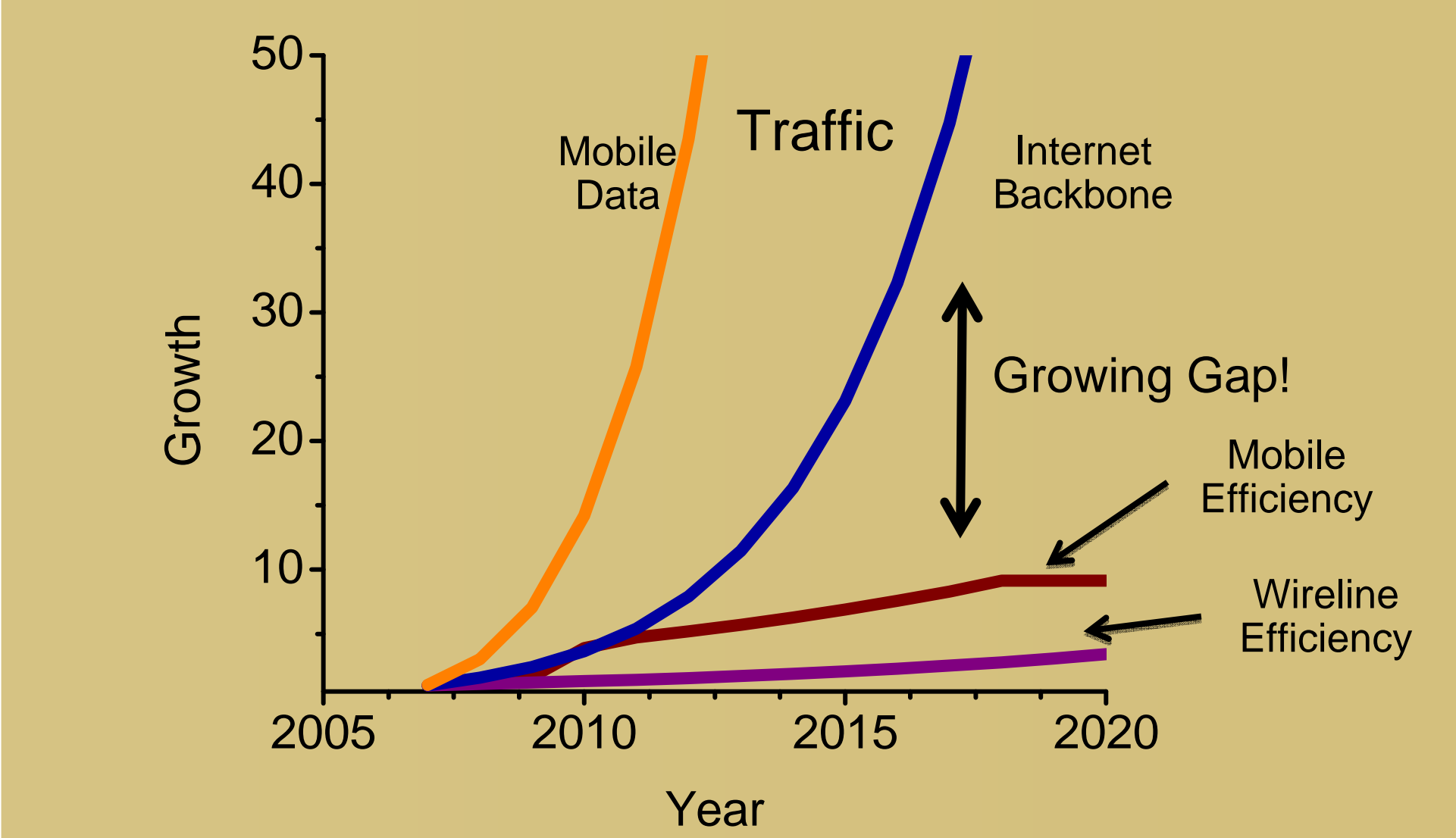


Network energy efficiency only increasing at 10-15% per year

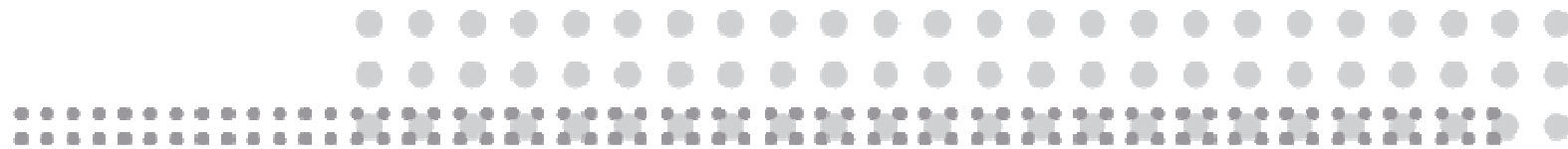




# THE NETWORK ENERGY GAP

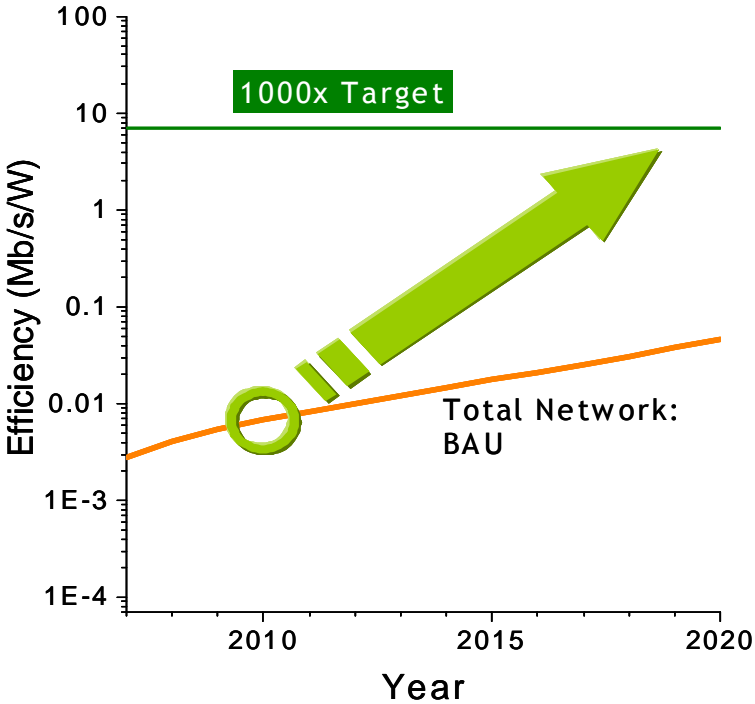


# GreenTouch Overview



# GREENTOUCH MISSION ([www.greentouch.org](http://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



# Why 1000x Network Efficiency?

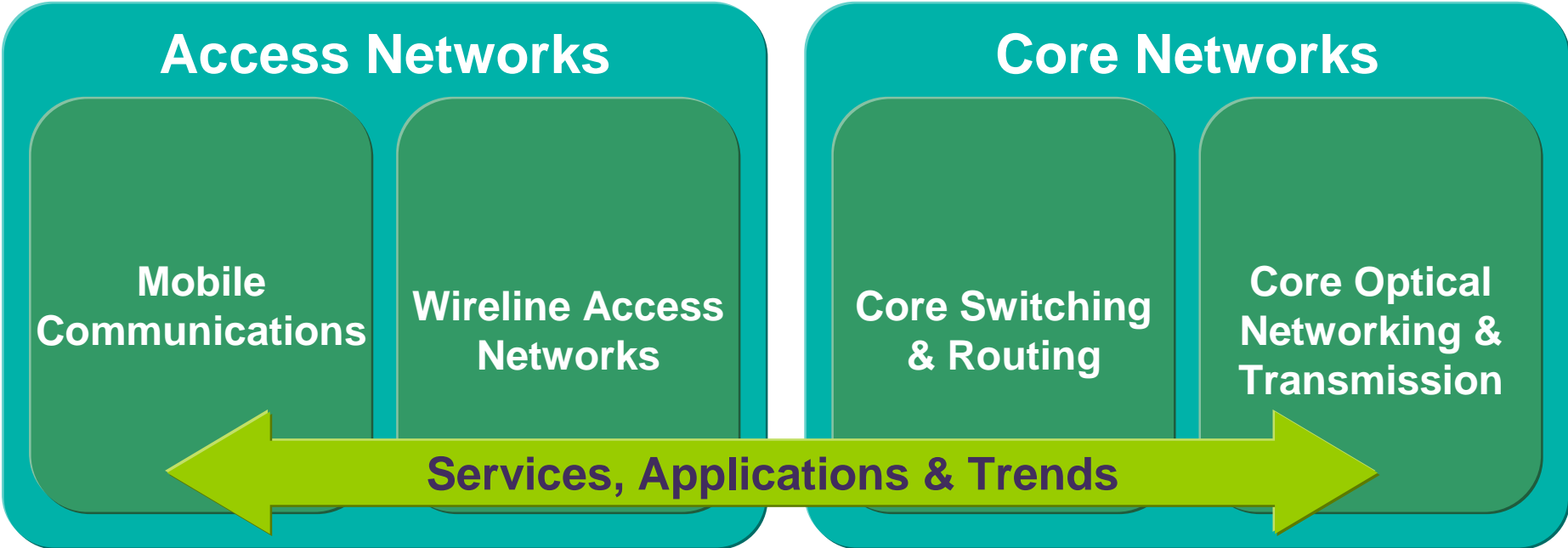
- Because...
  - Traffic will grow by 1000 within 20 years
  - All parts of the network will matter
  - All technologies we use in networks will matter
  - It makes you question all aspects of the network
  - It requires a highly scalable network
  - You can't solve it with growth alone
  - You can't solve it with power reduction alone
  - The goal should fit the problem...

# It takes a (large) ecosystem...




■ ■ ■



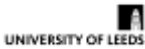
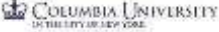





# GT Structure




# SOME RESEARCH PROJECTS...



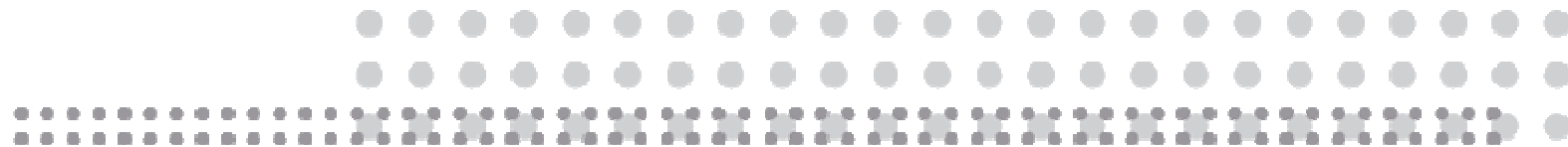


Beyond Cellular - Green Mobile Networks	
Virtual Home Gateway	
Optimal End-to-End Resource Allocation	
Service Energy Aware Optical Networks	
Green Transmission Technologies	
Minimum Energy Access Architectures	
Single-Chip Linecards	Bell Labs
Large-Scale Antenna Systems	
Highly-Adaptive Layer Mesh Networks	Bell Labs
Massive MIMO	 



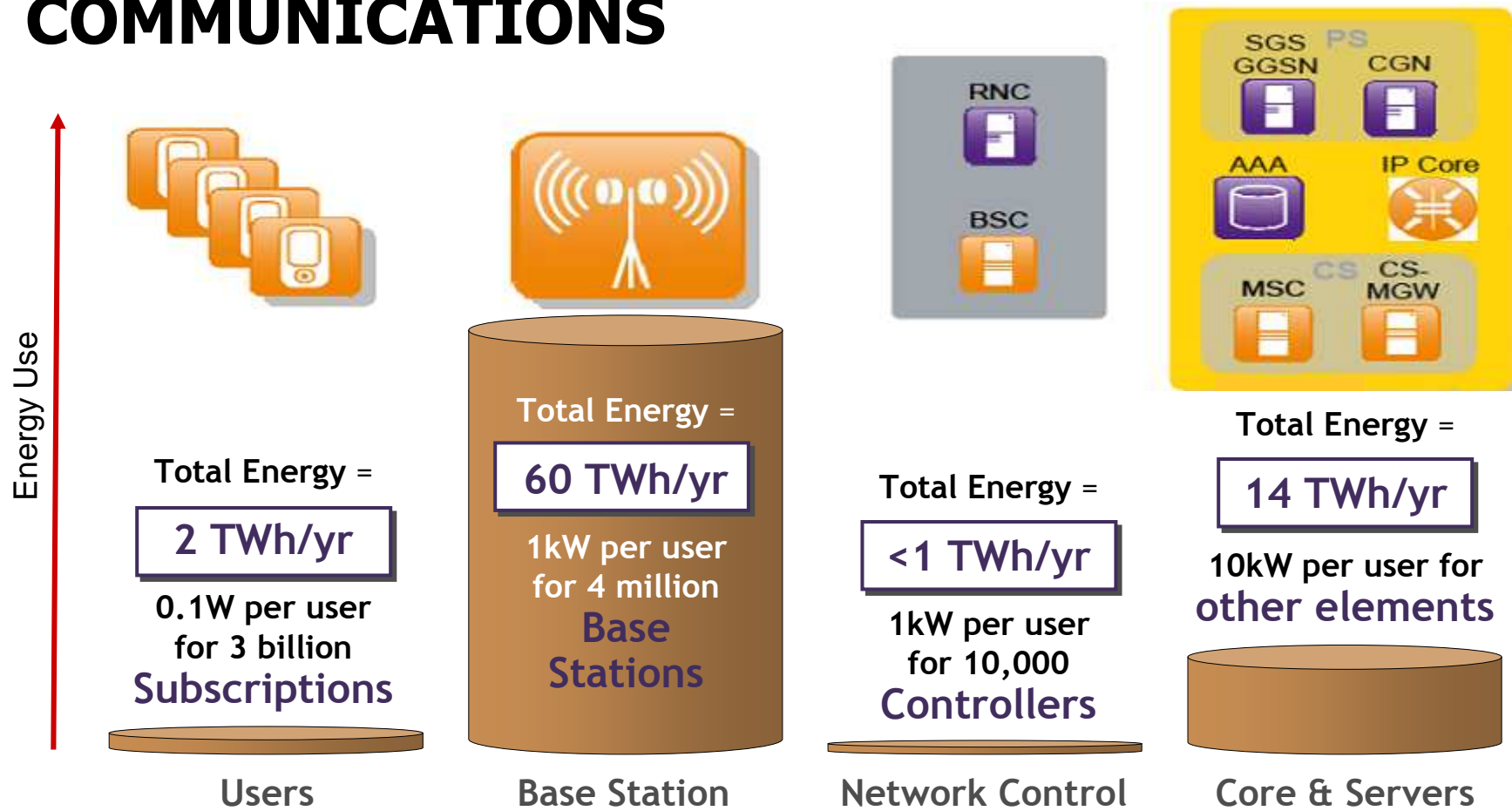
25+ Projects

# Research Directions for Green Wireless Networks





# POWER CONSUMPTION OF MOBILE COMMUNICATIONS



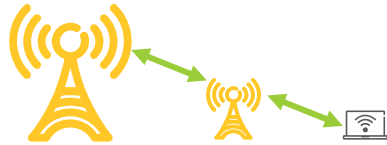
**The greatest opportunity to reduce energy consumption is to improve base stations**

Based on: ETSI RRS05\_024, NSN

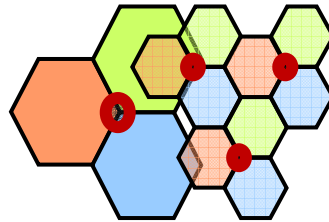
# GREEN NETWORK OPPORTUNITIES (I)

## Deployment:

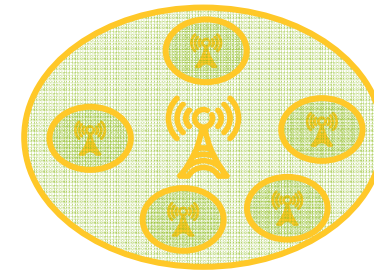
### *Relays Nodes*



### *Multi RAT*

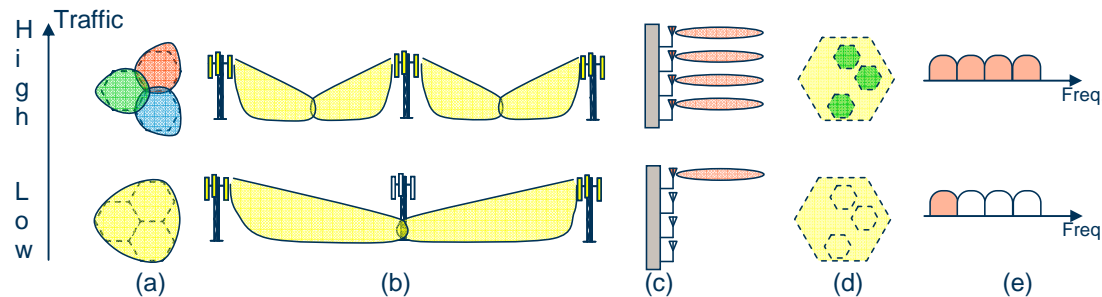


### *Heterogeneous Networks*



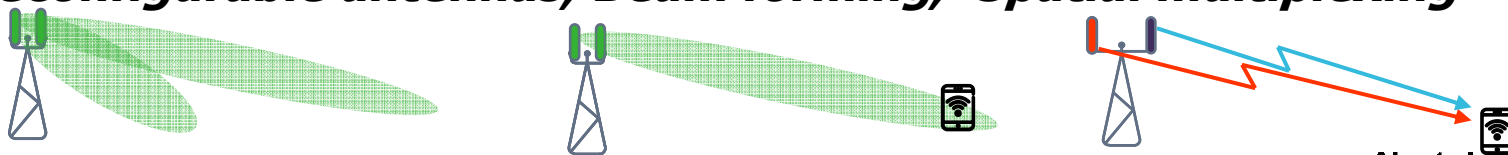
## Network Management:

### *BS cooperation, Adaptive NW configuration*



## Multi-Antenna Techniques:

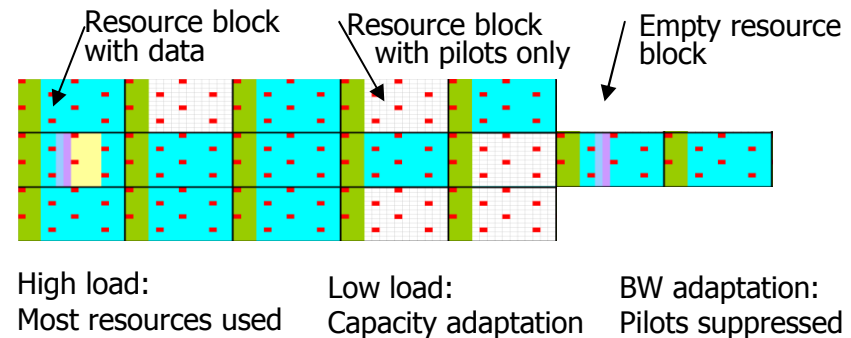
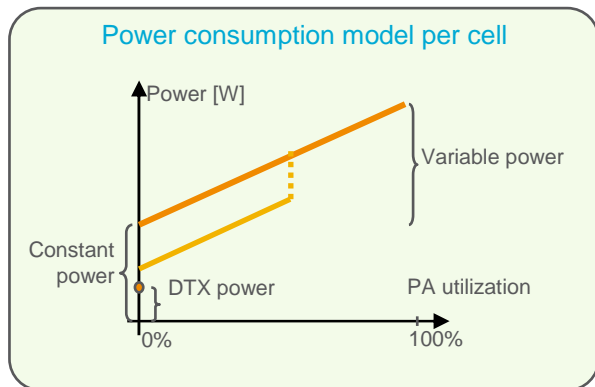
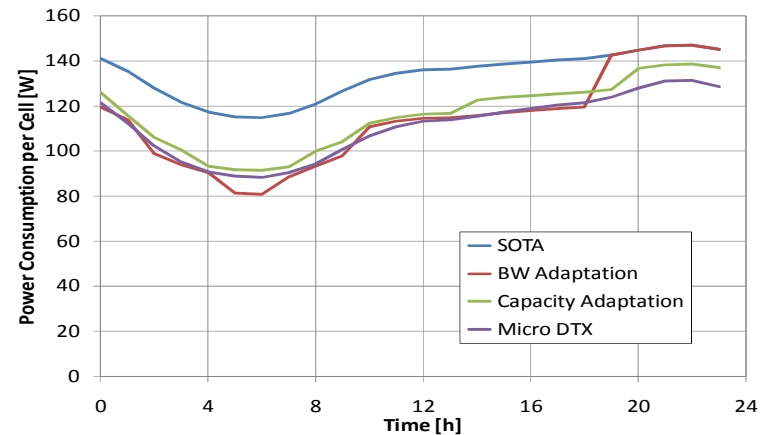
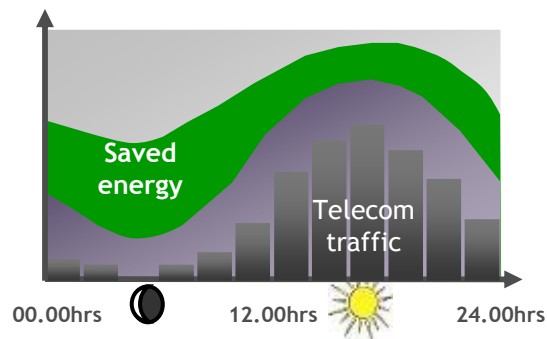
### *Reconfigurable antennas, Beam forming, Spatial multiplexing*



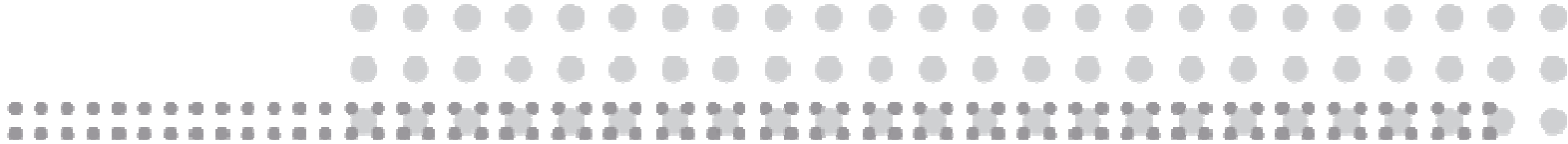
# GREEN NETWORK OPPORTUNITIES (II)

## 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

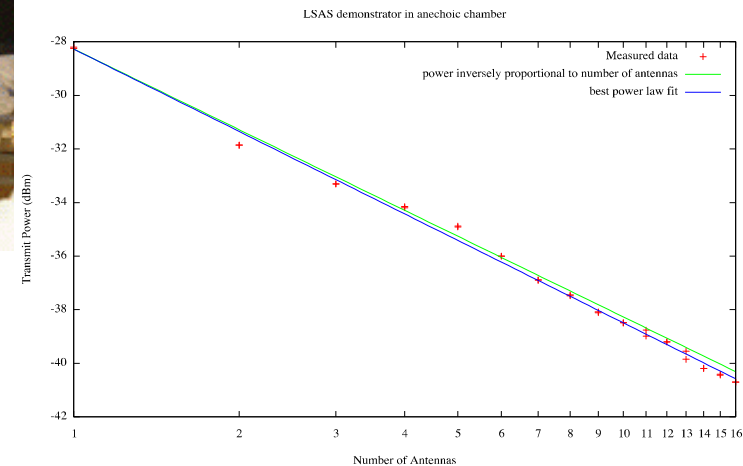
## 2. BCG<sup>2</sup> (Beyond Cellular Green Generation)

- Green network management / intelligent power management
- Independent network configuration for data and signaling

# LARGE SCALE ANTENNA SYSTEM



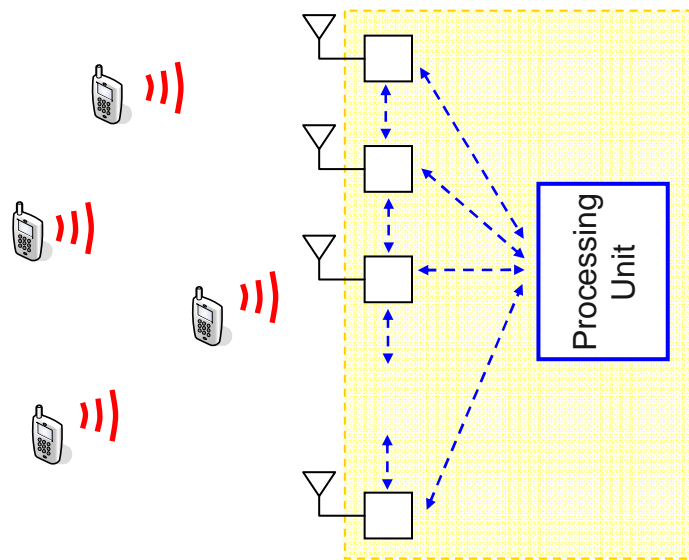
Measured transmit power is inversely proportional to the number of antennas:



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

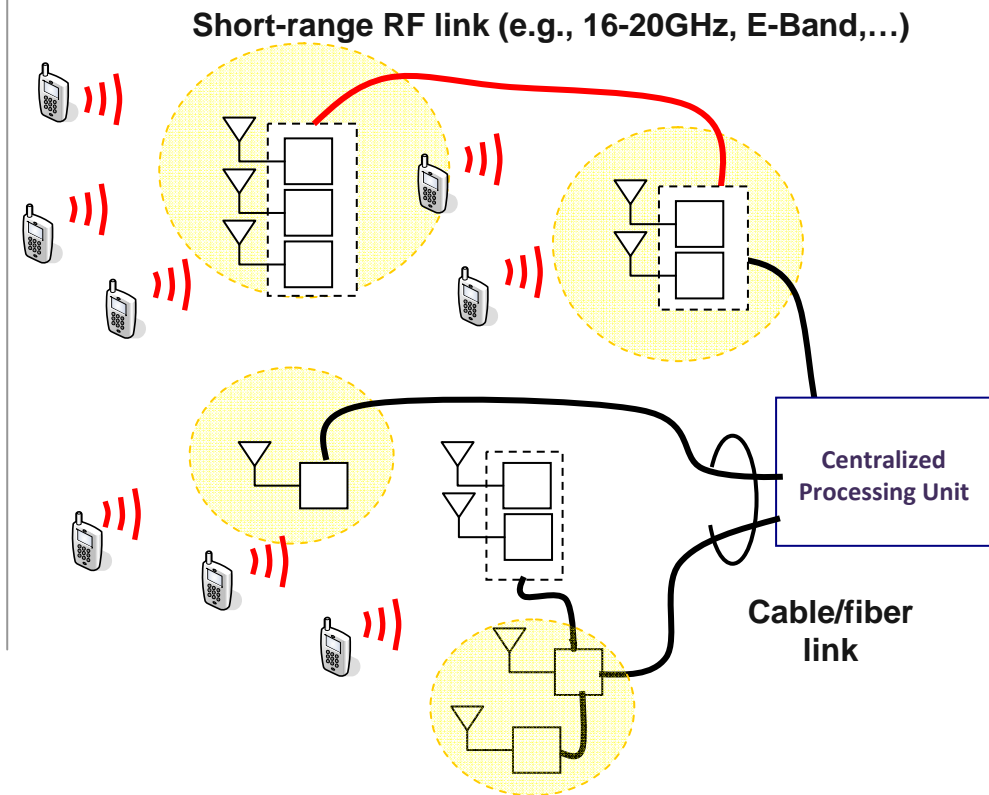
# APPLICATION SCENARIOS

## Massive Co-located Antennas



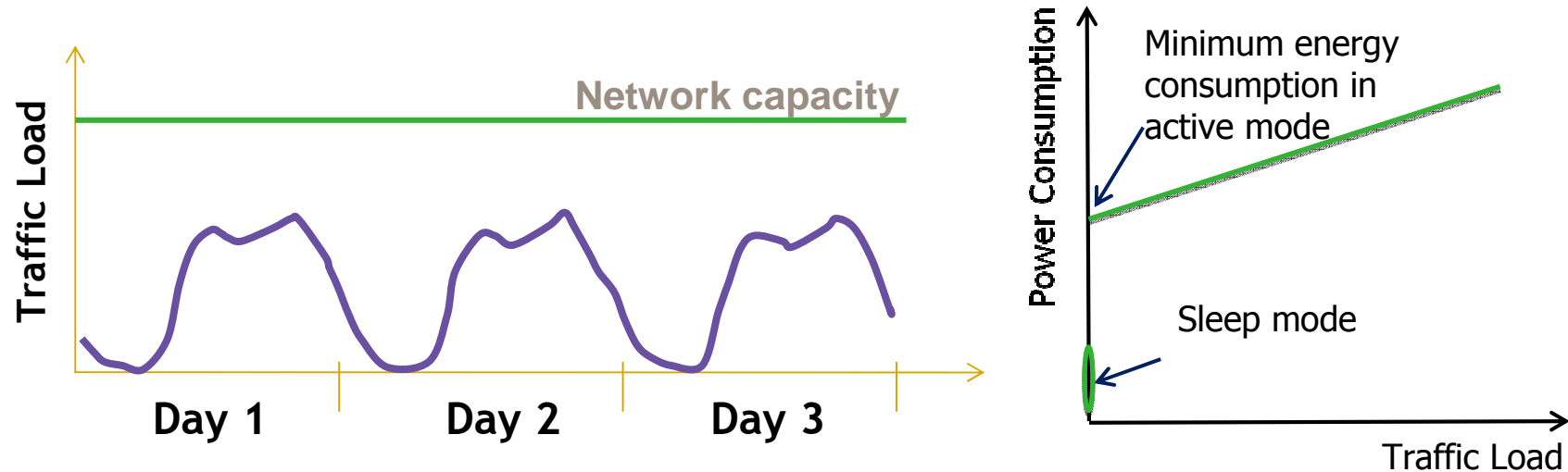
Marzetta, T. L., IEEE Trans Wireless Communications, Nov 2010

## Spatially Distributed Antennas



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

# BEYOND CELLULAR GREEN GENERATION (BCG<sup>2</sup>)

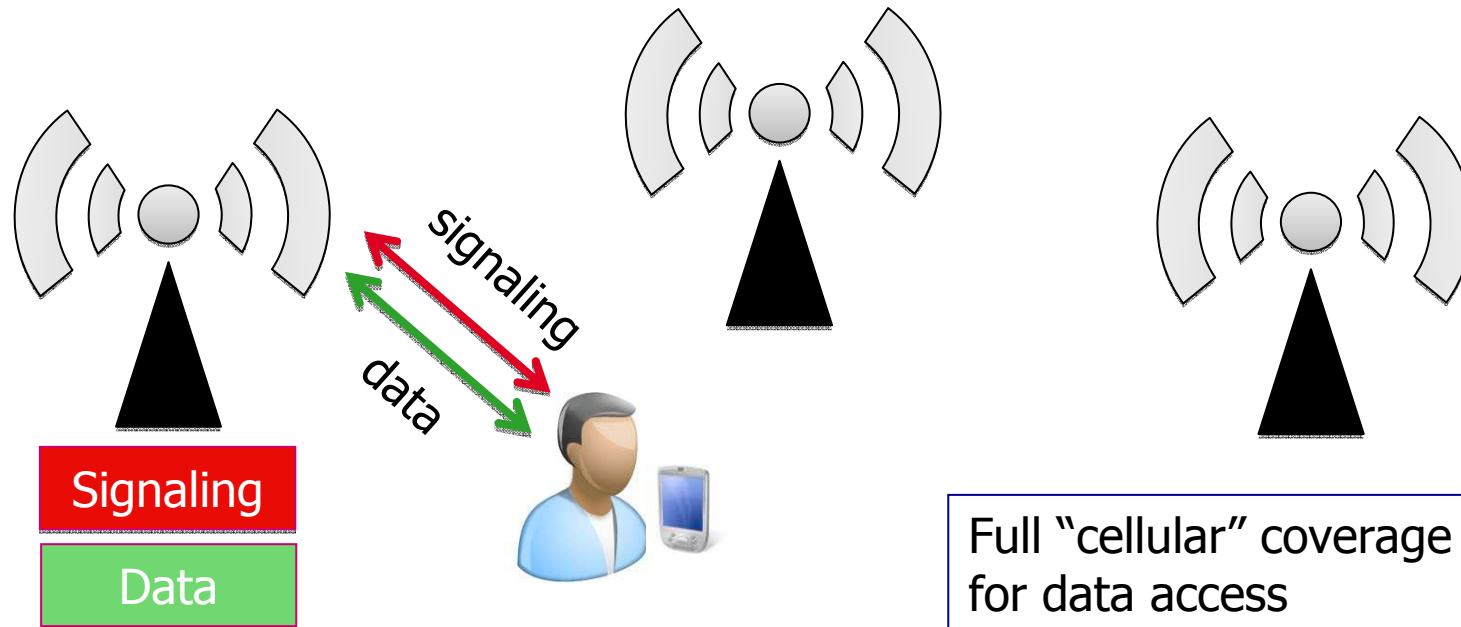


- Wireless access networks are dimensioned for estimated peak demand using dense layers of cell coverage
- Traffic varies during the day
- Energy consumption is almost constant – Due to the power consumed by signaling





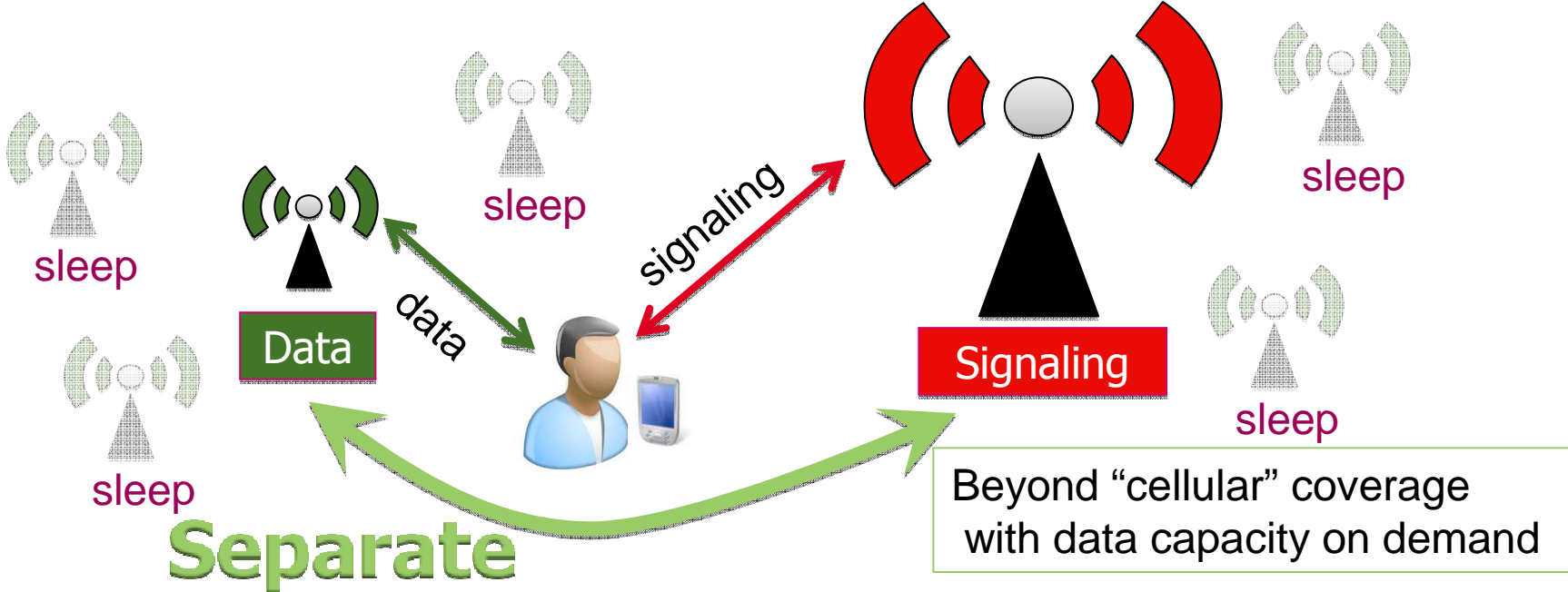
# TRADITIONAL CELLULAR ARCHITECTURE



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

# BCG<sup>2</sup> ARCHITECTURE



- 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

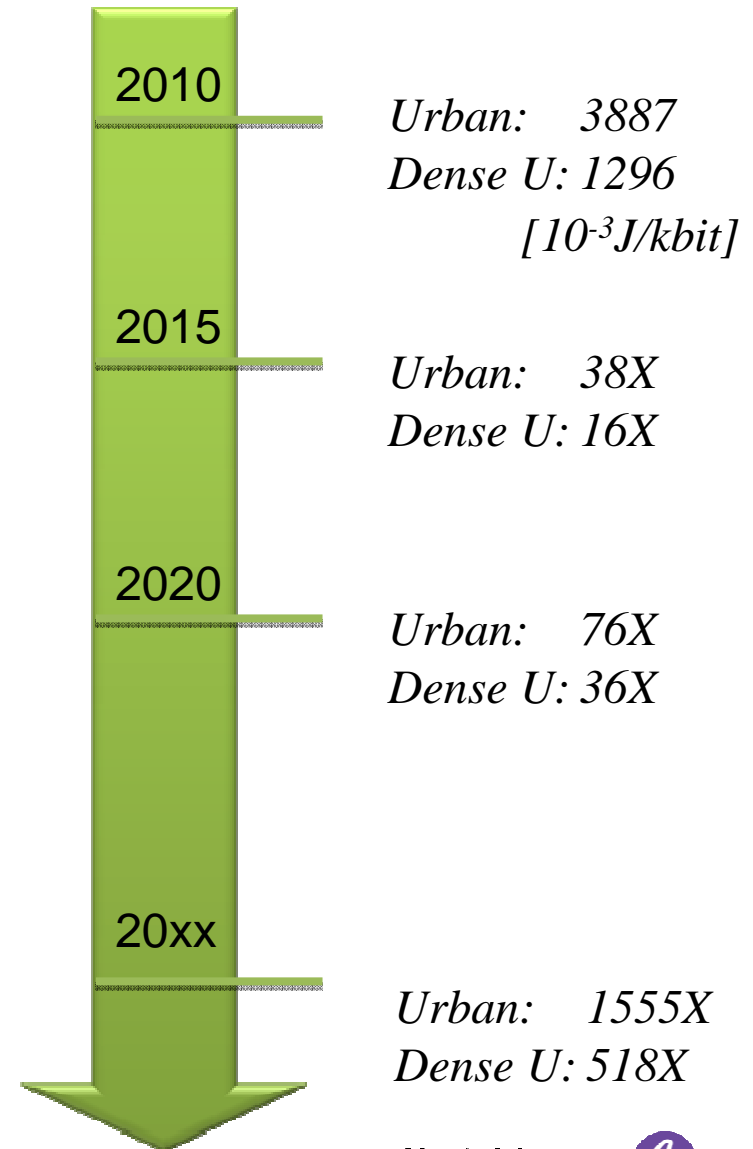


**2010**  
Reference scenario:  
Macro BSs only (SCENARIO 1)  
Always-on  
Low traffic level

**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

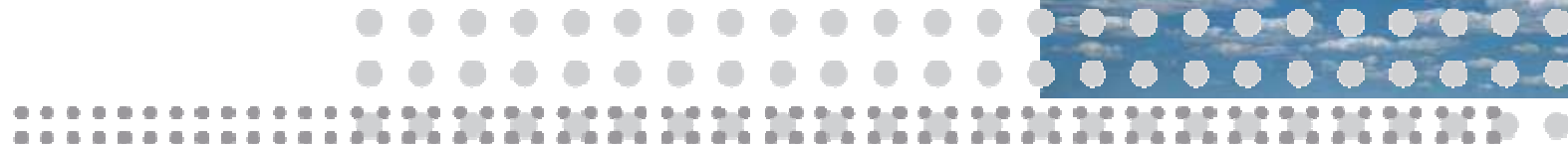
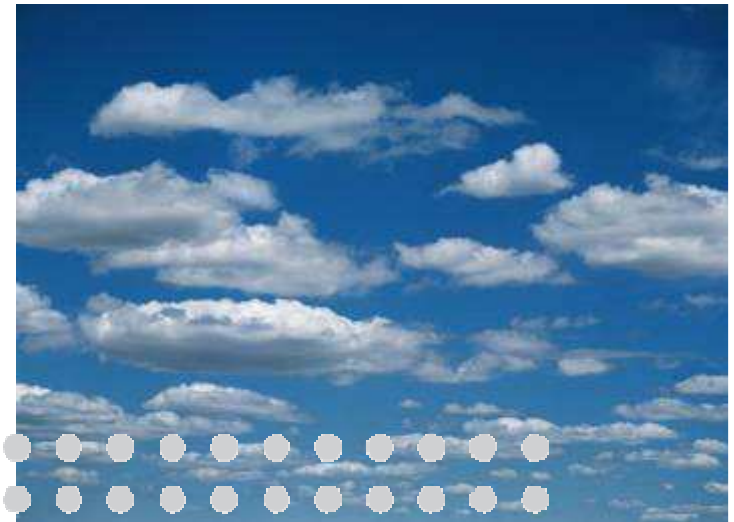
**Long term scenario**  
Atto cellular scenario  
100% atto BSs  
BCG energy management  
Any traffic level



# 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