Politecnico di Milano

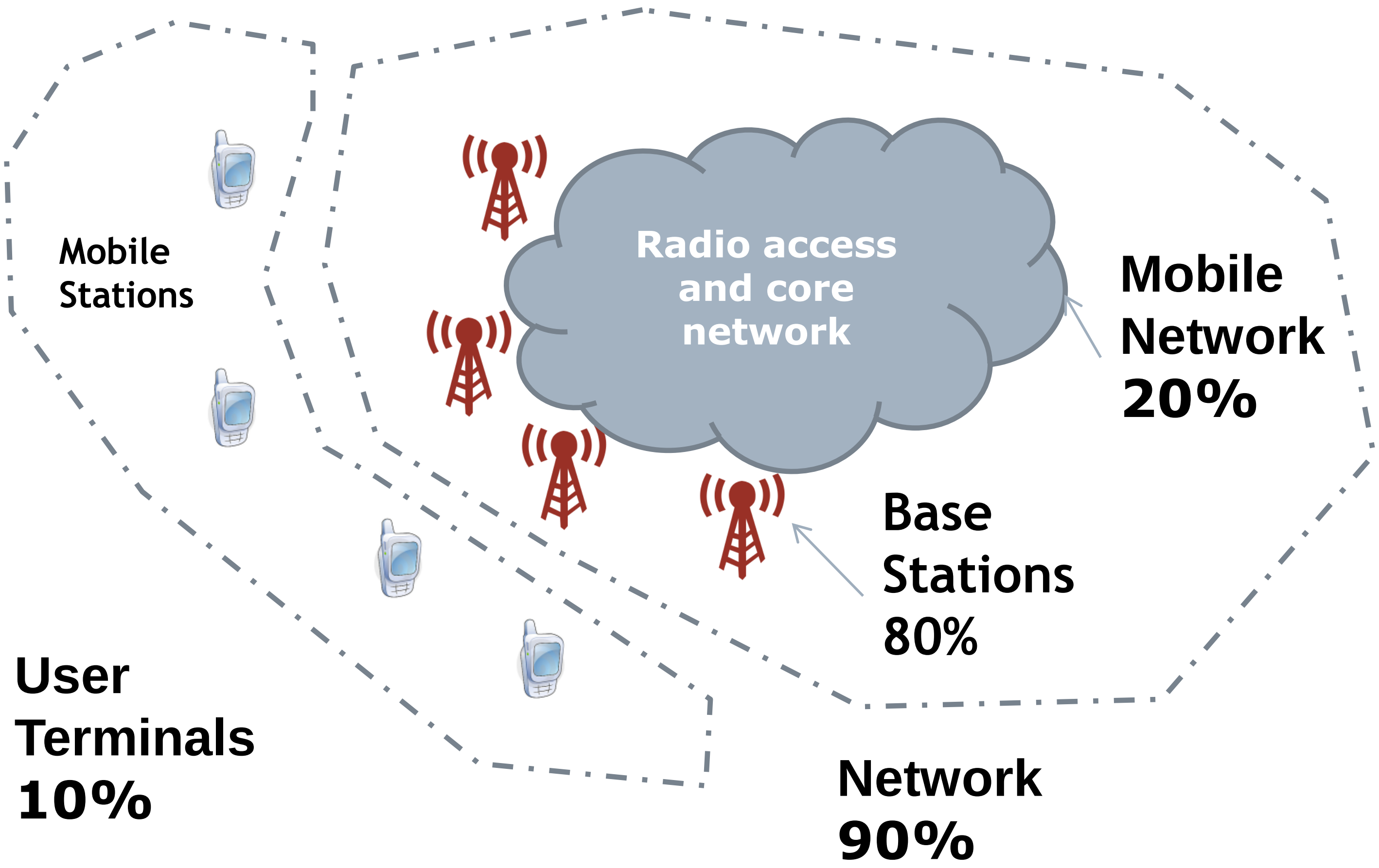
Advanced **N**etwork **T**echnologies **Lab**oratory

Energy and Mobility: Scalable Solutions for the Mobile Data Explosion

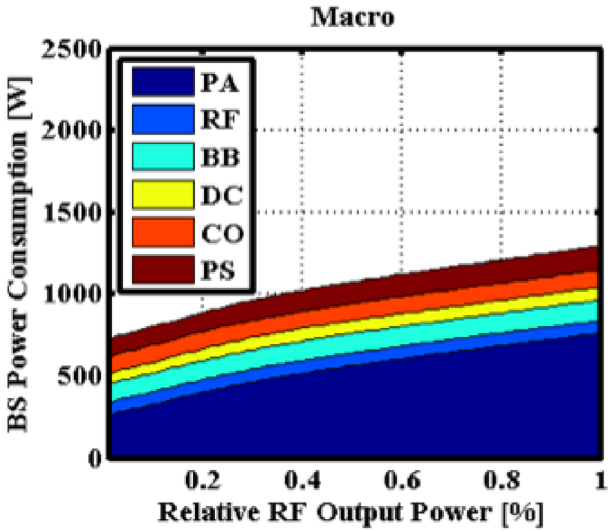
Antonio Capone

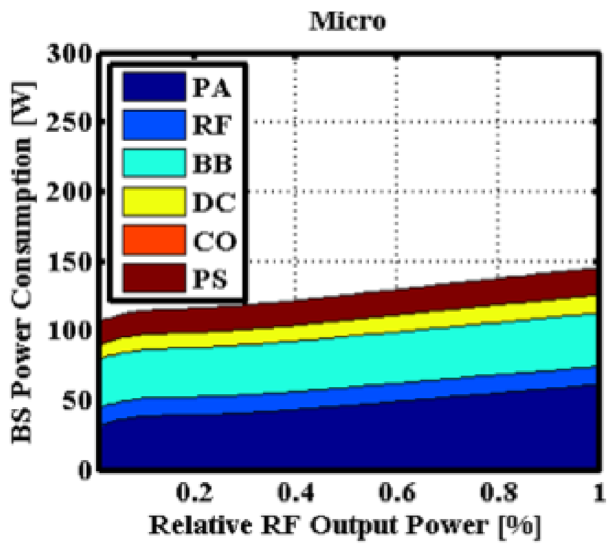
TIA 2012 – GreenTouch Open Forum
June 6, 2012

Energy consumption in wireless access networks



Energy consumption in wireless access networks

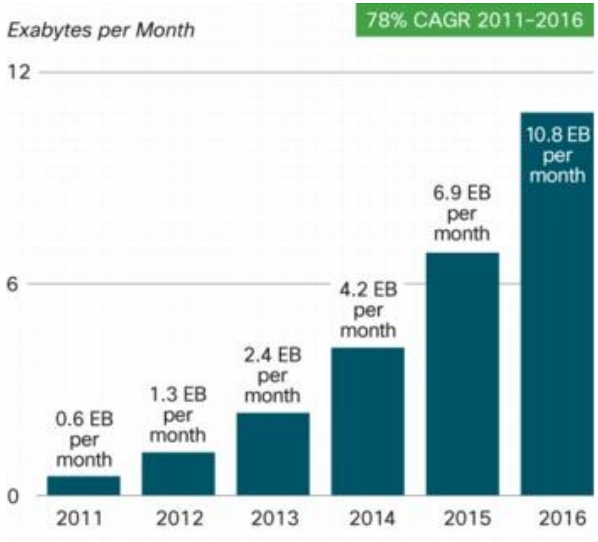




- Baseline energy consumption comparable (macro) or much larger (micro) than load dependent component
- Technology improvements:
  - Power amplifiers
  - Advanced transmission technologies
  - Multiple antenna systems
  - Centralized base band processing
  - Etc.

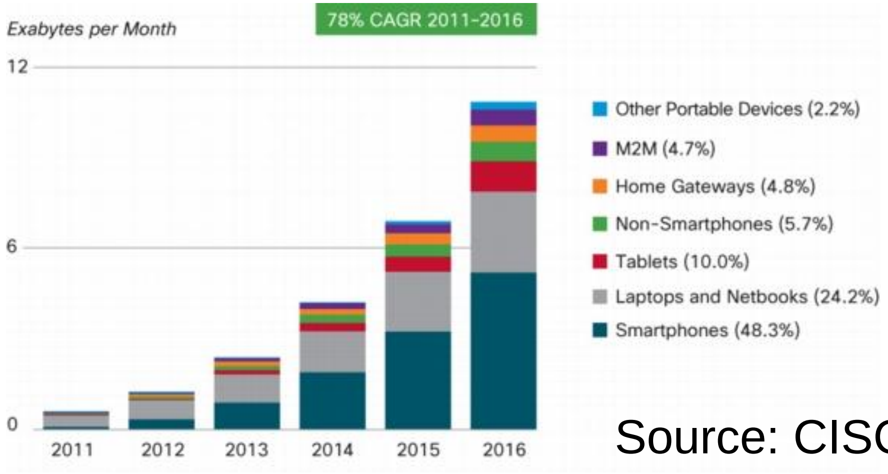
Source: EARTH project

Energy consumption in wireless access networks



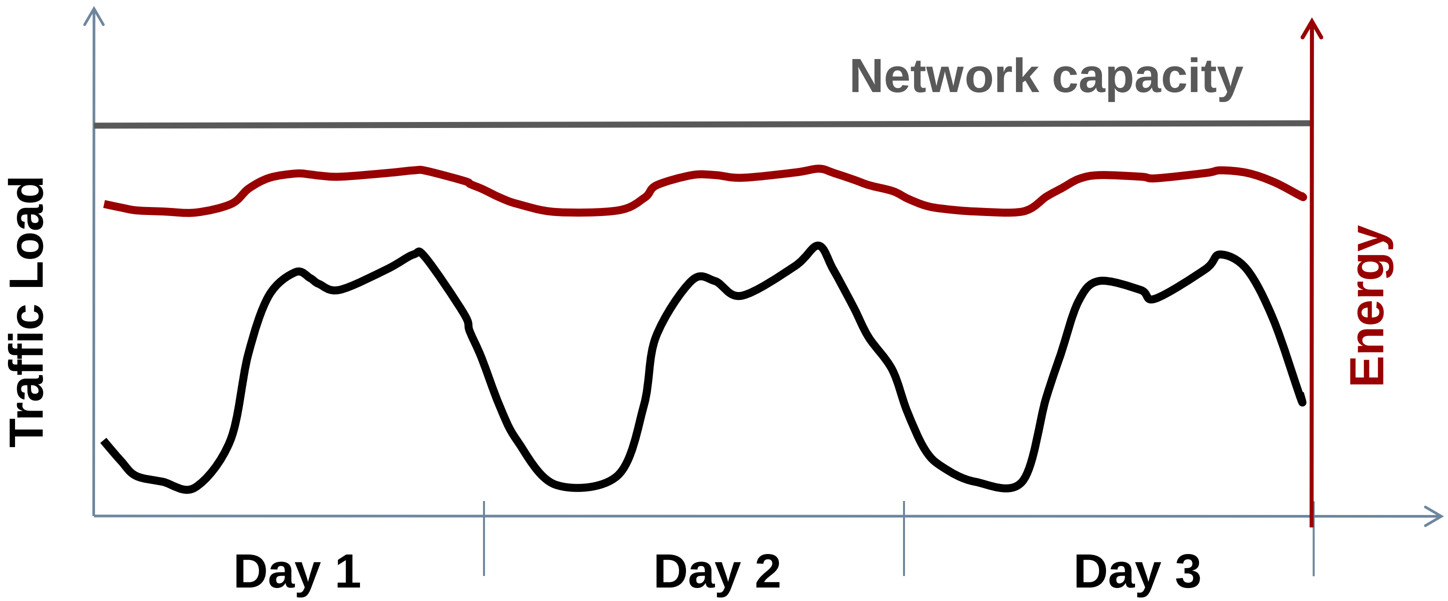
- Mobile traffic explosion
- Stimulated by smart phone diffusion

- Faster technology evolution
- From macro cells to small cells (micro, pico, femto)



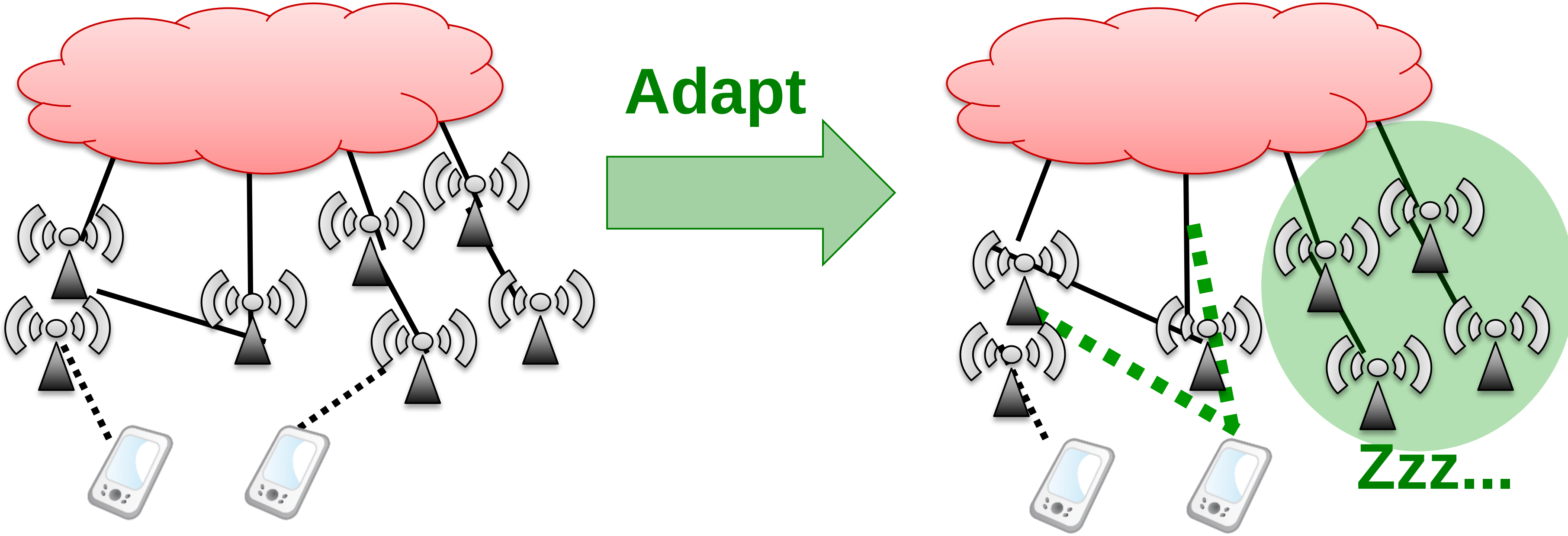
Source: CISCO VNI Mobile 2012

Variable Traffic load



- 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

Energy Management Approaches

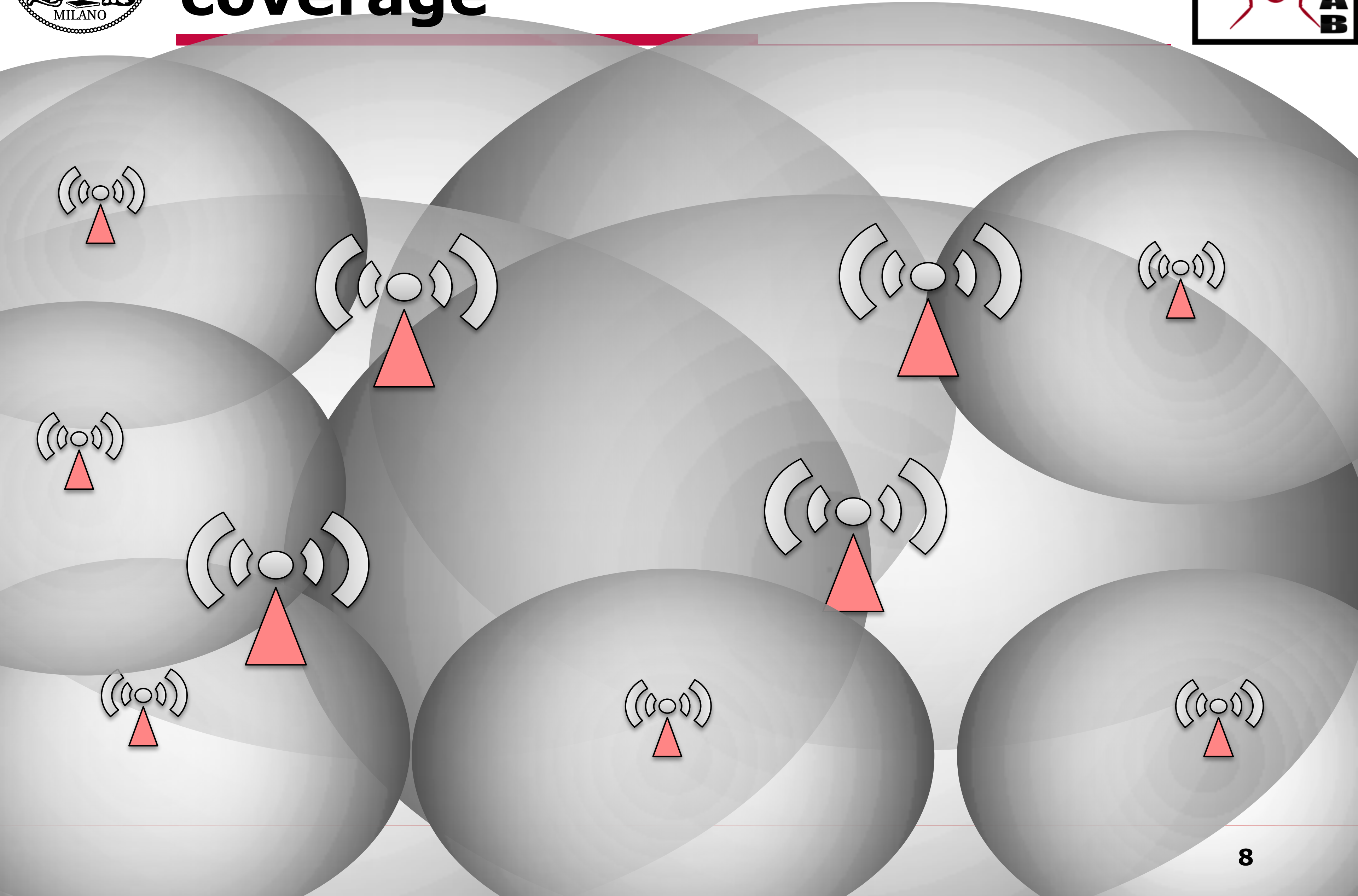


- Novel network structures and management policies that maximizes Energy Efficiency:
  - Efficient utilization of space;
  - Real-time network adaptation based on load requirements;
  - Support of sleep modes

Limits of traditional cellular architectures

- Unfortunately, there are some limiting constraints of the traditional cellular architecture that prevent high energy savings
- Cellular networks require **full coverage** of the service area for supporting the **any-time everywhere service** paradigm
- Turning off some base stations is possible only if their areas are covered by some other base stations that are active
- **Large overlaps** among cells is required
- **Capacity over-provisioning** for flexibility allowance

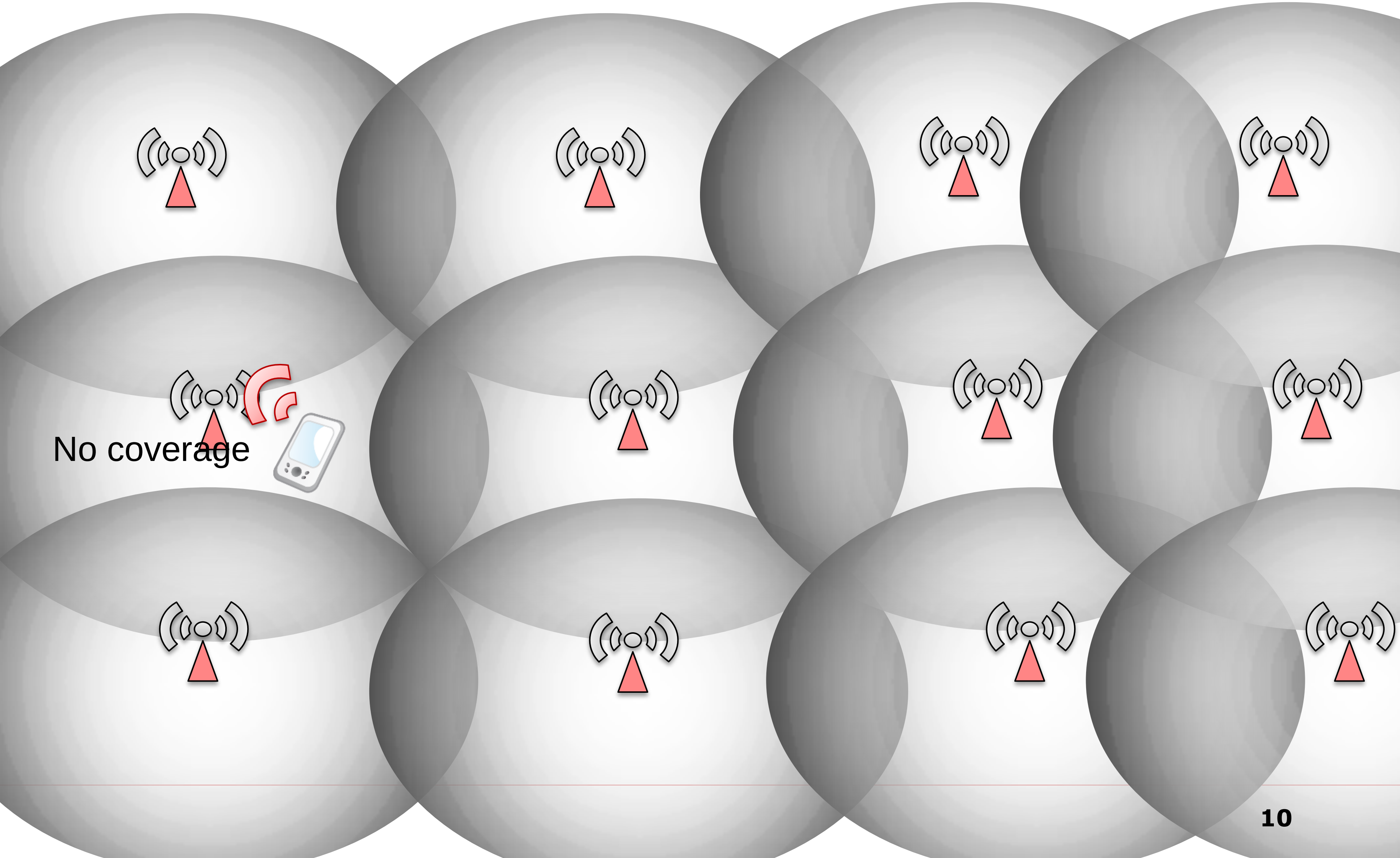
Energy adaptation with full coverage



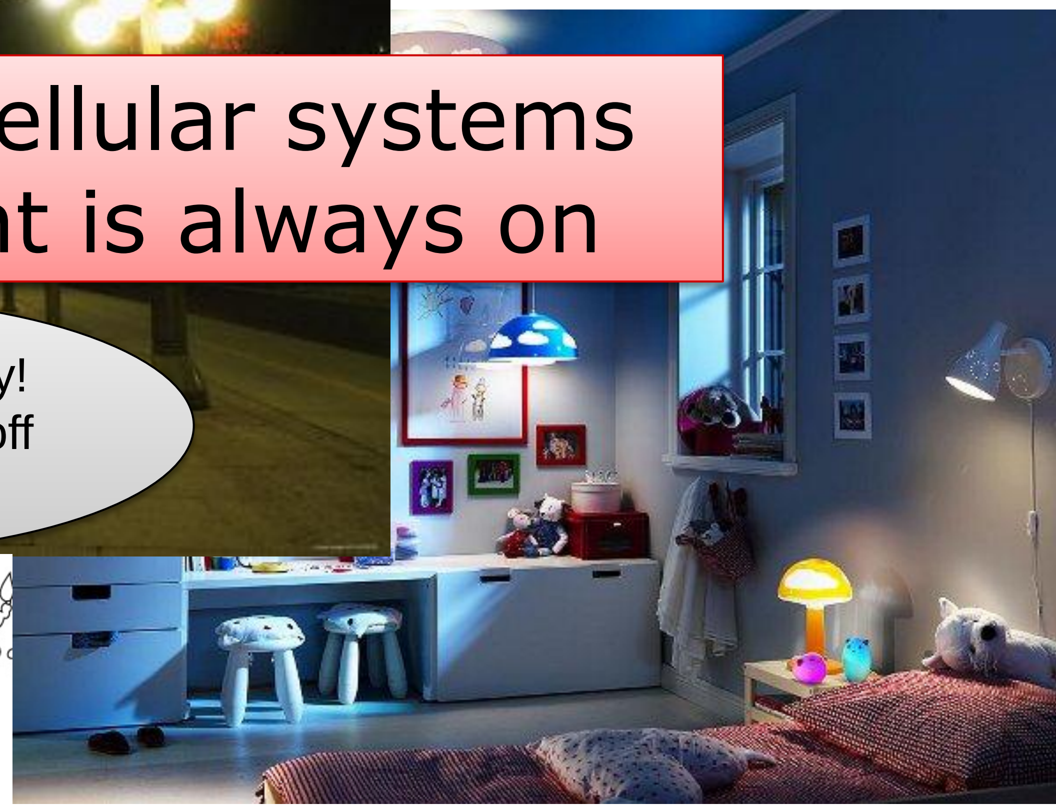
Limits of traditional cellular architectures

- It has been shown that with traditional cellular technologies **energy savings** in the range of **20%-40%** can be achieved
- Due to traffic increase an higher energy efficiency it is expected that in the **future micro and pico cellular layouts** will be preferred over traditional macro cellular ones
- This may even **reduce the savings** achievable with energy management since most of the base stations are essential for providing full coverage

Micro-cellular coverages

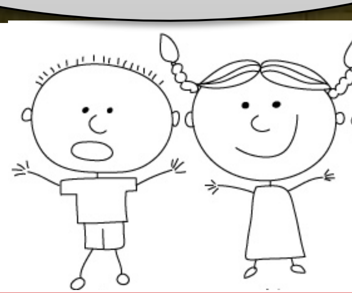


"Remember to turn off the light"



In cellular systems light is always on

Kids, dinner is ready! Remember to turn off the light



Beyond cellular

- We need to go beyond the cellular paradigm that requires always-on full coverage
- And move towards an **"on demand" coverage** model
- While guaranteeing service availability everywhere and anytime

Beyond Cellular Green Generation (BCG²)

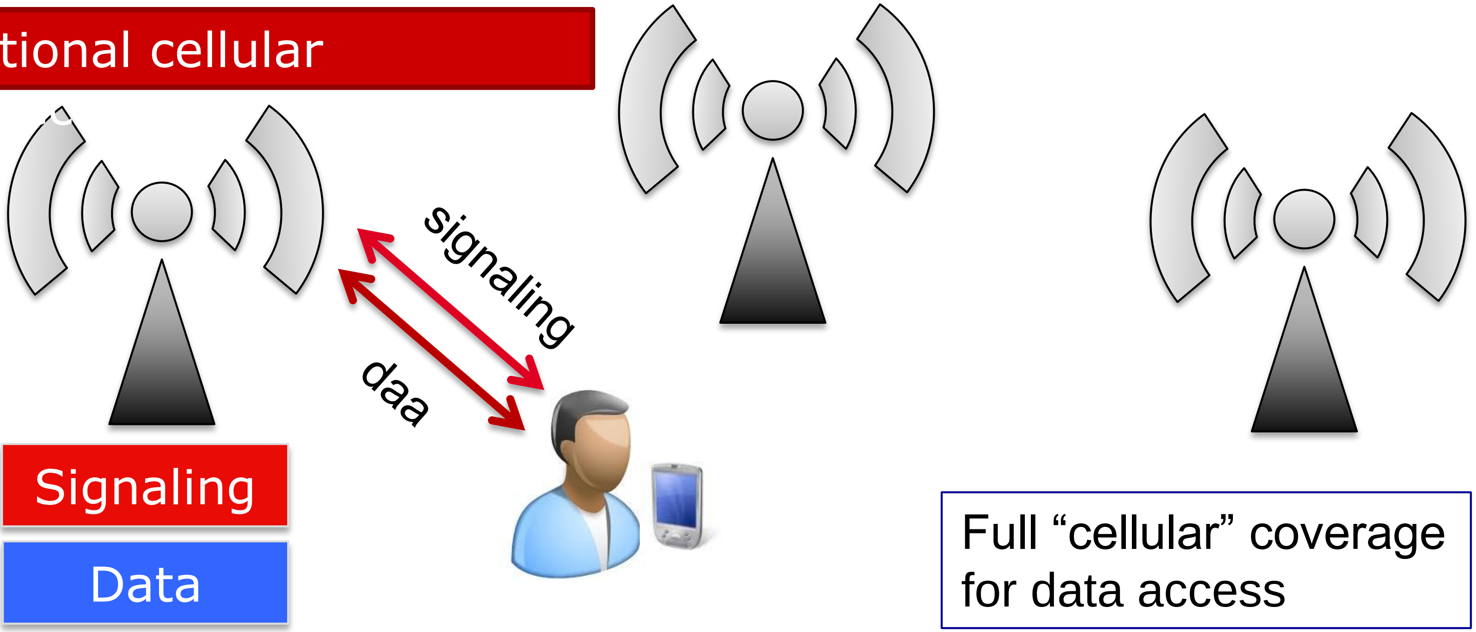
GreenTouch™

Partners:

- Alcatel·Lucent
- HUAWEI
- SAMSUNG
- orange™
- TNO
- INRIA
- UNIVERSITÄT PADERBORN
  Die Universität der Informationsgesellschaft
- TECHNISCHE UNIVERSITÄT DRESDEN
- POLITECNICO DI MILANO
- Fondazione Politecnico di Milano
- POLITECNICO DI TORINO

BCG²: Basic idea

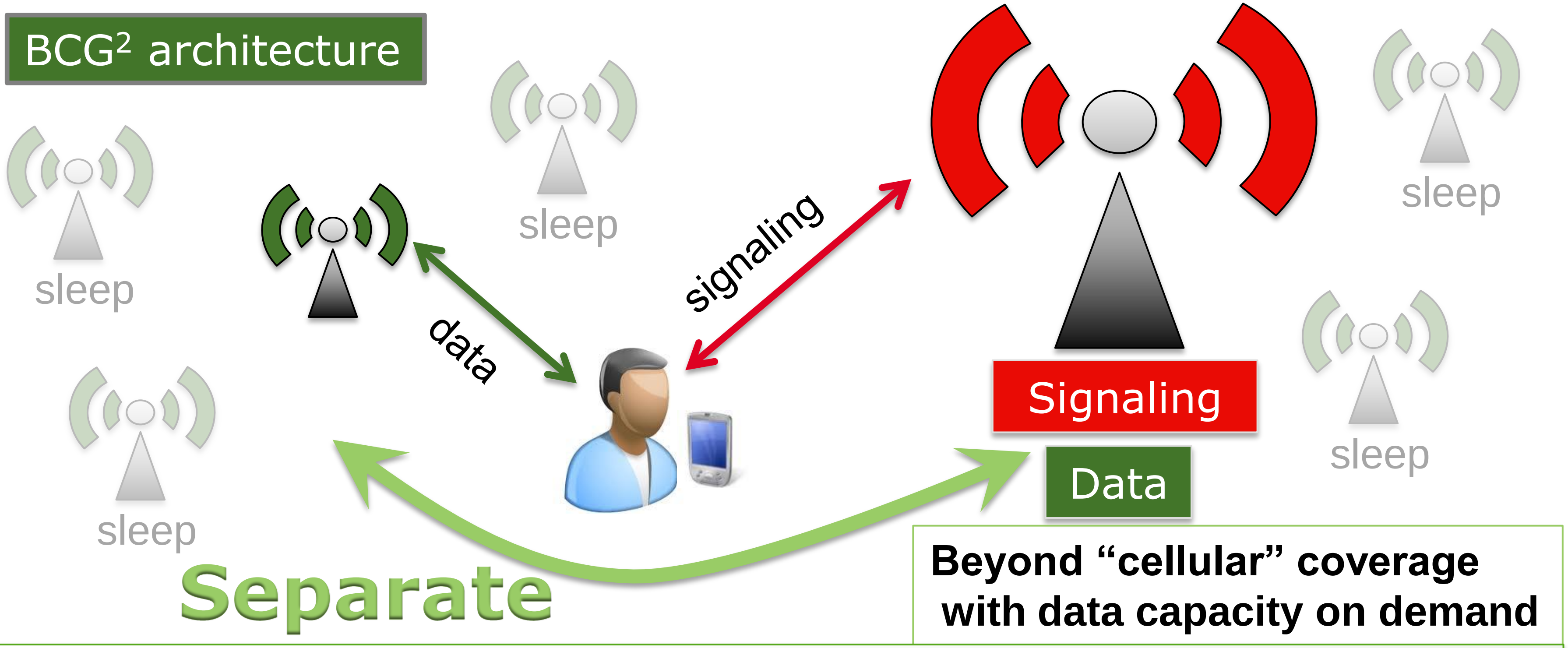
Traditional cellular



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

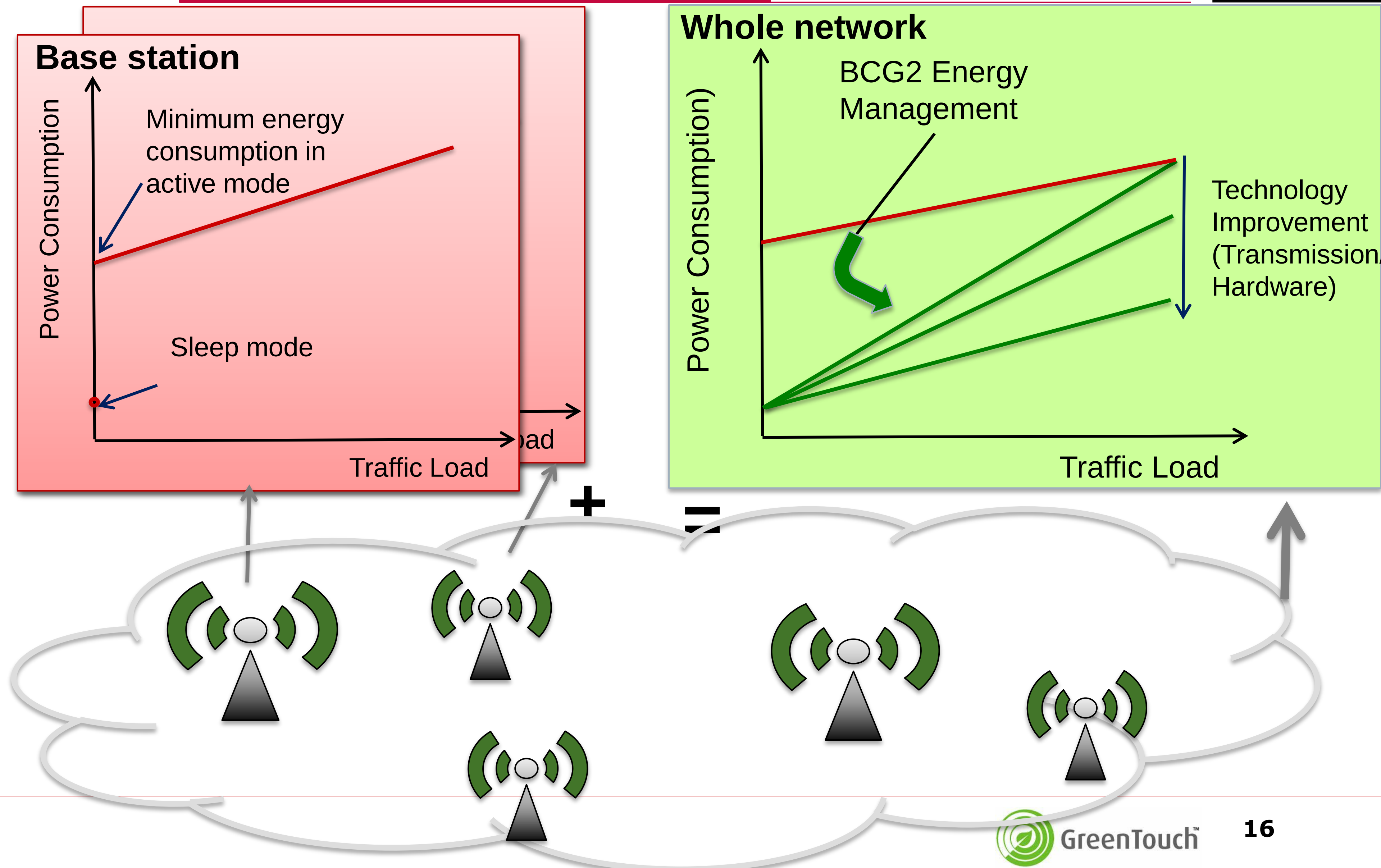
BCG²: Basic idea



Separation of signaling and data functions at the radio interface:

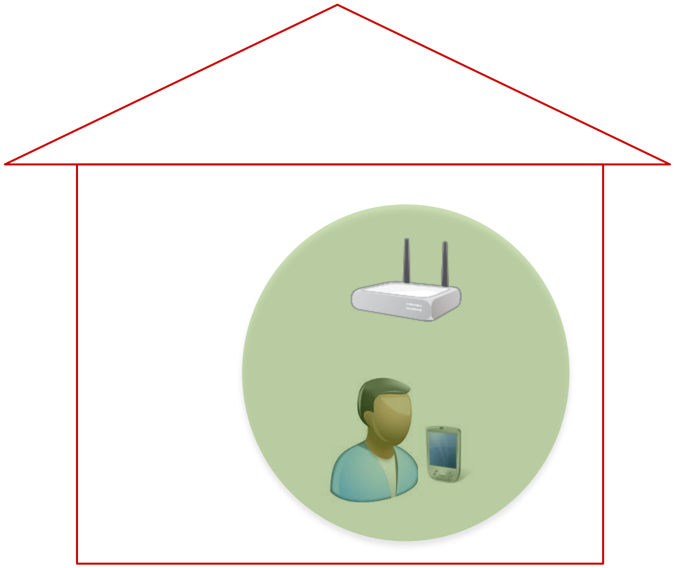
- Full Coverage and always available connectivity ensured by signaling base stations only
- Data access capacity provided by data base stations on demand

From base station power profile to network profile

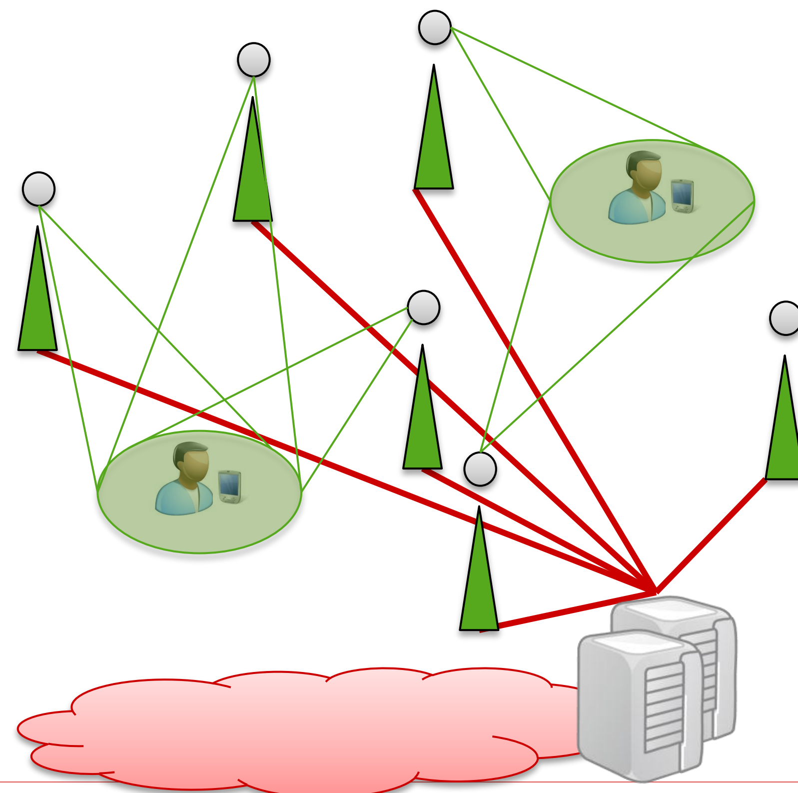


Individual cells

- Long term scenario



1) From femto cells
to individual “**atto cells**”



2) Individual **virtual cells** with centralized processing and distributed antennas

Technical challenges (1)

- **Quantitative analysis of the fundamental advantages of the BCG architecture**, primarily in terms of energy consumption.
- We are working on:
  - Analytical models based on: stochastic processes, mathematical programming, integral and stochastic geometry
  - Simulation: Monte Carlo, discrete event simulation at system level
- Estimated gains vary based on traffic statistics (over time and space), coverage layout, etc.

BCG² Energy efficiency gain

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

2010
Urban: 3887
Dense U: 1296
[10^{-3} J/kbit]

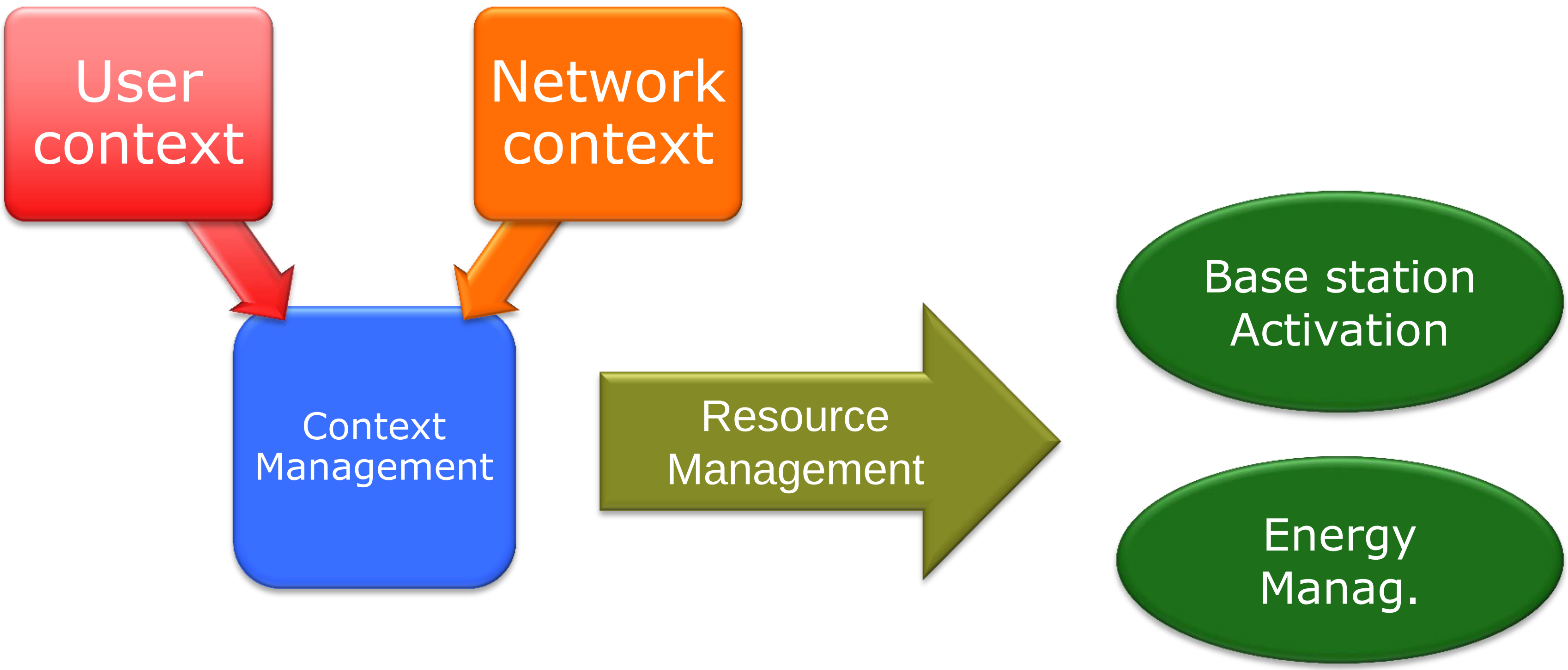
2015
Urban: 30-50X
Dense U: 15-25X

2020
Urban: 70-90X
Dense U: 30-50X

20xx
Urban: >1000X
Dense U: >500X

Technical challenges (2)

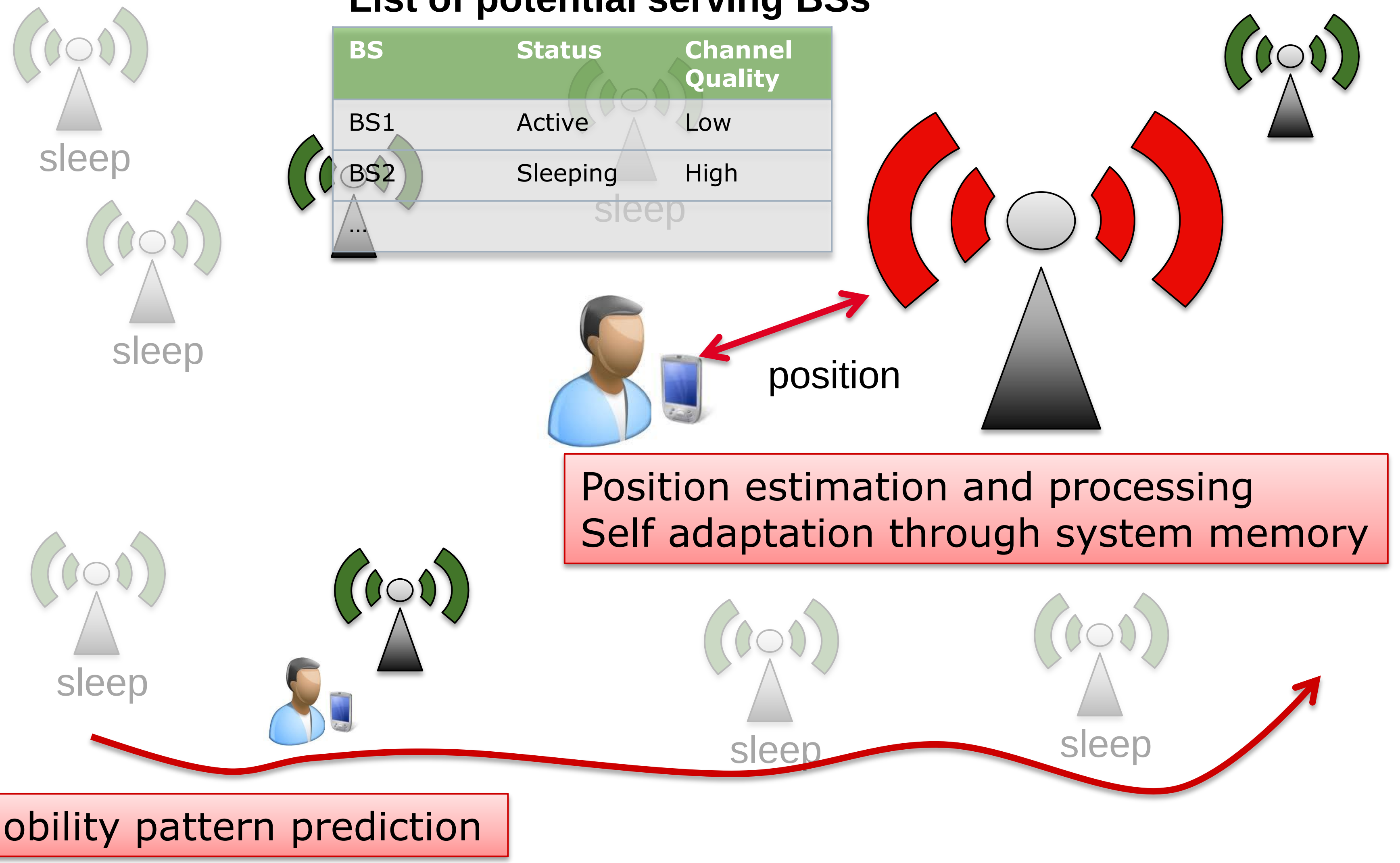
- **"Context" information** for intelligent resource selection algorithms that assign requests to access points and activates radio resources.



Context Awareness: Position & Mobility

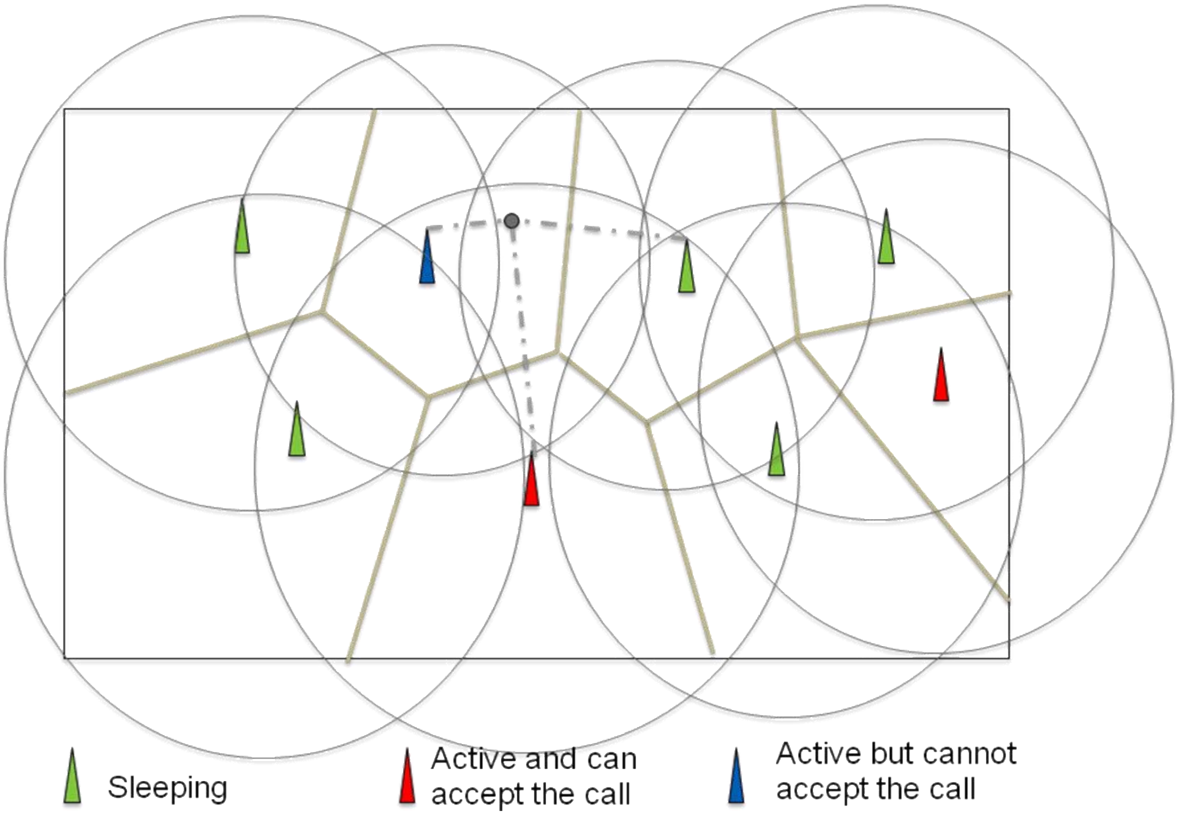
List of potential serving BSs

BS	Status	Channel Quality
BS1	Active	Low
BS2	Sleeping	High
…		



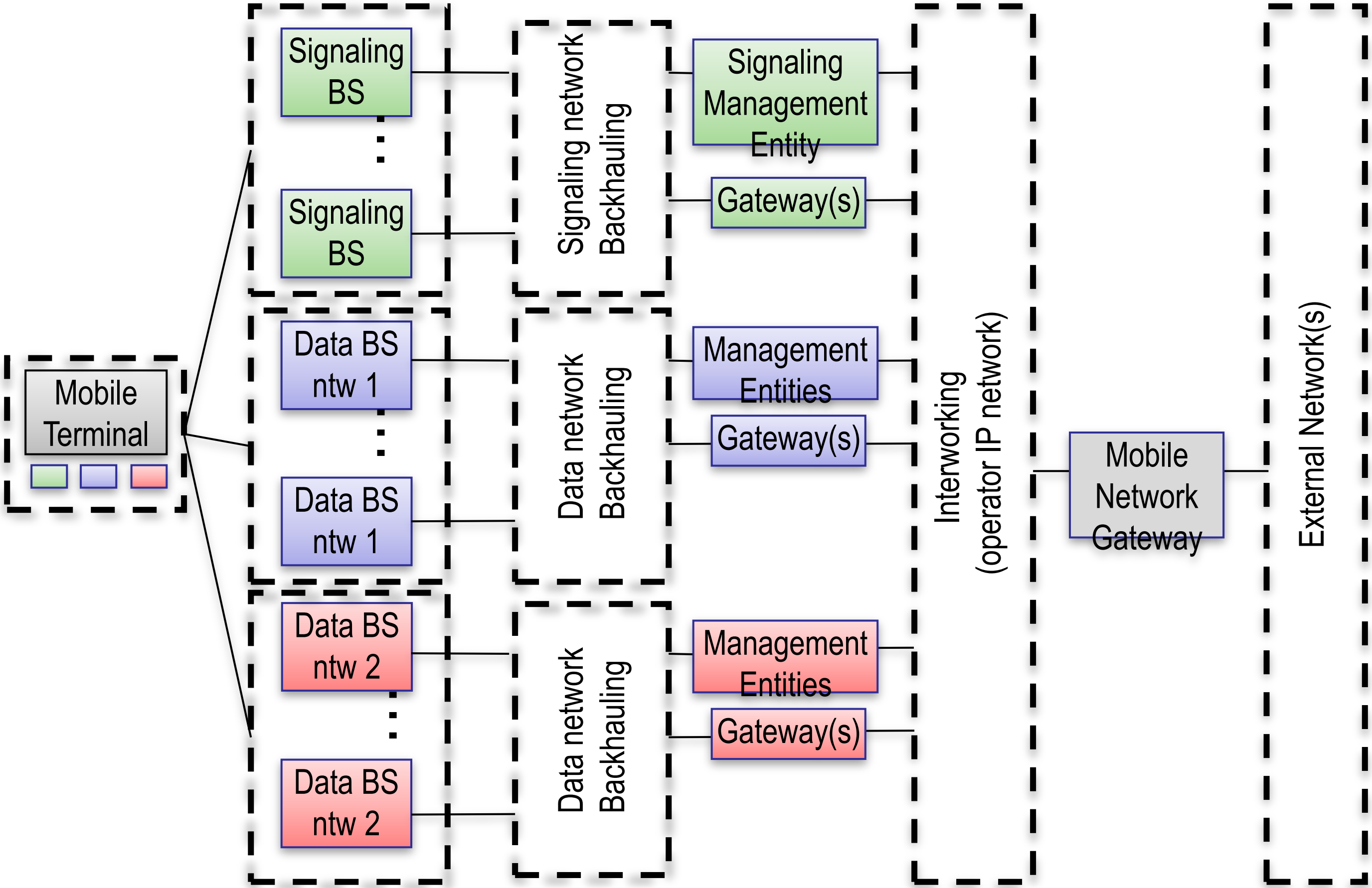
Technical challenges (3)

- **Agile resource selection algorithms** to select the most suitable access point and radio resources to serve traffic requests.



Technical challenges (4)

- Signaling network architecture and functionalities



Technical challenges (5)

- **Interaction mechanisms between the signaling network and the (heterogeneous) data networks** for the resource activation, call control, mobility management, power management
  - Energy efficiency is not the only advantage of the new architecture
  - Integrated management of heterogeneous wireless access technologies, possible new business models and interaction between operators
  - Critical issues related to the signaling overhead due to smart phone state transitions

Conclusion

- BCG² is a revolutionary mobile system architecture based on the separation of data access (capacity) and signaling (coverage)
- It allows unprecedented reduction of energy consumption
- Moreover it makes the management of mobile system more agile and cost efficient

Thanks!

Questions

Antonio Capone
Politecnico di Milano
Email: antonio.capone@polimi.it