Politecnico di Milano

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

Energy and Mobility: Scalable Solutions for the Mobile Data Explosion

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SEW – GreenTouch
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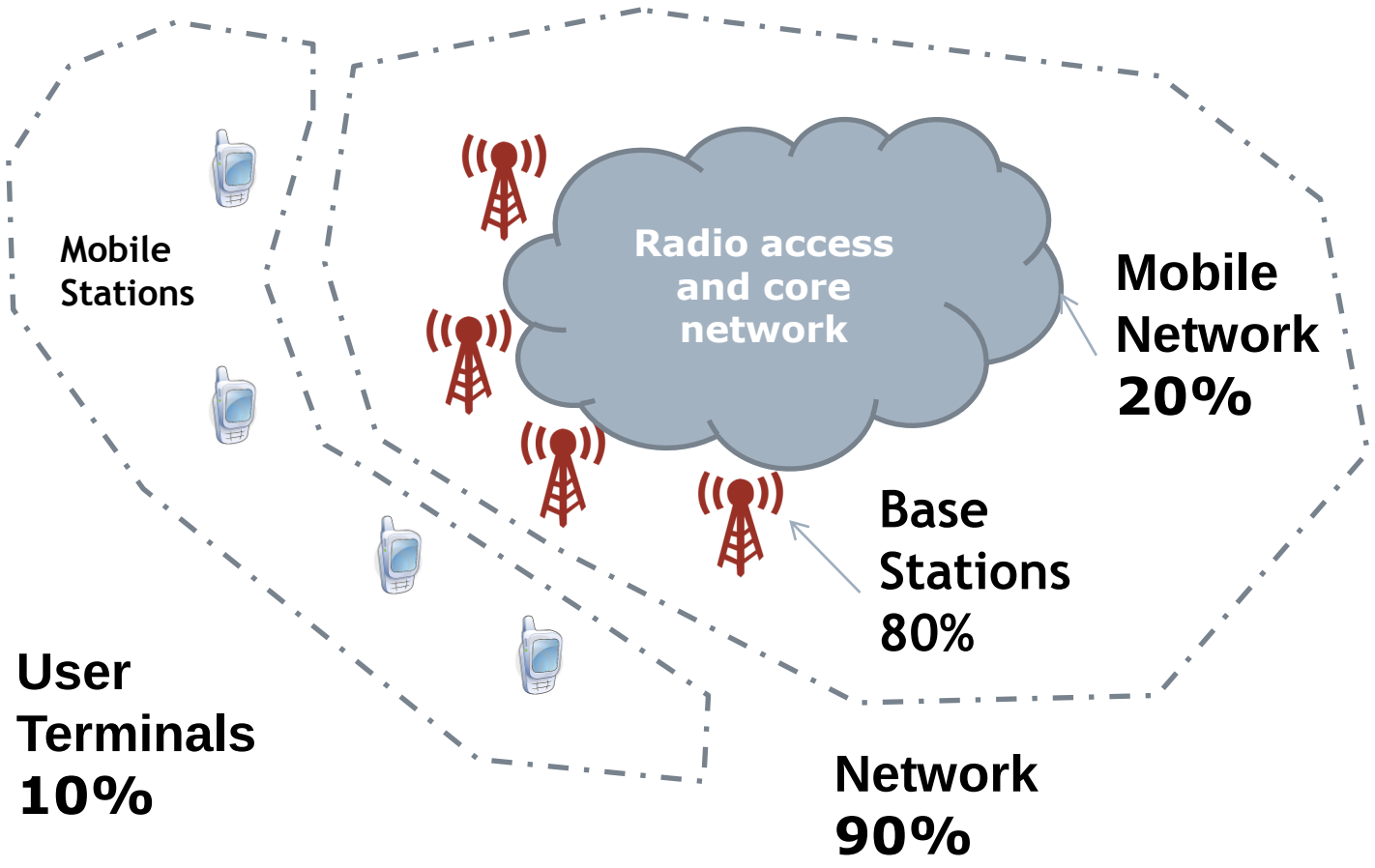
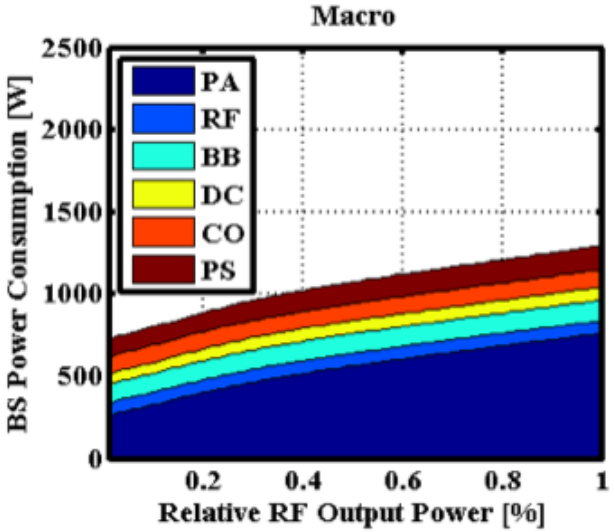
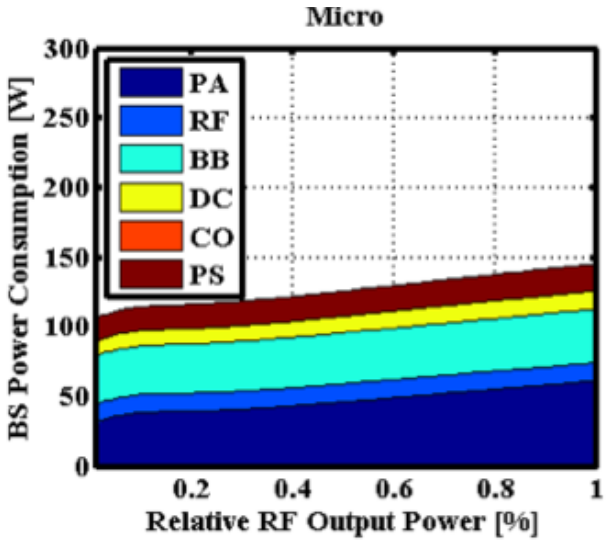
GreenTouch™

Energy consumption in wireless access networks



Energy consumption in wireless access networks

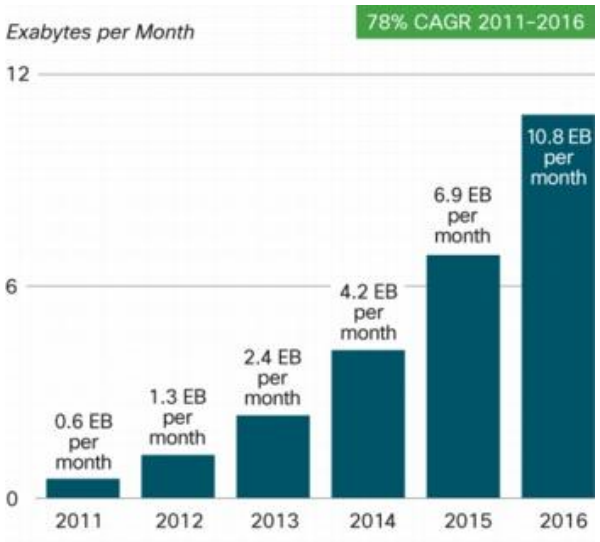




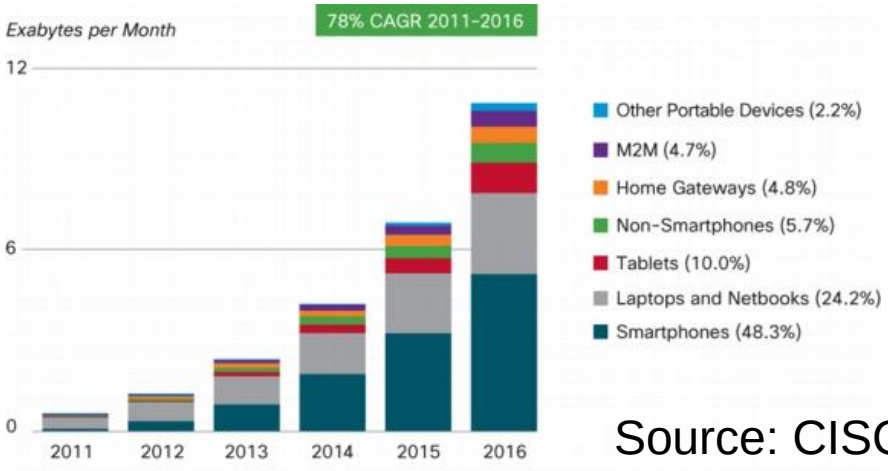
- Baseline energy consumption comparable (macro) or much larger (micro) than load dependent component
- Technology improvements:
  - Power amplifiers
  - Advanced transmission technologies
  - Multiple antenna systems
  - Centralized base band processing
  - Etc.

Source: EARTH project

Energy consumption in wireless access networks

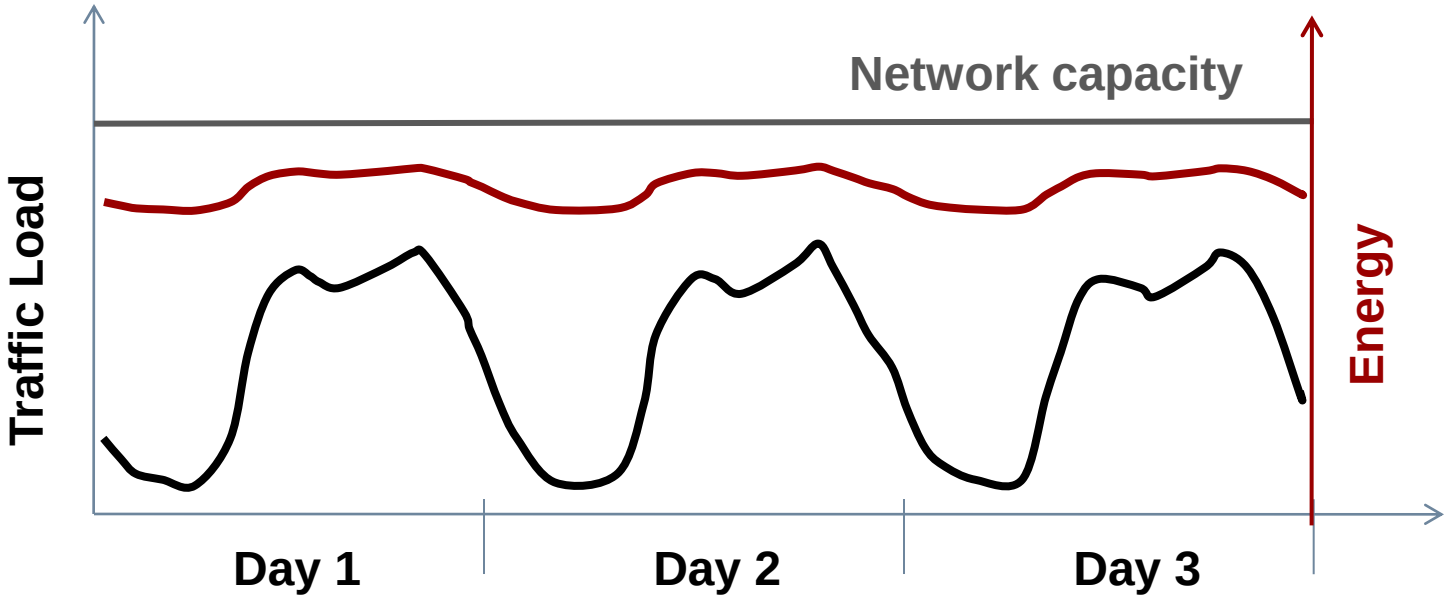


- Mobile traffic explosion
- Stimulated by smart phone diffusion
- Faster technology evolution
- From macro cells to small cells (micro, pico, femto)



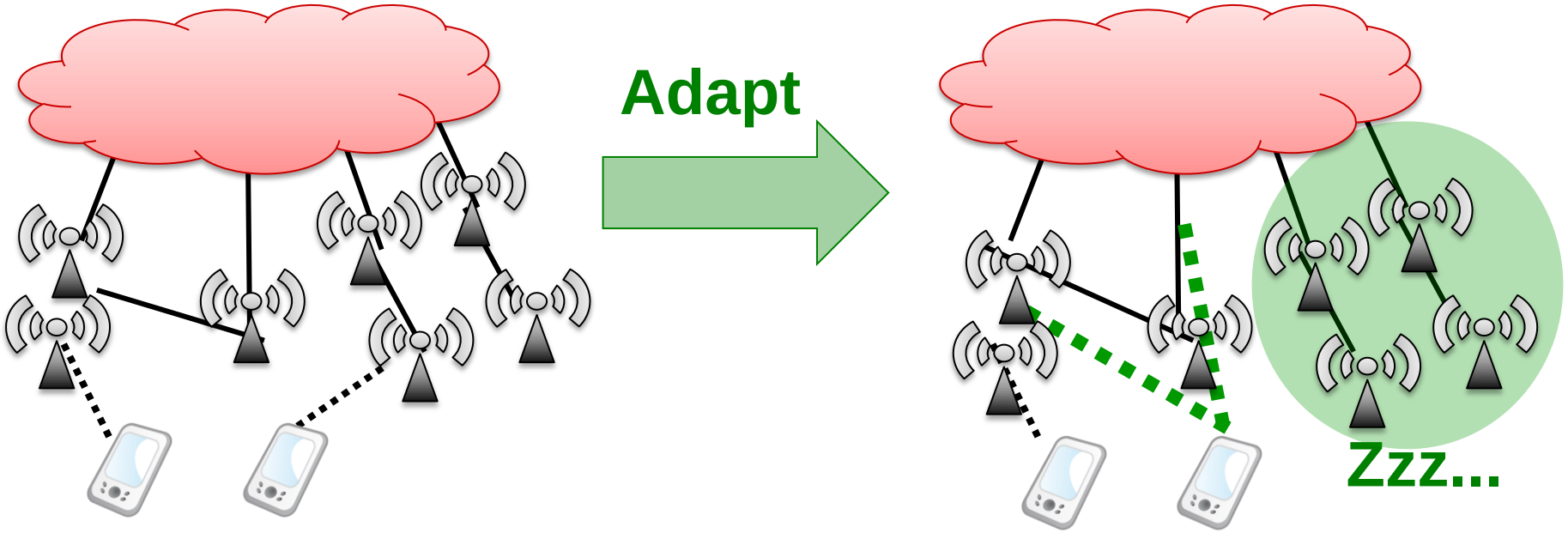
Source: CISCO VNI Mobile 2012

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

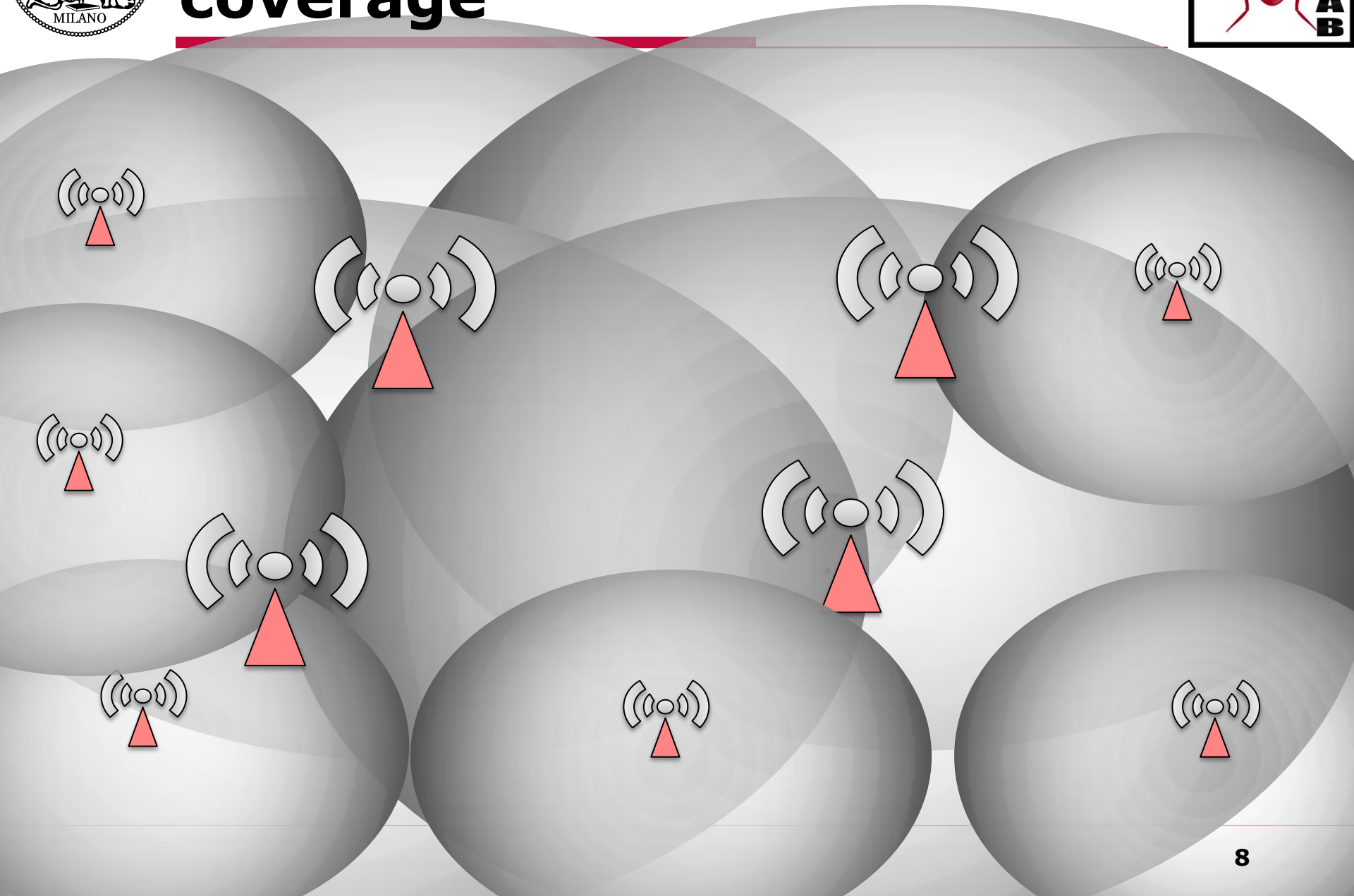


- Novel network structures and management policies that maximizes Energy Efficiency:
  - Efficient utilization of space;
  - Real-time network adaptation based on load requirements;
  - Support of sleep modes

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

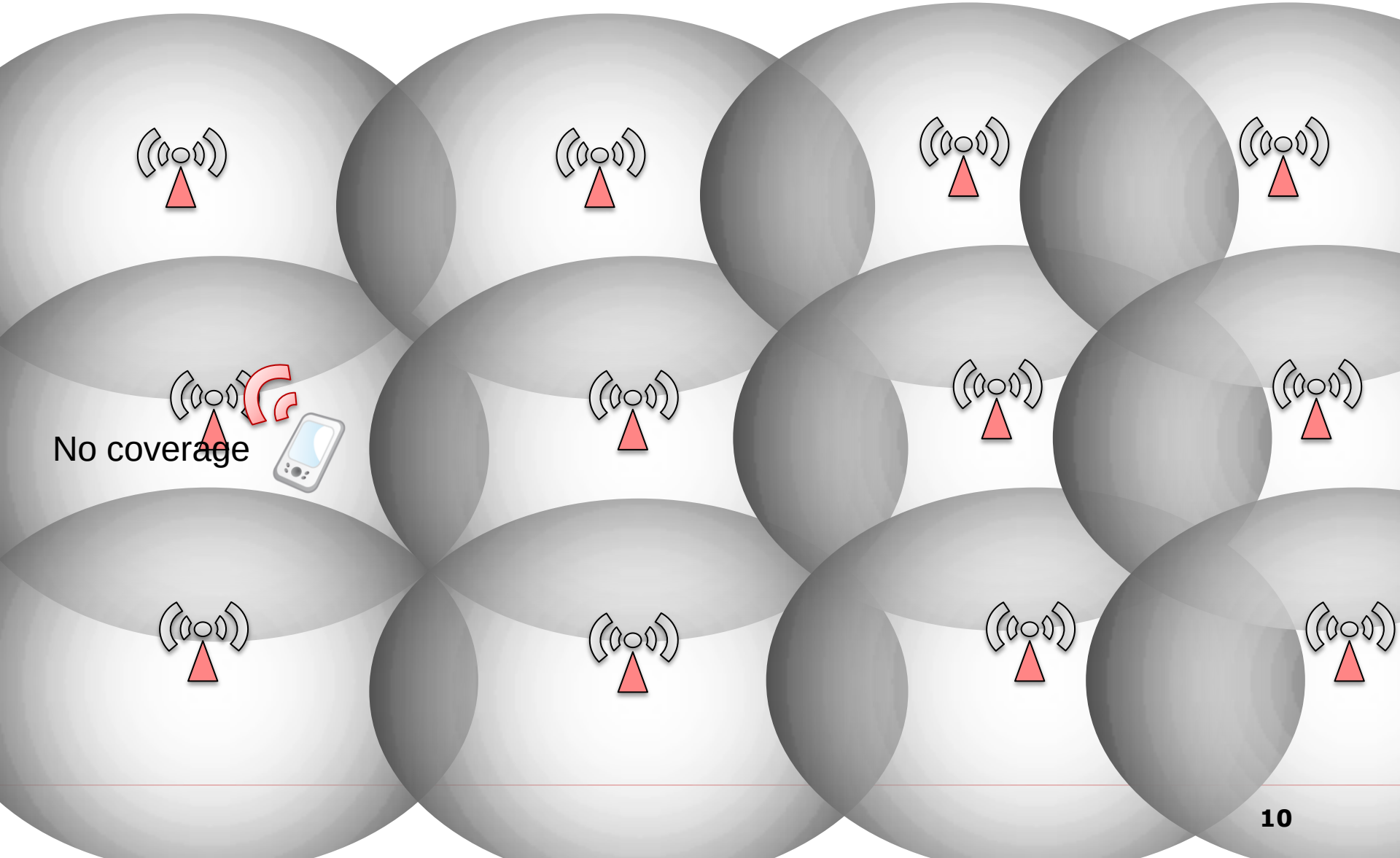
Energy adaptation with full coverage



Limits of traditional cellular architectures

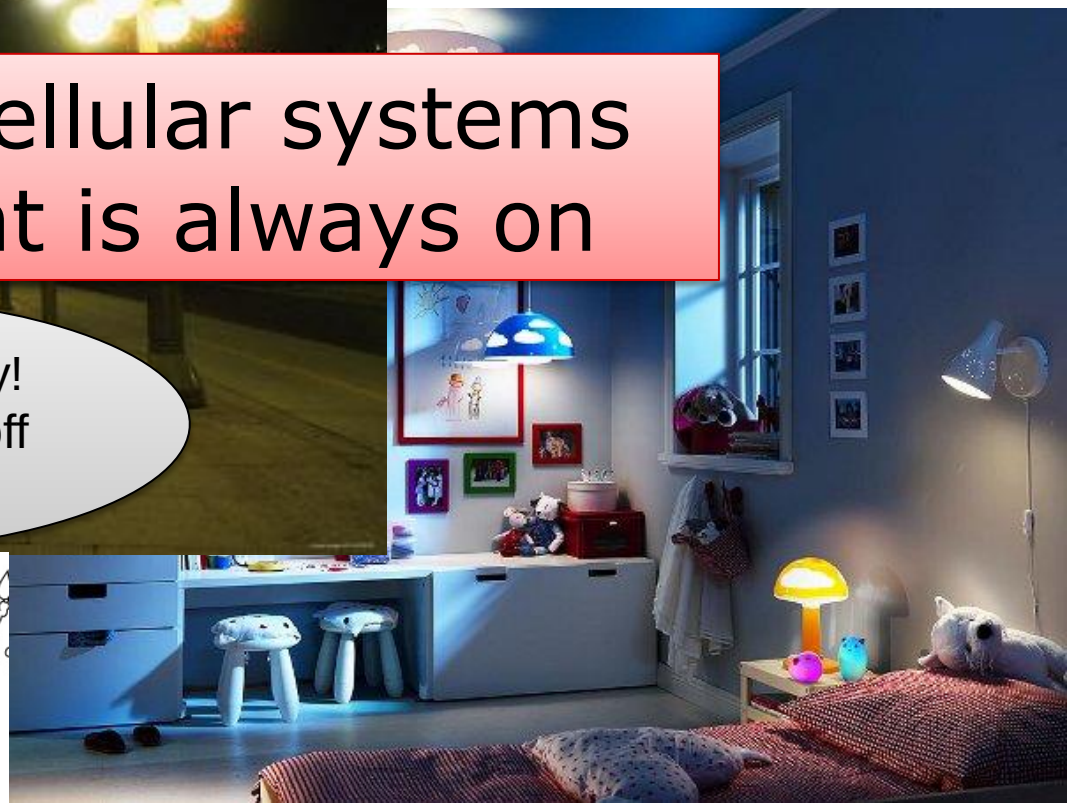
- It has been shown that with traditional cellular technologies **energy savings** in the range of **20%-40%** can be achieved
- Due to traffic increase an higher energy efficiency it is expected that in the **future micro and pico cellular layouts** will be preferred over traditional macro cellular 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

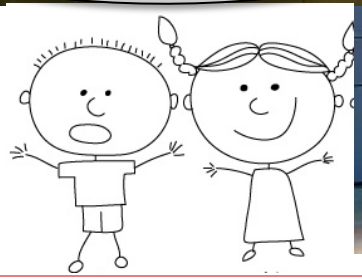


“Remember to turn off the light”

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)

Partners:

GreenTouch™

Alcatel·Lucent

HUAWEI

SAMSUNG

orange™

TNO

INRIA

UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft

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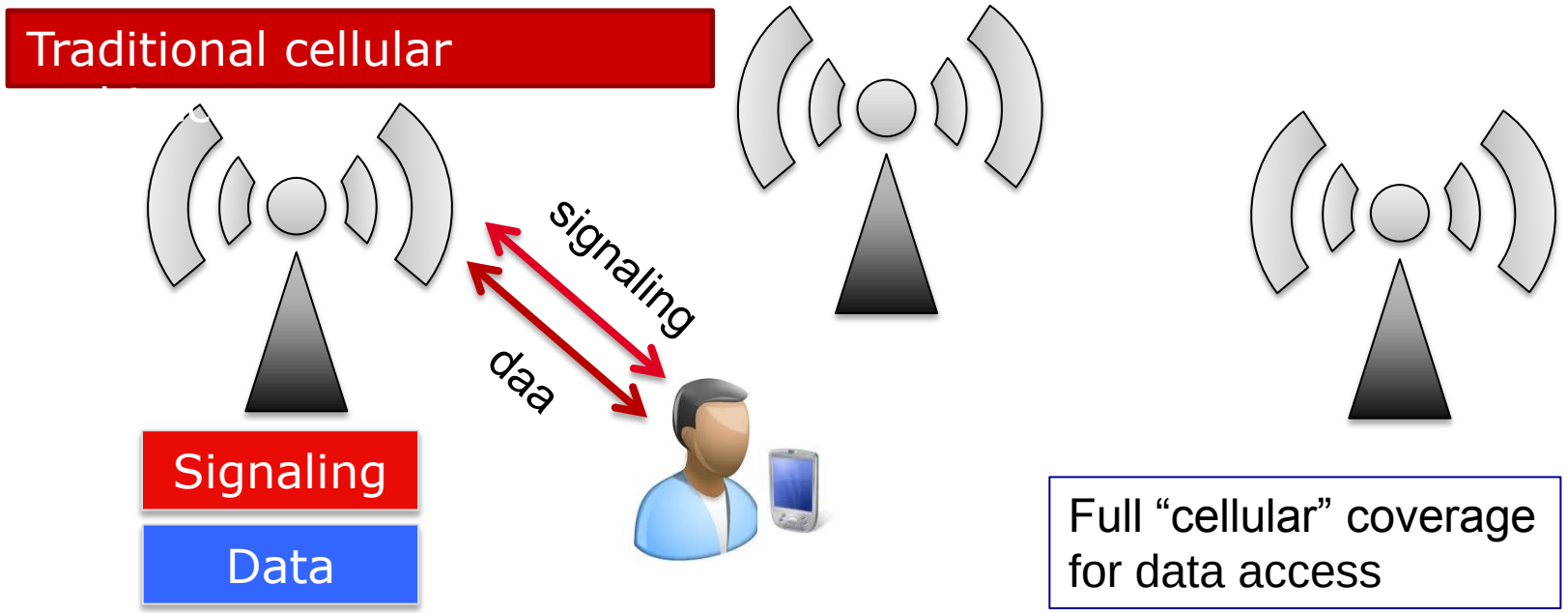
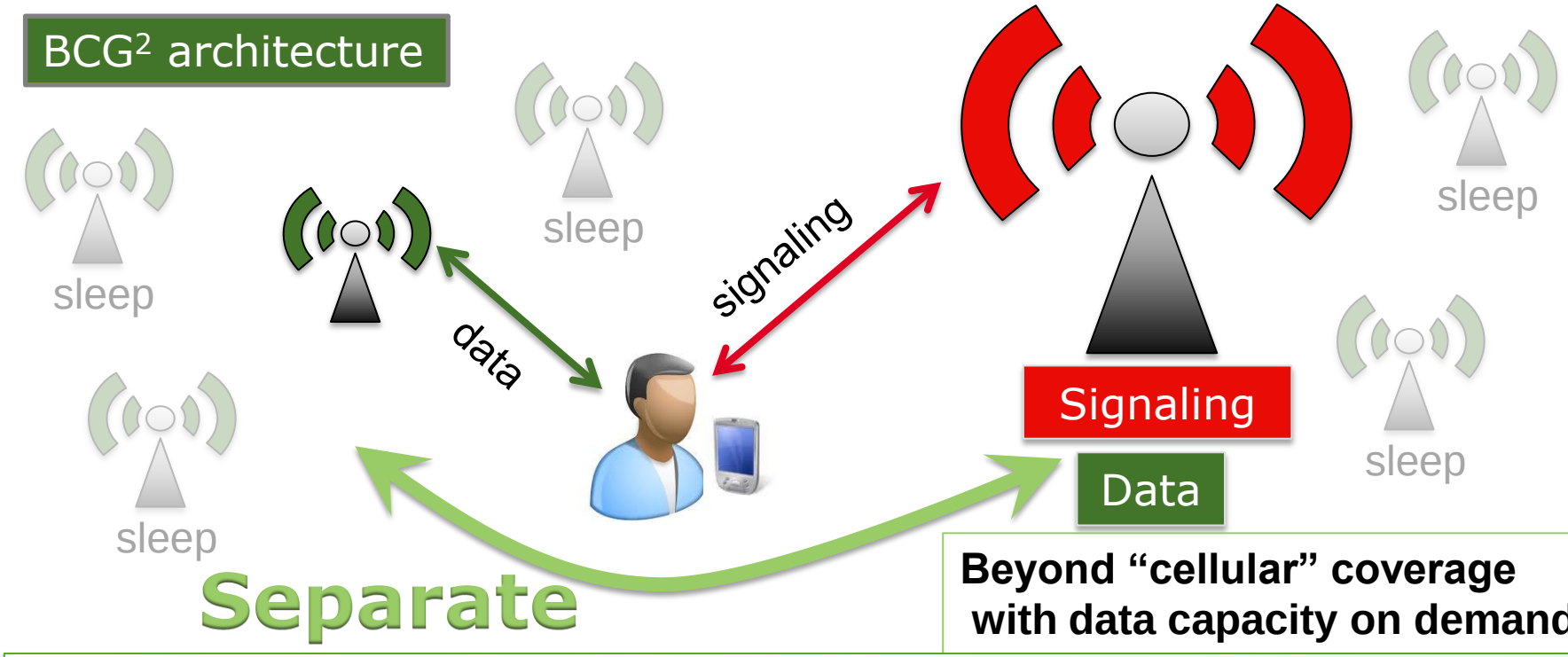
BCG²: Basic idea



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

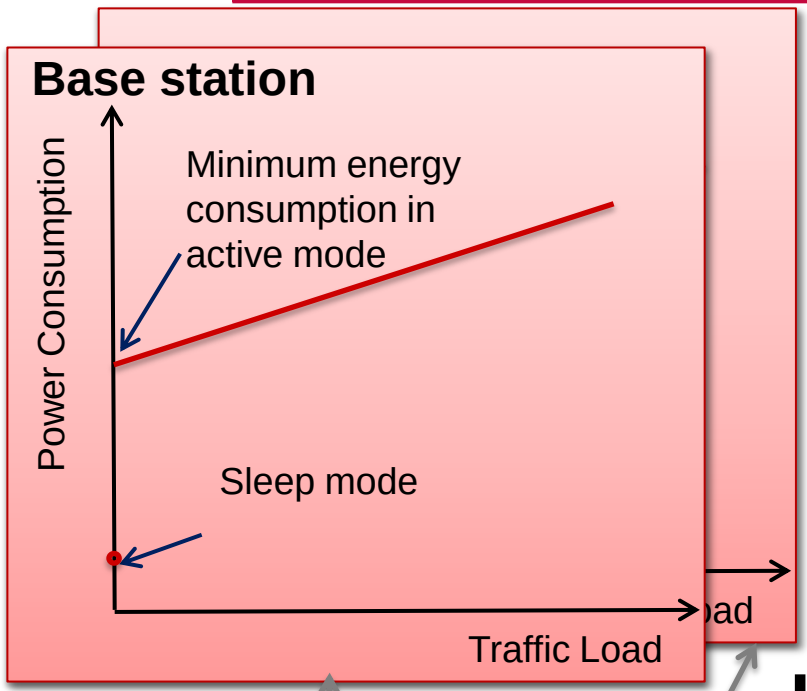
BCG²: Basic idea

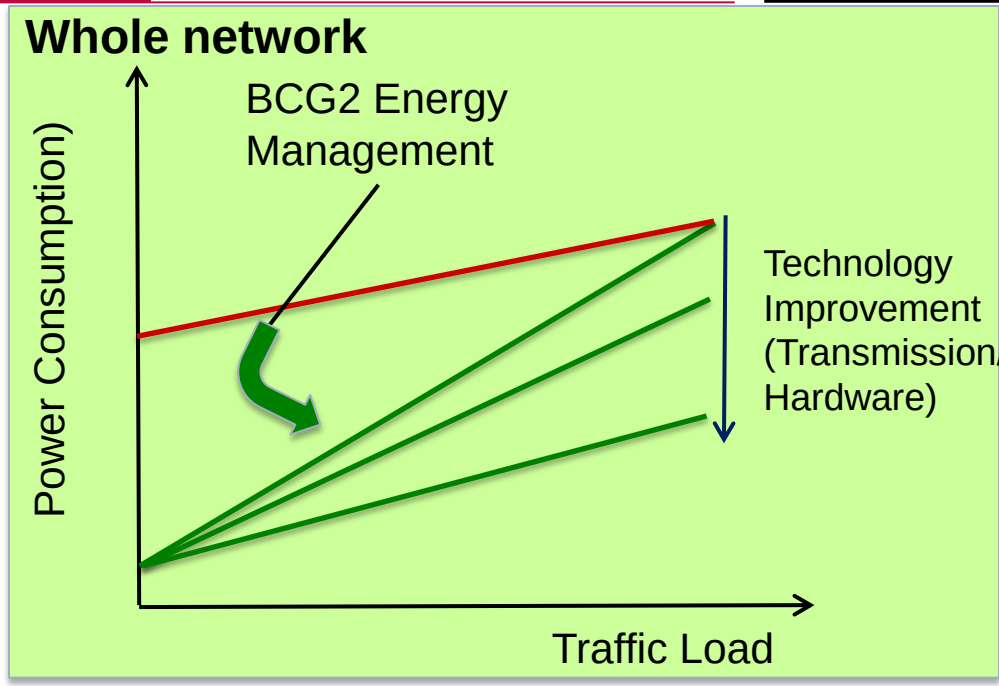


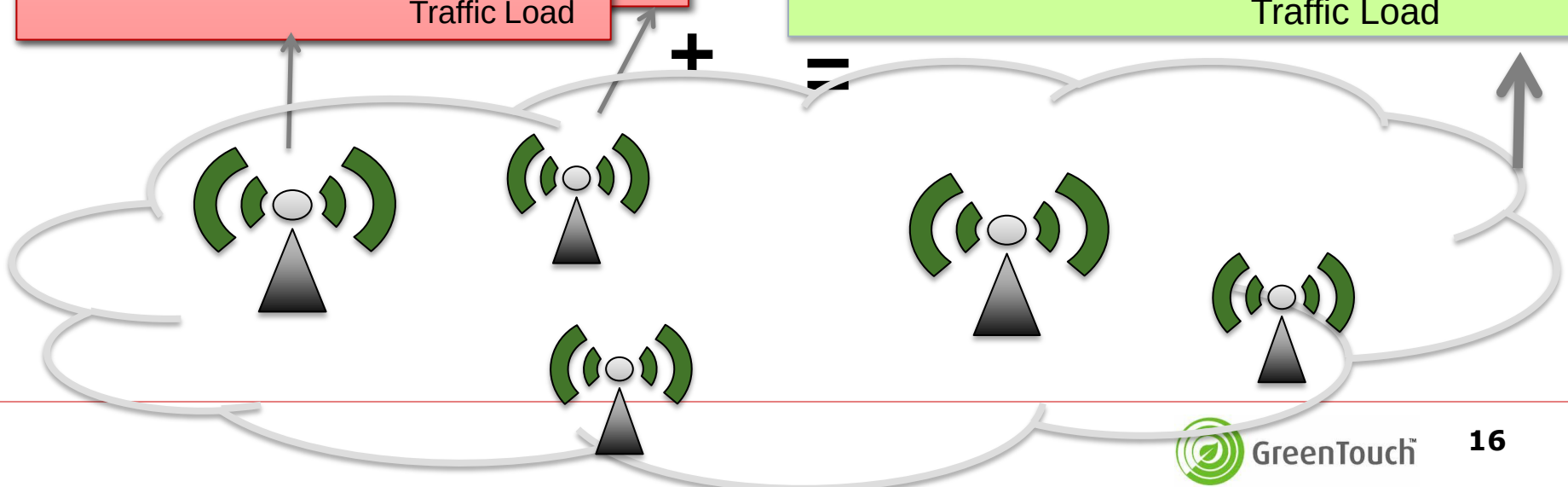
Separation of signaling and data functions at the radio interface:

- 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

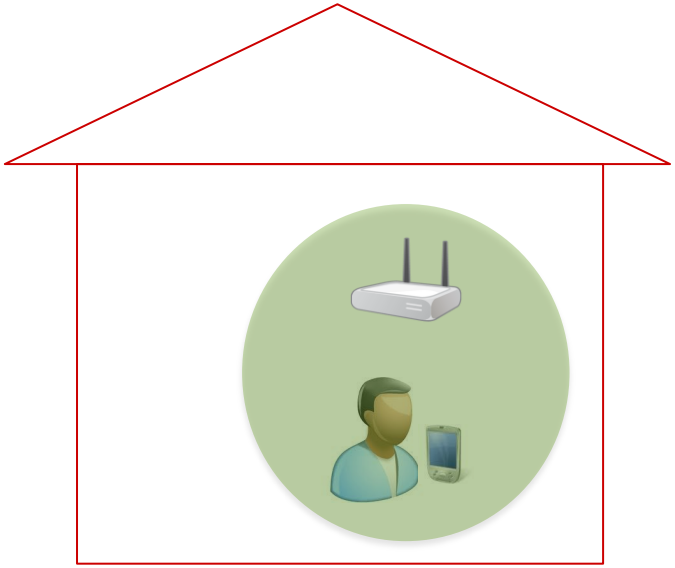




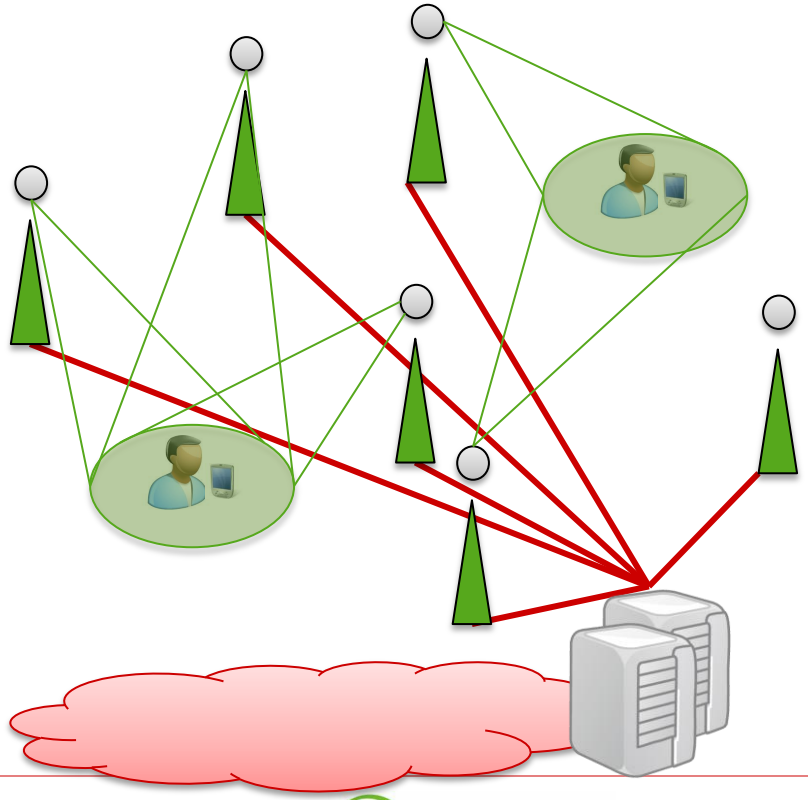


Individual cells

- **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.

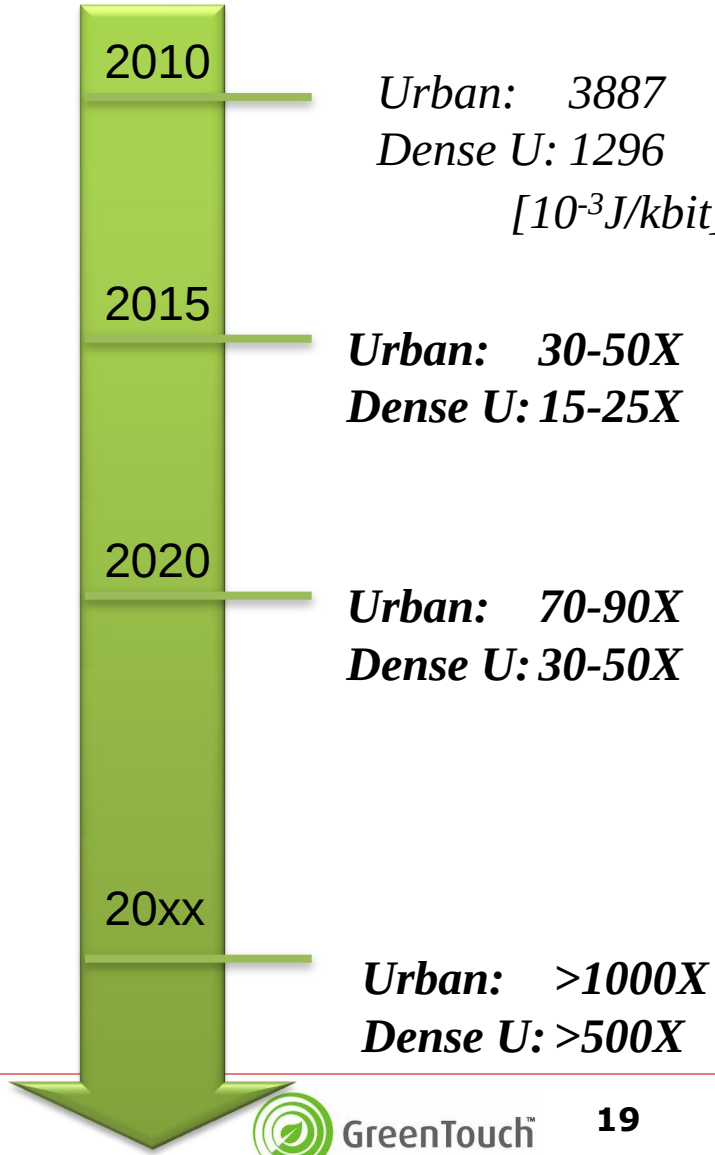
BCG² Energy efficiency gain

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

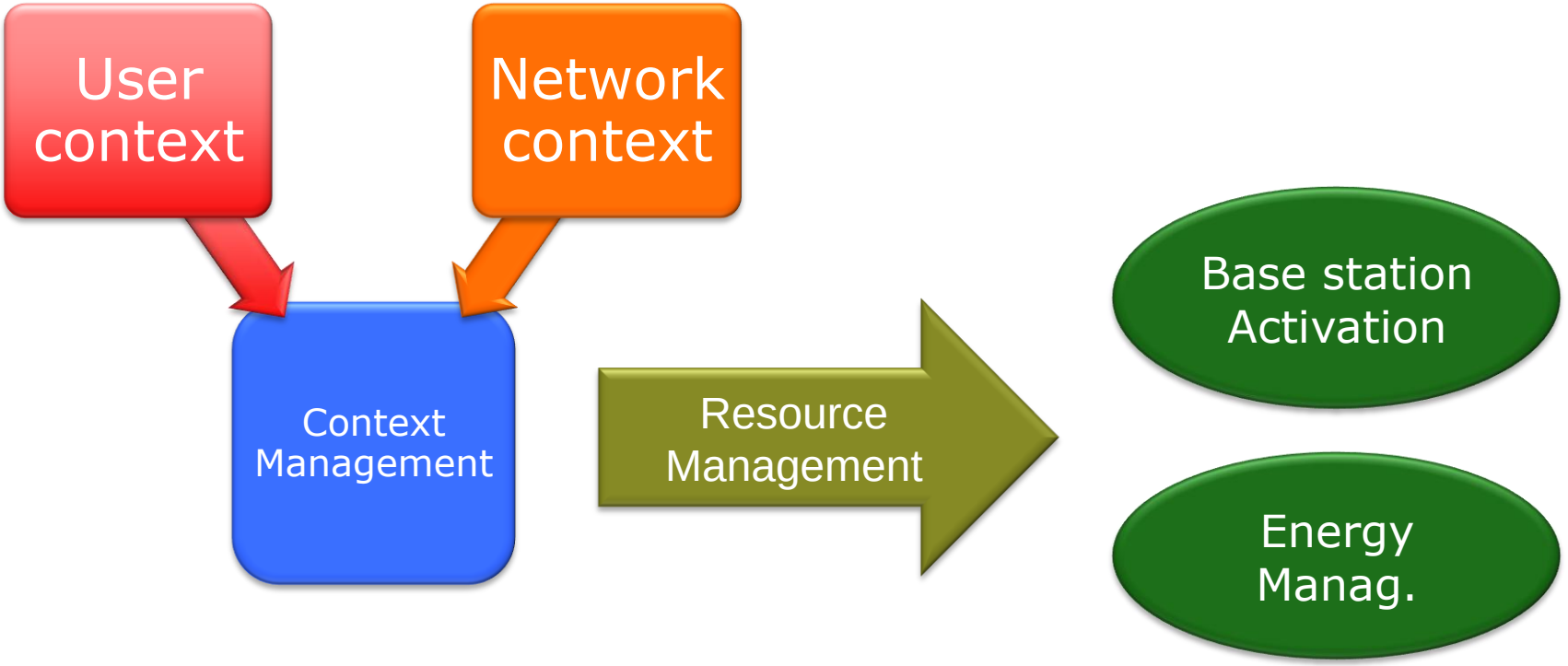
2020
Micro/pico cellular scenario
10% macro, 60% micro, 30% pico BSs (SCENARIO 3)
BCG energy management
High traffic level

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

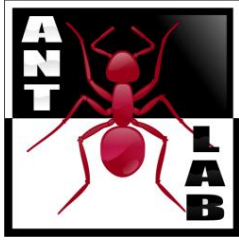


Technical challenges (2)

- **"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
...		

sleep

sleep

sleep

position

Position estimation and processing
Self adaptation through system memory

sleep

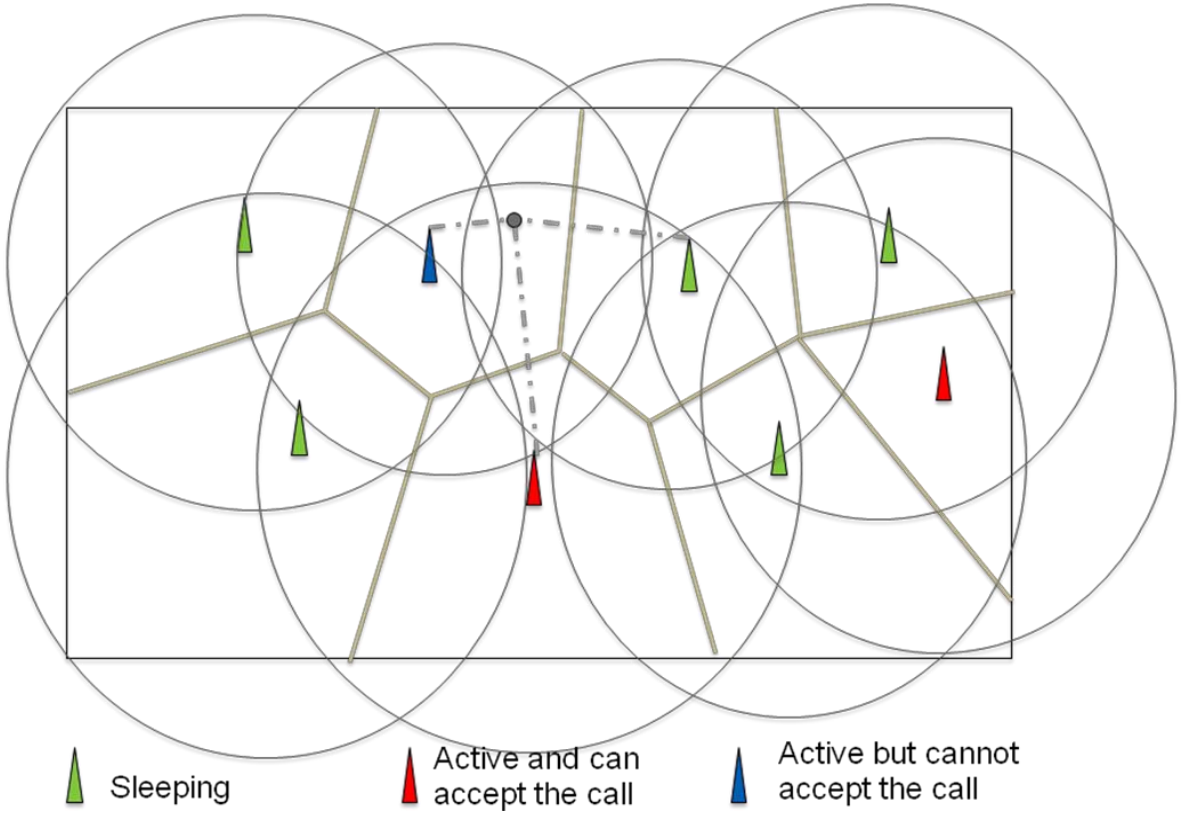
sleep

sleep

Mobility pattern prediction

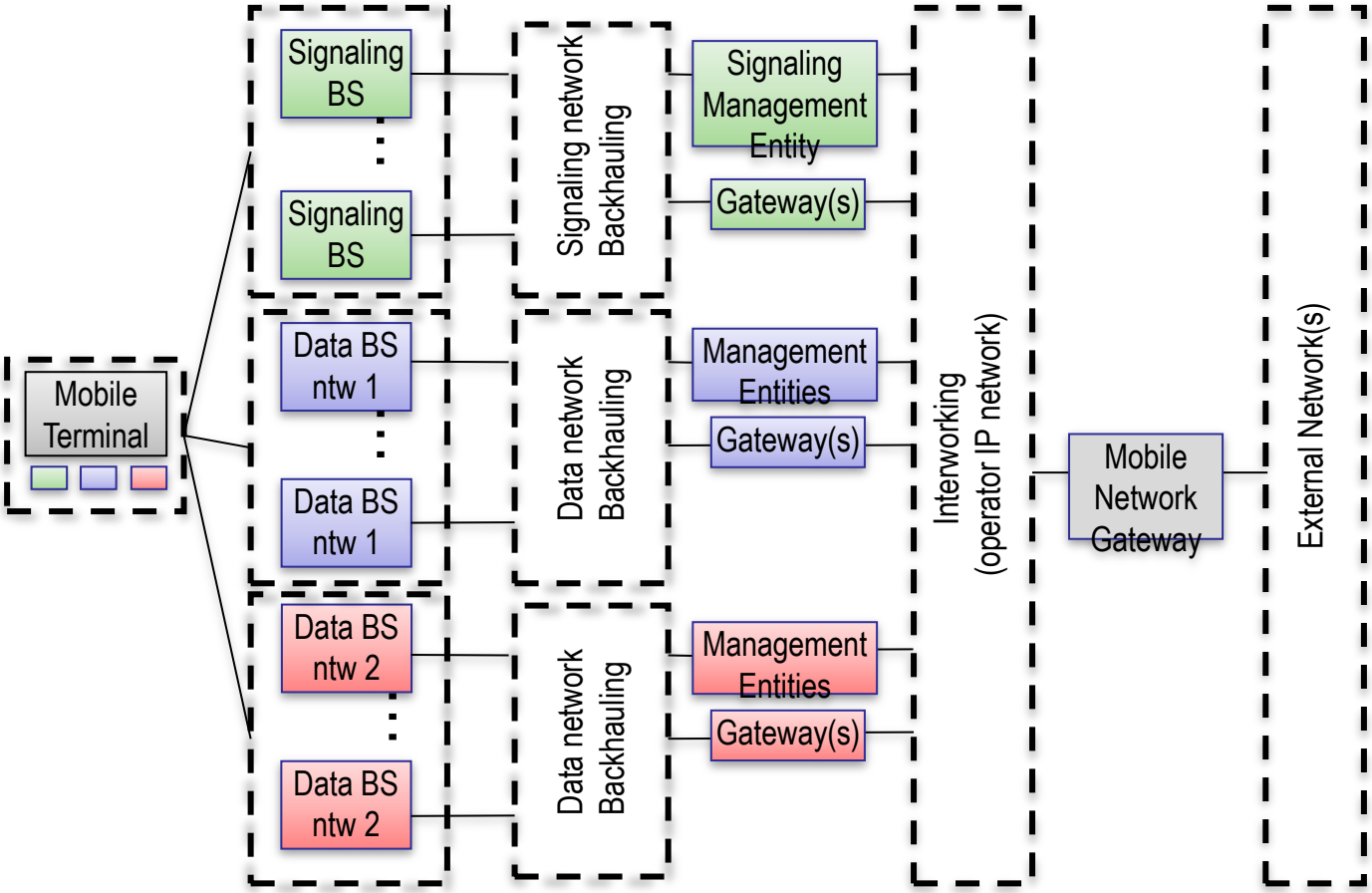
Technical challenges (3)

- **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

- BCG^2 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

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