Wireless Targets and Challenges

Mobile Communication Working Group

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17 Nov 2011 @ GreenTouch Seattle Meeting

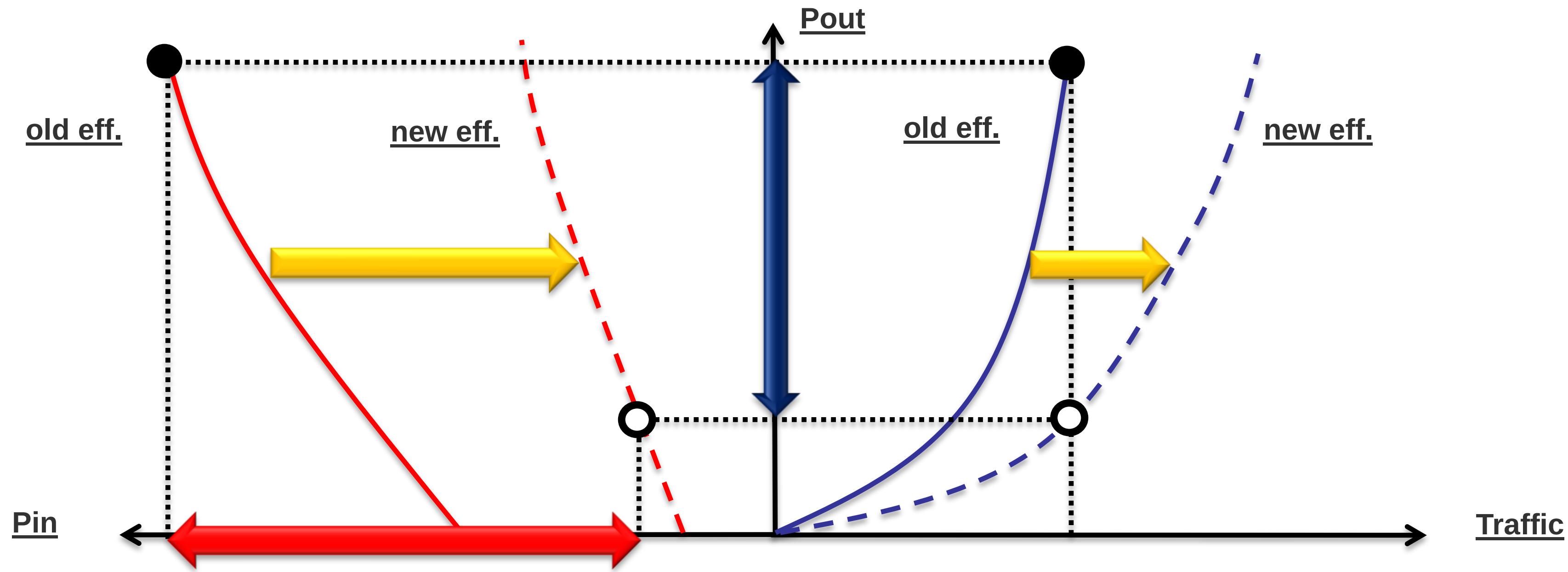
Scope and mission

- The Mobile Communications Working Group addresses all functions and nodes needed in the access network to provide wireless communication services to mobile and stationary users.
- It includes all types of access points from public macro cellular base stations to residential femto base stations and WLAN access points.
- Backhaul provisioning for these access points is also covered by this working group as well as the mobility related functions in the Mobile Gateways.
- The objective is to contribute by the wireless access with a significant part to the factor 1000 of energy saving in GreenTouch

Project Portfolio

- **Large Scale MIMO Demo (Feb. 1st 2011 in London)**
- **Large scale antenna systems (LSA)**
  - Massive MIMO
  - Distributed Antenna Systems
- **Green transmission technologies (GTT)**
  - Very high bandwidth wireless systems
  - Tradeoff btw. energy efficiency and spectrum efficiency, bandwidth, service delay
- **Beyond cellular green mobile networks / architectures (BCG)**
  - Green Network Management / Intelligent Power Management
  - Independent network configuration for data and signaling

Relations between Projects



System level

- Component eff. Improvement
- Processing & Tx power Tradeoff
- Dynamic micro BS sleep mode
- Tx capability/functionality adaptation

- Advanced AI tech. like LSA
- Advanced RRM like GTT

Network level

- Network management (cell switch on/off)
- Signalling and data separation like BCG

- Advanced BS/antenna cooperation
- Advanced cooperative RRM like GTT

The Large Scale Antenna System (LSAS)

GreenTouch™

- Project leader: Tom Marzetta, Bell Labs

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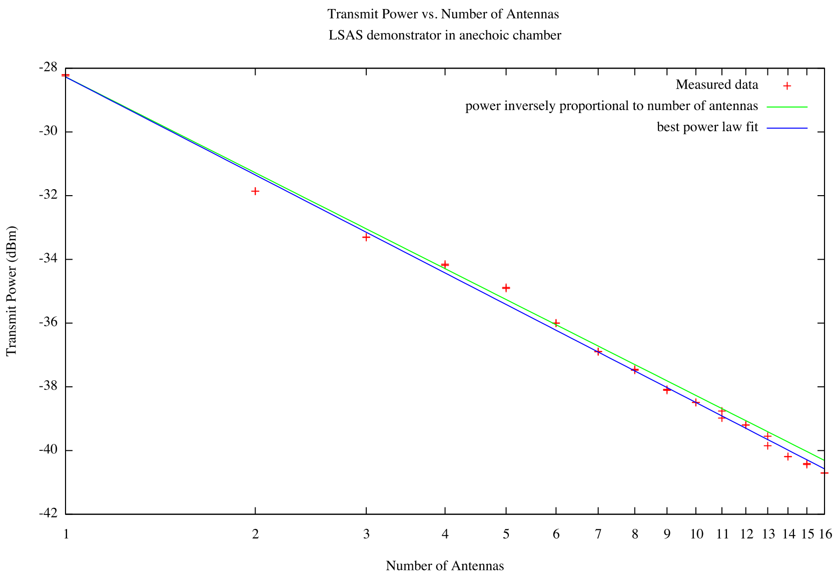
The Large Scale Antenna System

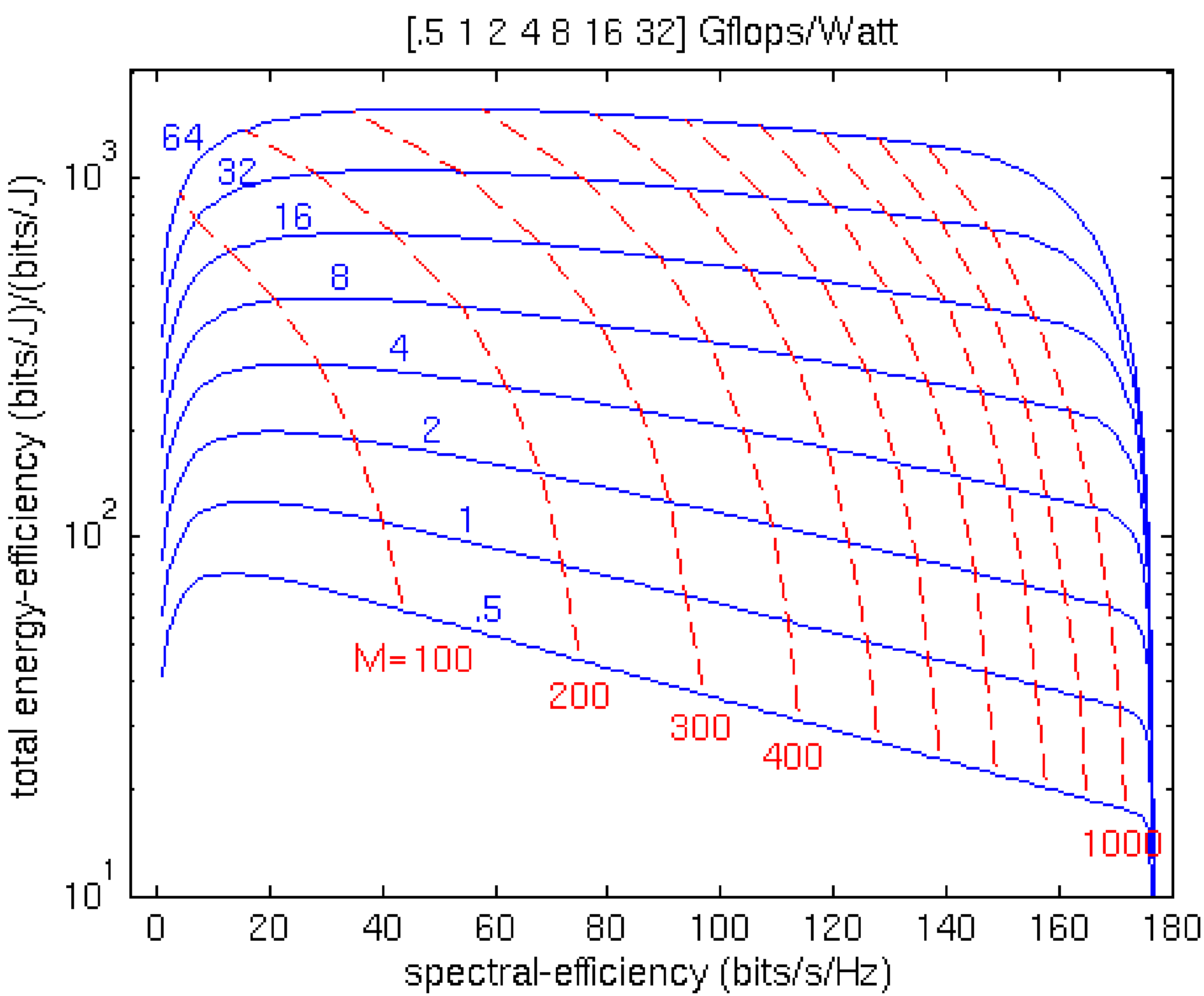
Measured transmit power is inversely proportional to the number of antennas:



LSAS: Major Achievements

- Under a wide variety of conditions, radiated energy-efficiency increases linearly with the number of service antennas
- Both total radiated power reduction and increased spectral-efficiency contribute to improved radiated energy-efficiency
- The simplest conjugate beam-forming (matched-filter) can be competitive
  - The “green” activity of reducing radiated power helps narrow the performance gap
  - Conducive to a de-centralized architecture
- LSAS robust to channel-estimation error and coarse quantization
- Initial simulations of total energy-efficiency improvement are encouraging

LSAS Total Energy Efficiency vs. Computational Energy Efficiency & Spectral Efficiency: Simplified Macro-Cellular Scenario (M = # service antennas)



LSAS Research Challenges

- Include other sources of power dissipation
- Quantify trade-off between LSAS performance and power-amplifier nonlinearity and efficiency
- Quantify trade-off between performance and A/D – D/A resolution
- Develop reliable acquisition (synchronization, timing-recovery, handshaking) for low-power regime
- Extend performance calculations to non-cellular deployments and distributed systems

LSAS Gaps

- Experimental research in LSAS propagation
- Obtain reliable estimates of future evolution of computational energy-efficiency
- Obtain reliable estimates of future evolutions: power amplifier efficiency; power dissipation of A-D/D-A conversion, r.f. chain, error-correction, routine base station activities
- Develop algorithms for scheduling the service of terminals
- Develop models for LSAS traffic
- Engineer a system

Beyond Cellular Green Generation (BCG²)

GreenTouch™

- Project leader: Antonio Capone, Politecnico di Milano

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SAMSUNG

orange™

New partner joining the project

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BCG^2: Basic idea

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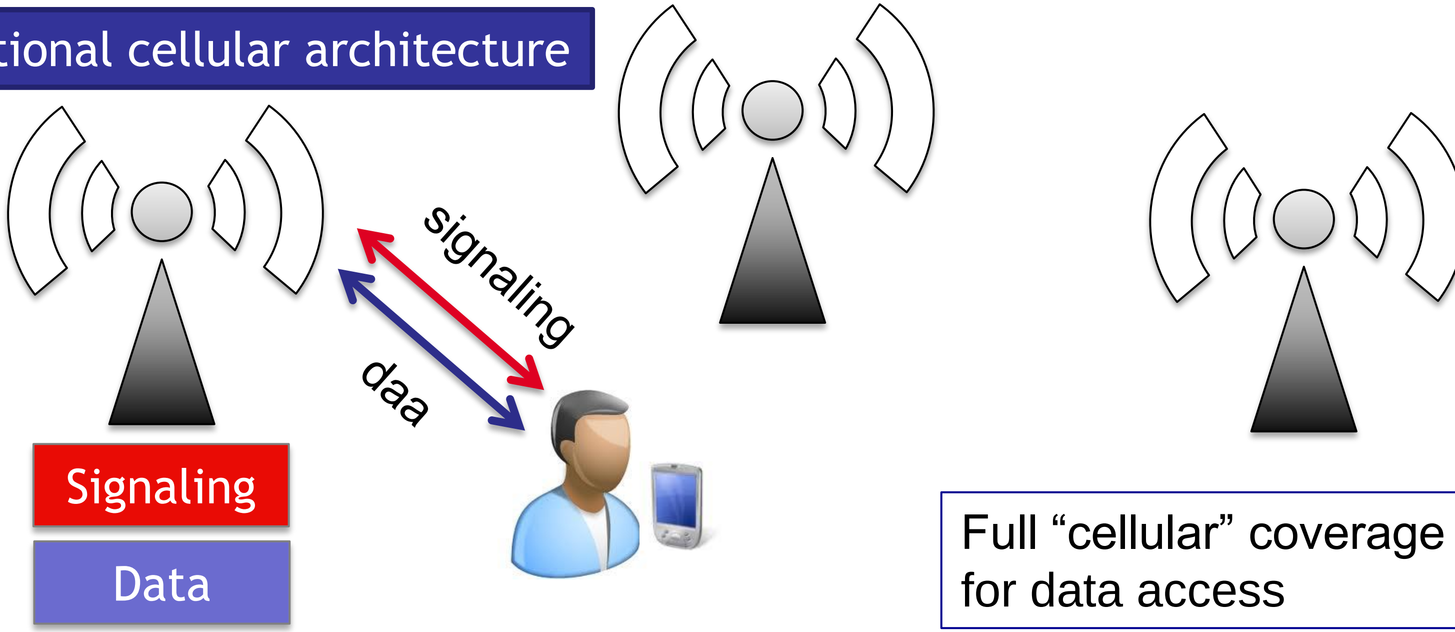
Traditional cellular architecture

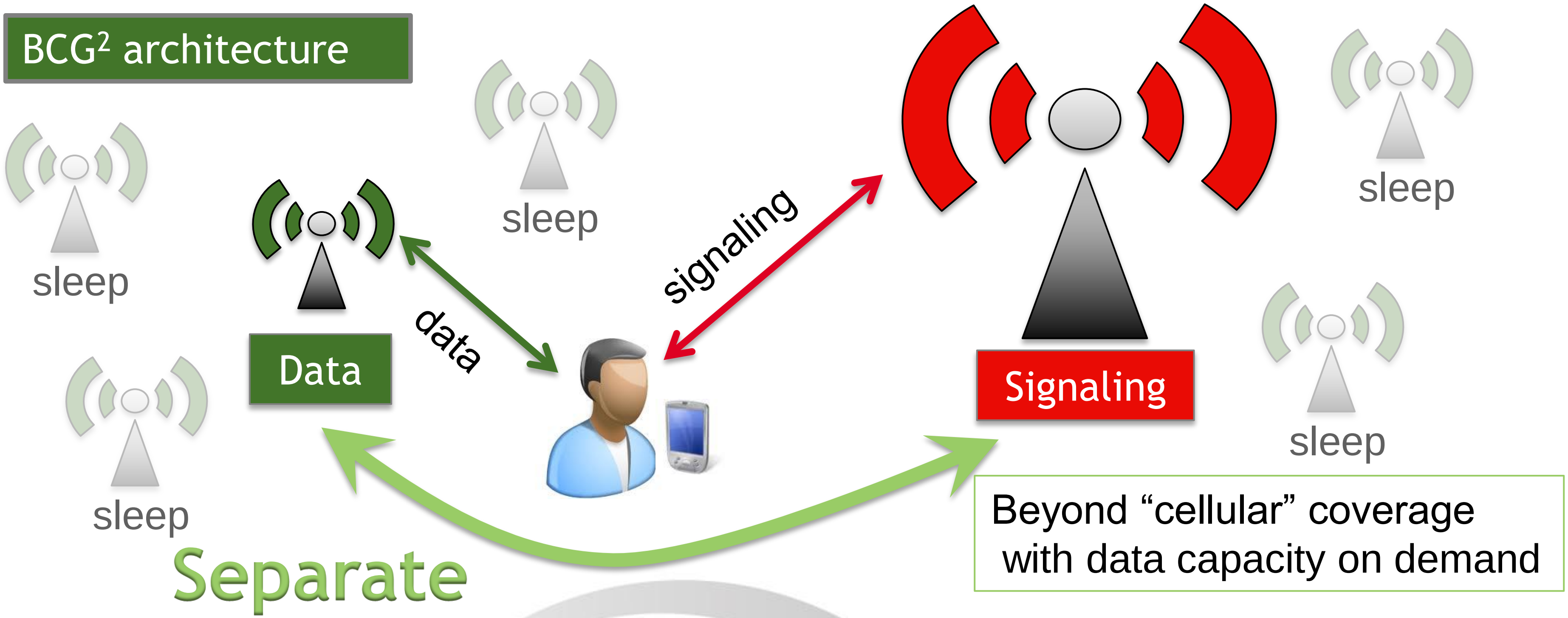


Full "cellular" coverage for data access

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

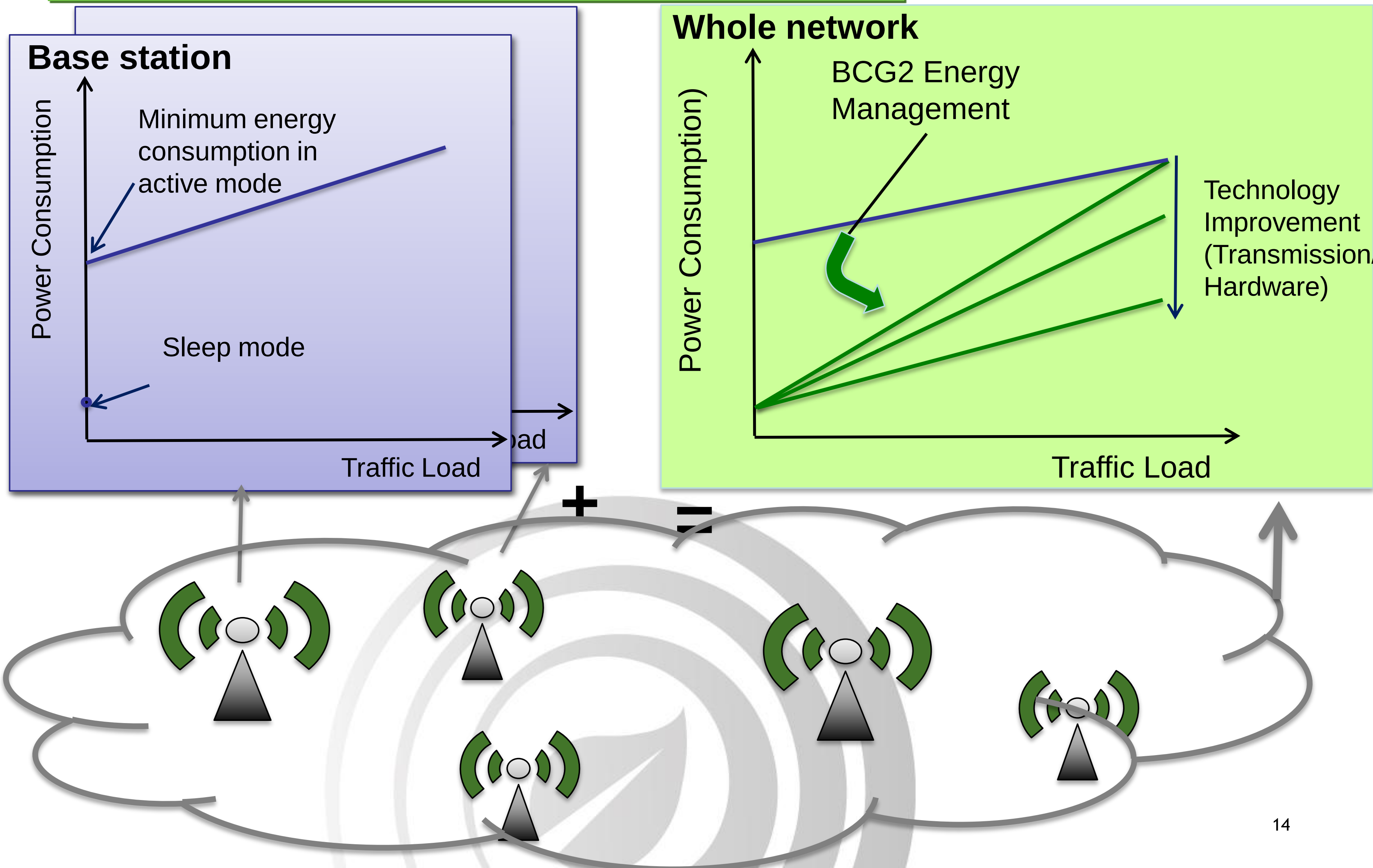
BCG²: Basic idea



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
- Adaptive network capacity and high energy efficiency

From base station power profile to network profile



BCG Achievements

- Defined the high level system architecture and main functionalities (Deliverables 1 & 2)
- Evaluation of energy efficiency gains through a simplified system model
- Advanced analytical models for performance evaluation:
  - Energy efficiency gains with cell overlap through integral geometry
  - Asymptotic system performance through stochastic geometry
  - Assessment of arbitrary topologies through integer linear programming
  - Evaluation of potential combination of energy management at system level with base station micro sleeps

BCG² Targets

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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

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

2015
Urban: 38X
Dense U: 16X

2020
Urban: 76X
Dense U: 36X

20xx
Urban: 1555X
Dense U: 518X

BCG Technical challenges

- Perform a quantitative analysis of the fundamental bounds of energy efficiency improvement of BCG architecture
- Add “context” information (like for example user position, etc.)
- Design resource selection and activation algorithms
- Define a brand new signaling network architecture
- Design the interworking between the signaling network and the (heterogeneous) data networks

Green Transmission Technologies (GTT)

GreenTouch™

- Project leader: Yan Chen, Huawei Technologies

Alcatel·Lucent

HUAWEI

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cea leti

Newly joined partners

orange™

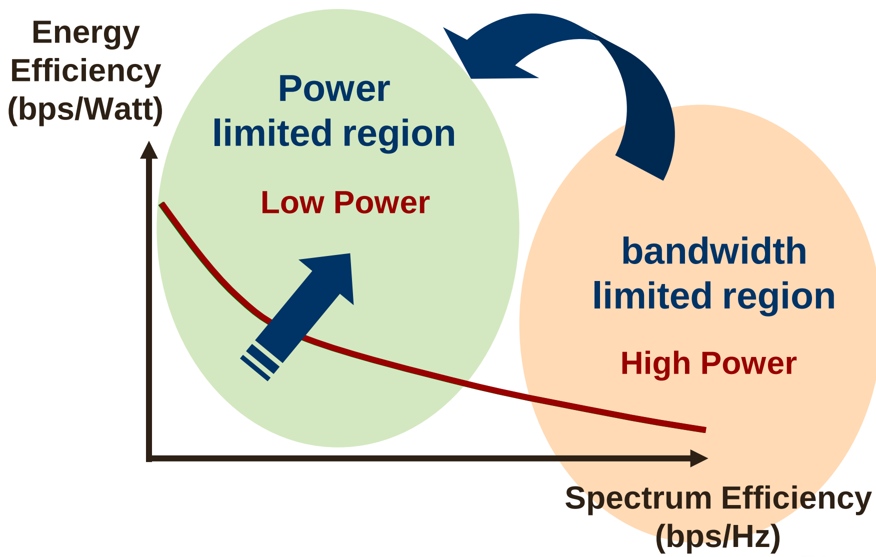
University of Maryland 1856

The University of Melbourne

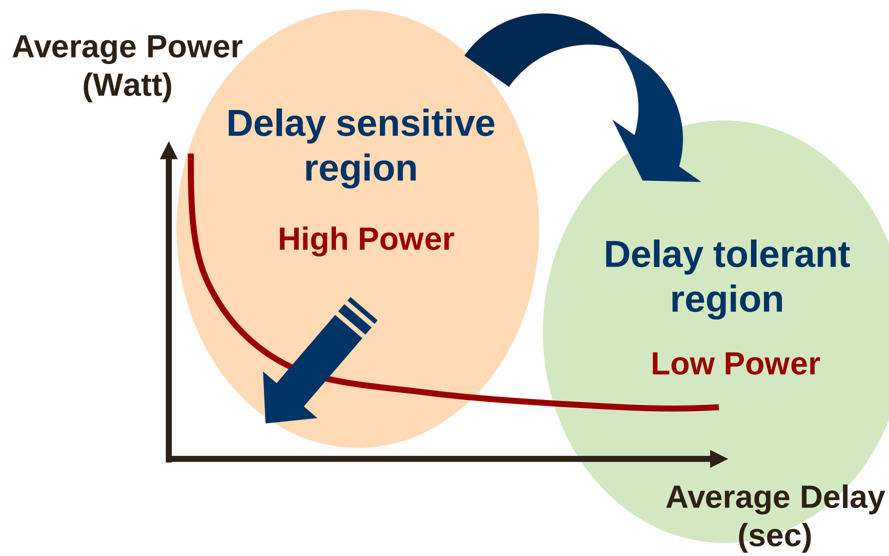
IBES
Institute for a Broadband-Enabled Society

Key Idea

SE – EE Tradeoff



Power – Delay Tradeoff



Insight from Shannon

- Larger bandwidth → Lower transmit power (for same rate)

Approaches

- Bandwidth expansion
- Advanced technologies to better use bandwidth

Insight from Shannon

- Longer bit transmission time → Lower transmit power

Approaches

- Enlarging transmission time or taking micro sleep to minimize power under delay constraint

Current Achievements

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1. **Quantifying the fundamental tradeoff between bandwidth efficiency and transmit power efficiency, given data rate requirements.**

   Brief of Key findings:

   1. The larger the initial bandwidth efficiency the system is working with, the larger the gain in power reduction would be by expanding bandwidth
   2. There is a sweet point (most efficient) of bandwidth expansion which is probably 10 dB
   3. Compared with single-cell case, bandwidth expansion in multi-cell scenario could bring larger power reduction, due to the impact of interference
   4. Advanced air-interface technologies (e.g. MIMO) help to improve the tradeoff

2. **Developing a sound framework for minimizing the *total* power,** accounting not only for the transmitted power, but also for baseband signal processing, etc.

   Brief of Key findings:

   1. Focusing just on tx power is appropriate only for large-range systems , processing power can be comparable with transmit power in short-distance.
   2. There is a tradeoff between transmit power and processing power. In some cases, even we may choose uncoded transmission to reduce total power.
   3. In multiuser scenarios, the trade—off would change. Processing power does not add interference!

Challenges & Gaps

Targets	*Scenarios*	*Tentative EE Target*
Overall Network	Rural	5 ~ 10 x
	Urban / Dense Urban	10 ~ 20 x

GTT Optimization

Challenges & Gaps	*Description*
Bandwidth Acquisition	• Both technical and regulation problem • Opportunistic and dynamic spectrum access
Scalable Processing	• Processing power modeling in BB and RF • How processing power scale with bandwidth
PHY Function Design in Low SNR Region	• Impact of impairments in synchronization, channel estimation, etc., on power-bandwidth tradeoff • Very-low-rate coding & novel algorithms for physical-layer functions at very low SINRs
Extension to Multi-user/ Multi-cell scenarios	• Complicated resource sharing between multi-user • Interference impacts and interference coordination

Green Touch™ Initiative

www.greentouch.org