8 Apr 2011 @ GreenTouch Open Forum, Seoul, Korea

GREAT Project Overview

Green Radio Excellence in Architectures & Technologies

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GREAT
Green Radio Excellence in Arch. & Tech.
绿色无线卓越计划

GREAT Project Overview

- Research Framework
- Energy Efficiency Evaluation (3E) Framework
- Fundamental Tradeoffs on Green Design

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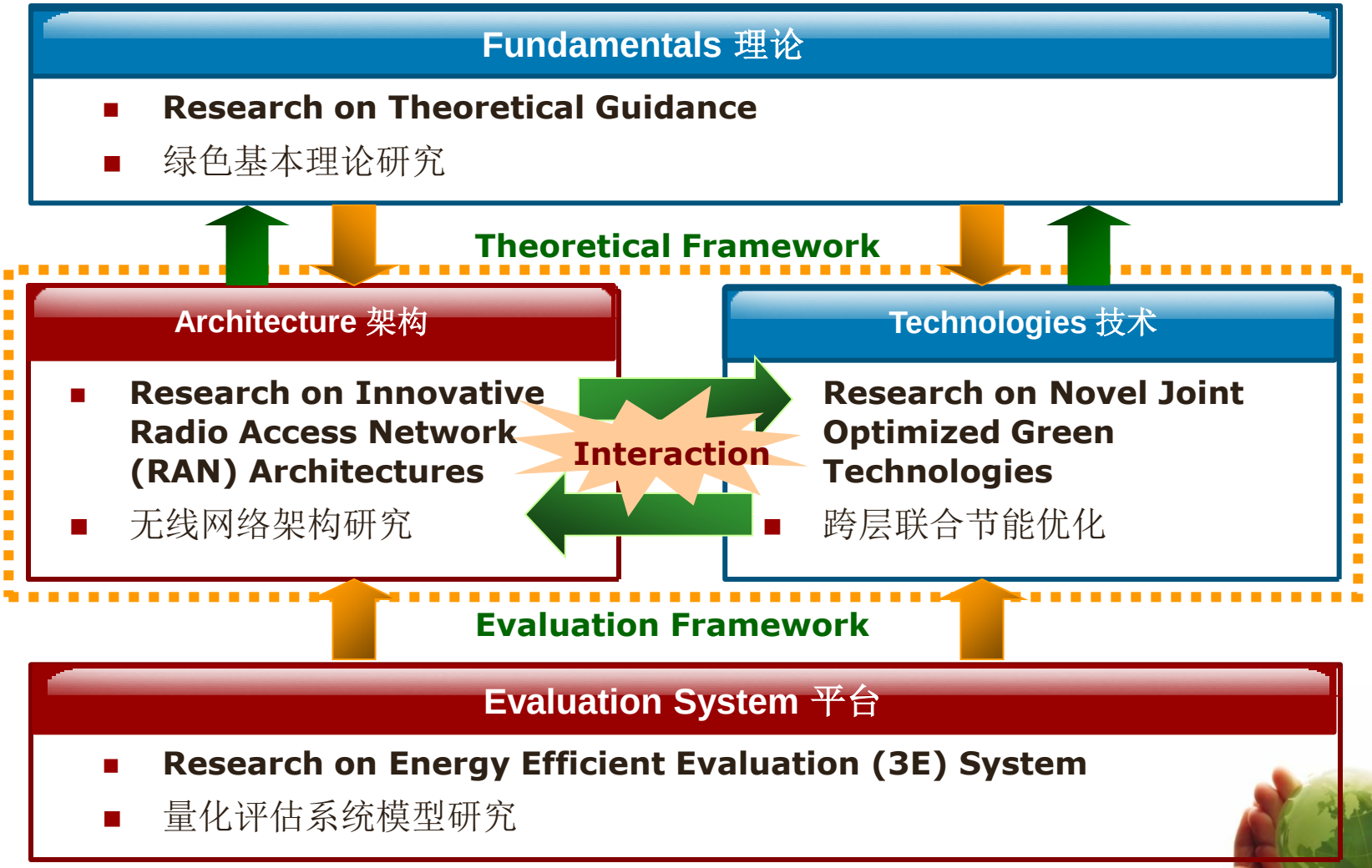
GREAT Project Overview

- **Research Framework**
- Energy Efficiency Evaluation (3E) Framework
- Fundamental Tradeoffs on Green Design

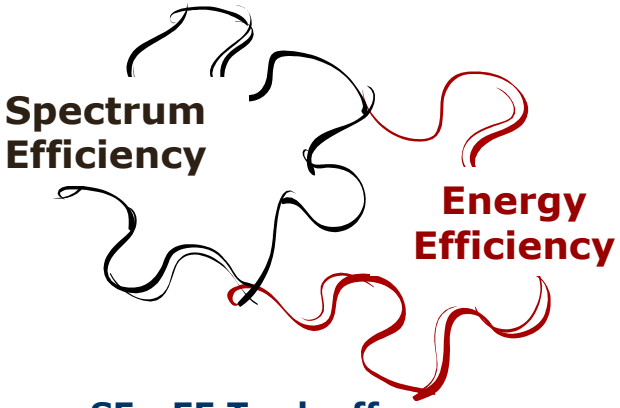
Research Areas – Sandwich Model



Research Areas

Fundamentals

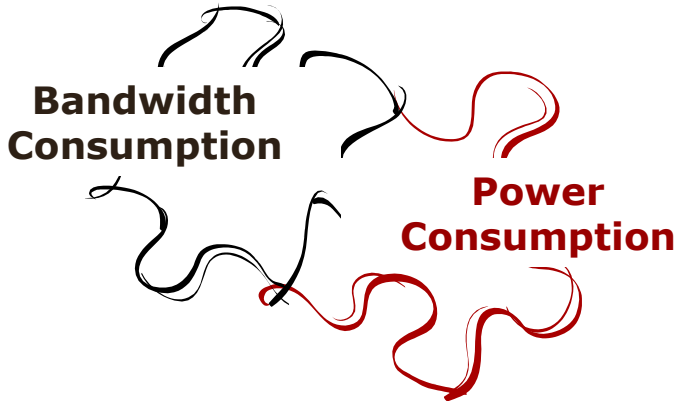
- **Research on Theoretical Guidance**



SE - EE Tradeoff

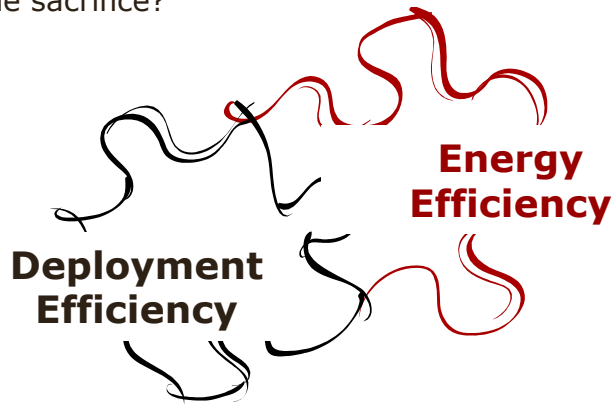
Do we need to sacrifice spectrum efficiency for power efficiency? How will the gain vary with the sacrifice?

4 Fundamental Tradeoffs



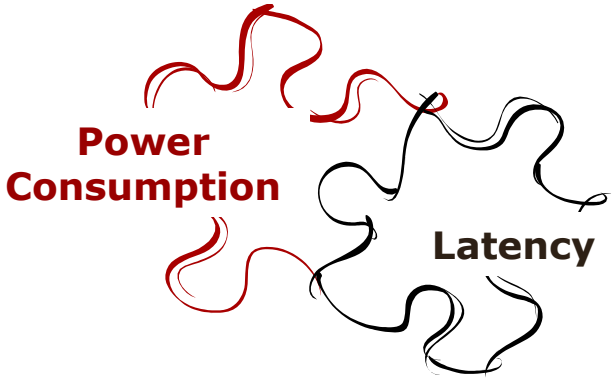
Bandwidth - Power Tradeoff

Is that possible to trade aggregated idle bandwidth for power?



DE – EE Tradeoff

How much gain can we get in energy efficiency? Does that worth the deployment cost?



Power - Delay Tradeoff

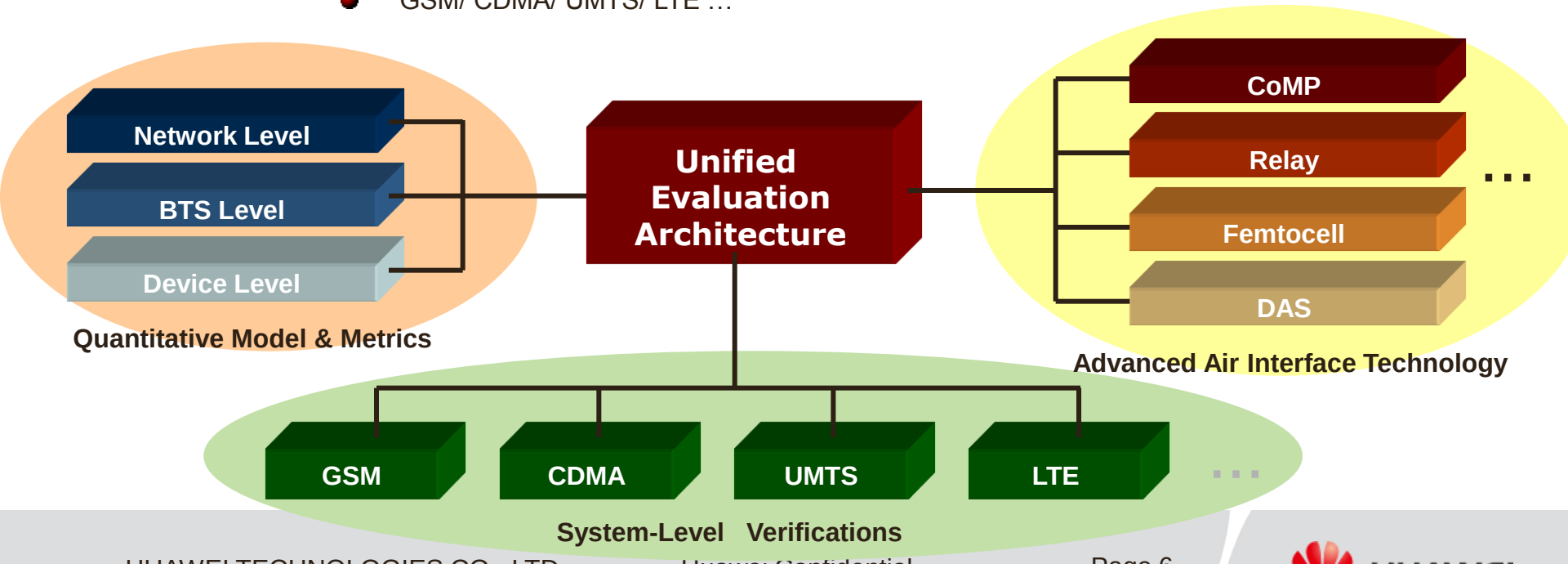
How to get balance between QoS (e.g. delay) and power consumption?

Research Areas

Evaluation System

- **Research on Energy Efficient Evaluation (3E) System**

- **Unified Architecture for Energy Efficiency Evaluation (3E)**
  - Define energy efficiency model & metrics for different levels
    - Device/Component Level
    - BTS level
    - Network level
  - Evaluate the gain of different technologies in the framework of energy efficiency
    - CoMP / Relay / Femtocell / DAS …
  - Build unified simulation platform/ testbed for system-level simulation
    - GSM/ CDMA/ UMTS/ LTE …

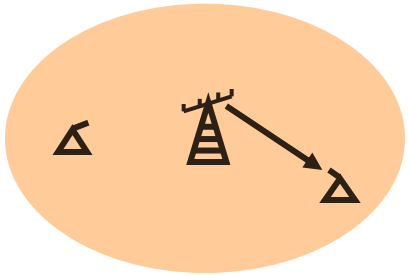


Research Areas

Architecture

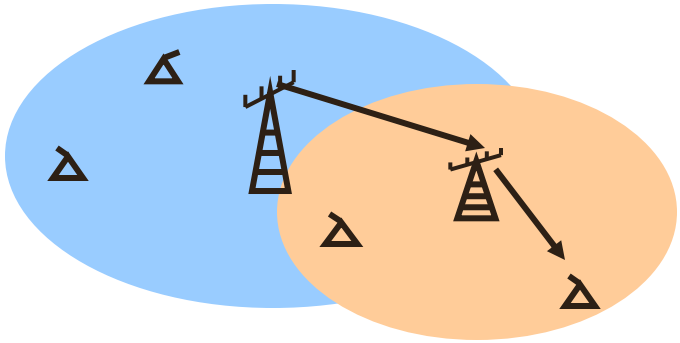
- **Research on Innovative RAN Architecture**

- **An Example of Deployment Related Study**

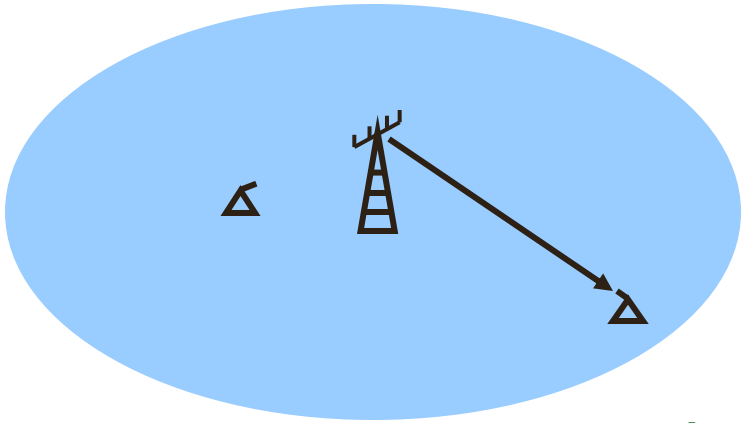


- Smaller path-loss
- Smaller Tx Power
- Lower PA Requirement
- More Infrastructure
- CAPEX? OPEX?
- Interference?

Small Cell Size



Relayed Architecture



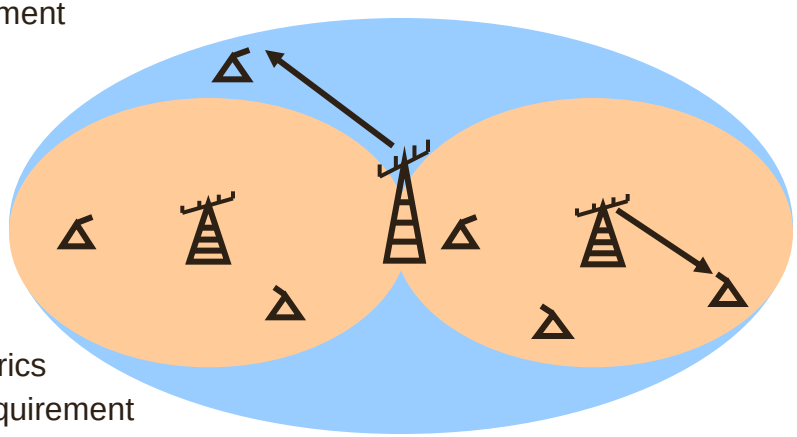
- Largerr path-loss
- Larger Tx Power
- Higher PA Requirement
- Less Infrastructure
- CAPEX? OPEX?
- Interference?

Large Cell Size

Which Architecture?

Depends on

- Unified Metrics
- Service Requirement
- Site/Equipment Cost
- Dynamic Management



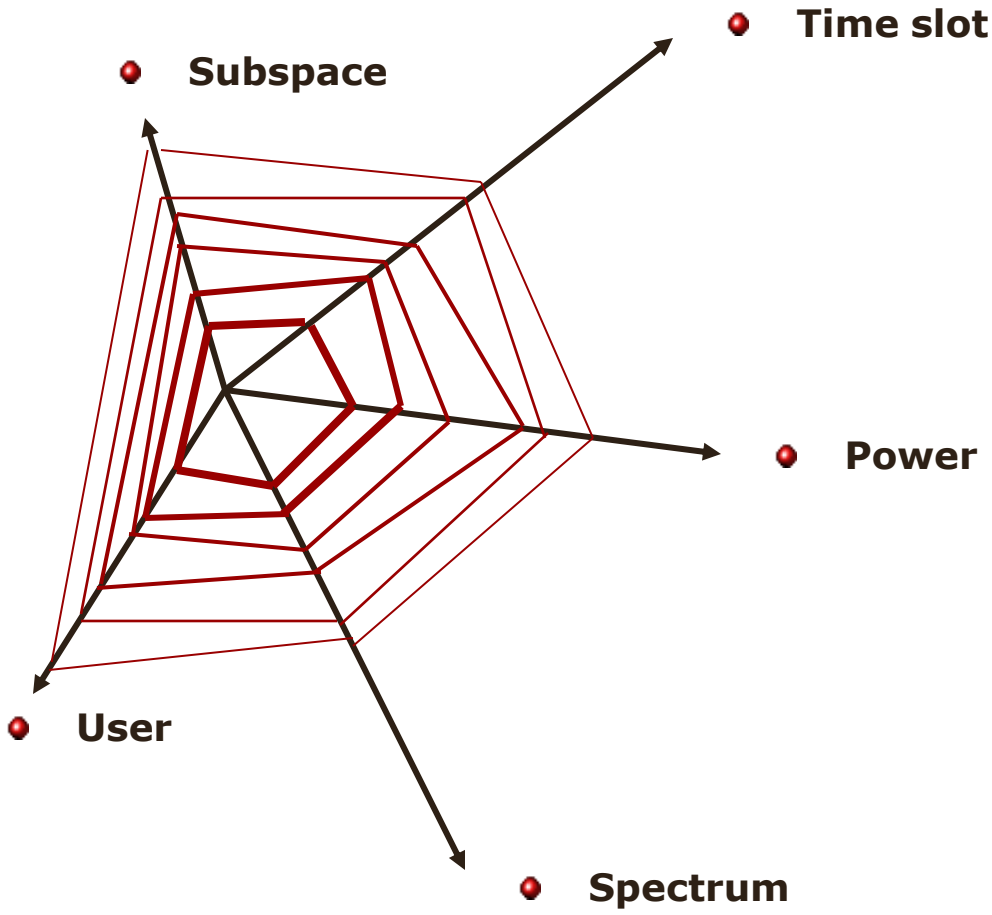
Heterogeneous Arch./Multi-RAT

Research Areas

Technologies

- **Research on Novel Joint Optimized Green Technologies**

- **An Example of Relay Study on Optimized Resource Scheduling**



Throughput-Oriented Resource Allocation

Shift to

Energy-Efficiency-Oriented Resource Allocation

How to

Given the QoS requirement, reduce unnecessary energy consumption in any possible way

GREAT Project Overview

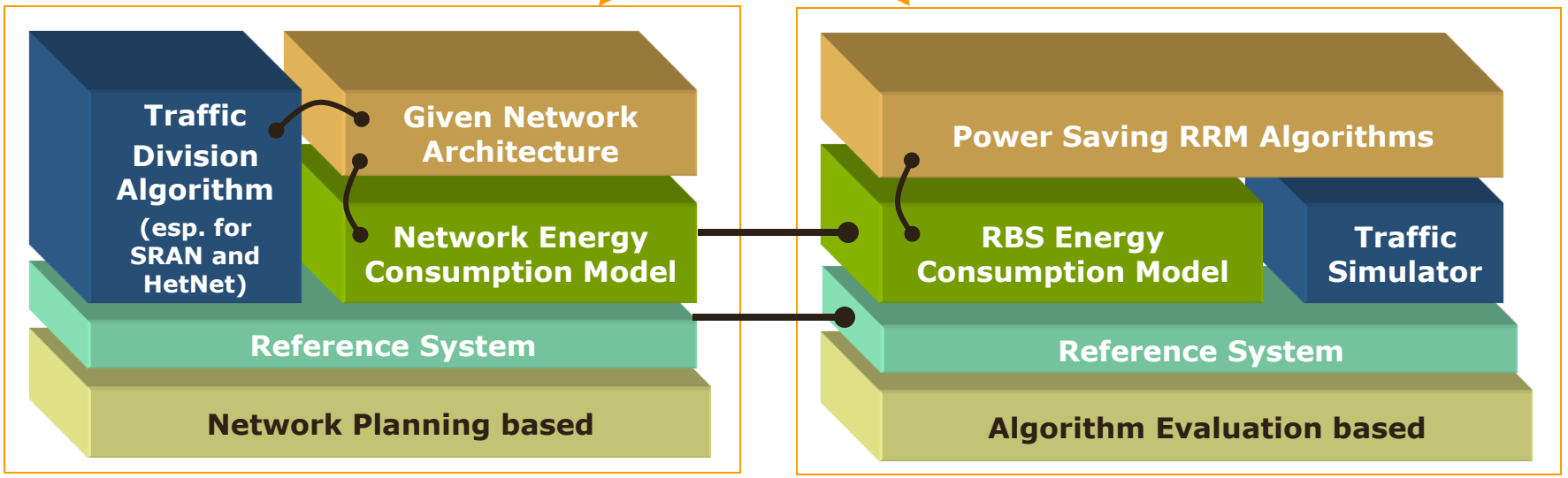
- Research Framework
- **Energy Efficiency Evaluation (3E) Framework**
- Fundamental Tradeoffs on Green Design

3E System

- **Simulation Platform: Walk with Two Legs**

3E System Construction

- Simu. Scenario
- For Algorithms
- For Architectures

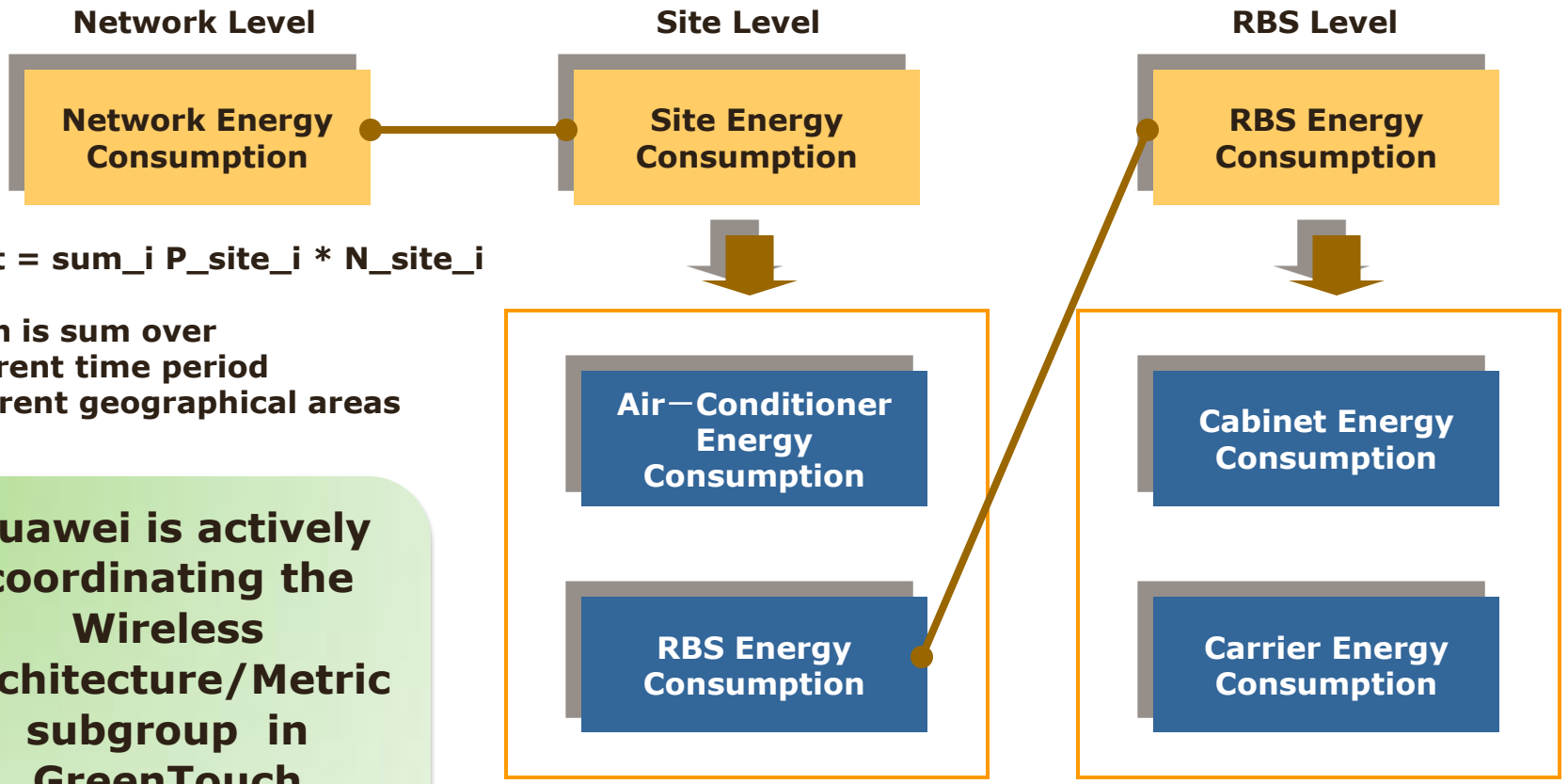


3E System

3E System Modeling

Basic Modeling (E for BTS/Site/ Network levels, etc)

- Energy Consumption Modeling



P_net = sum_i P_site_i * N_site_i

Which is sum over
•different time period
•Different geographical areas

Huawei is actively coordinating the Wireless Architecture/Metric subgroup in GreenTouch

Pin = A (conf, traffic, Pout) * Pout + B (conf, traffic, Pout)

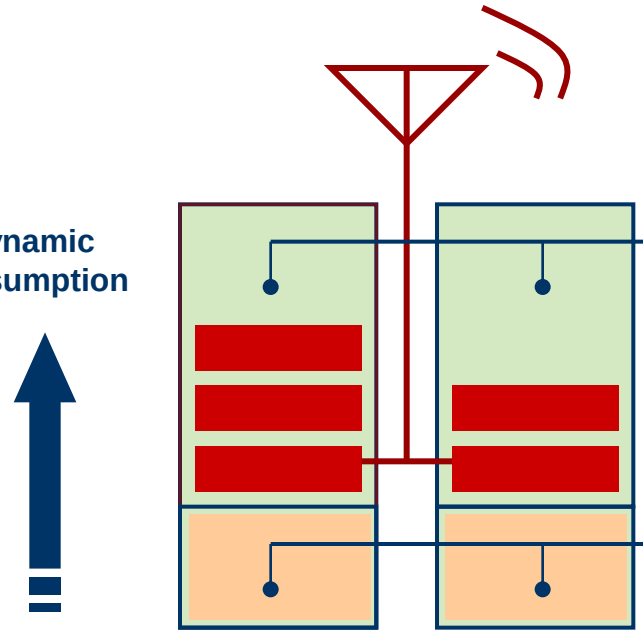
3E System

3E System Modeling

Basic Modeling (E for BTS/Site/ Network levels, etc)

- Energy Consumption Modeling

Carrier Energy Consumption



Dynamic consumption

PA dynamic consumption

Dynamic consumption is closely related to the amount of data traffic

PA static consumption

The PA always has quiescent current to meet raw linearity requirements, which contributes to the static consumption

TRX consumption

Digital IF circuits, AD/DA, small signal RF circuits

TRX

Static consumption

Baseband

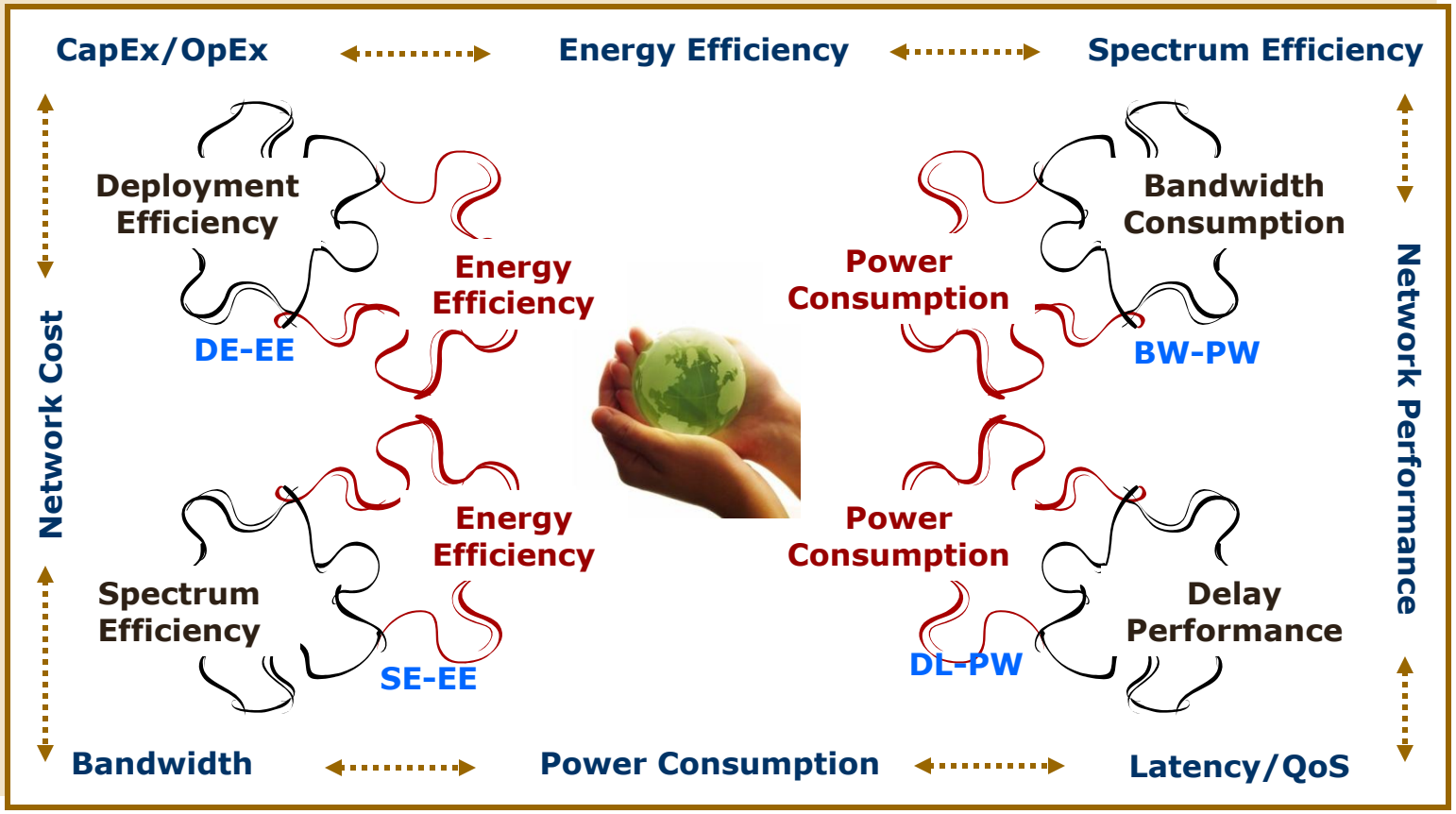
Baseband consumption

DSP, FPGA, CPU, and other core devices in baseband processing

GREAT Project Overview

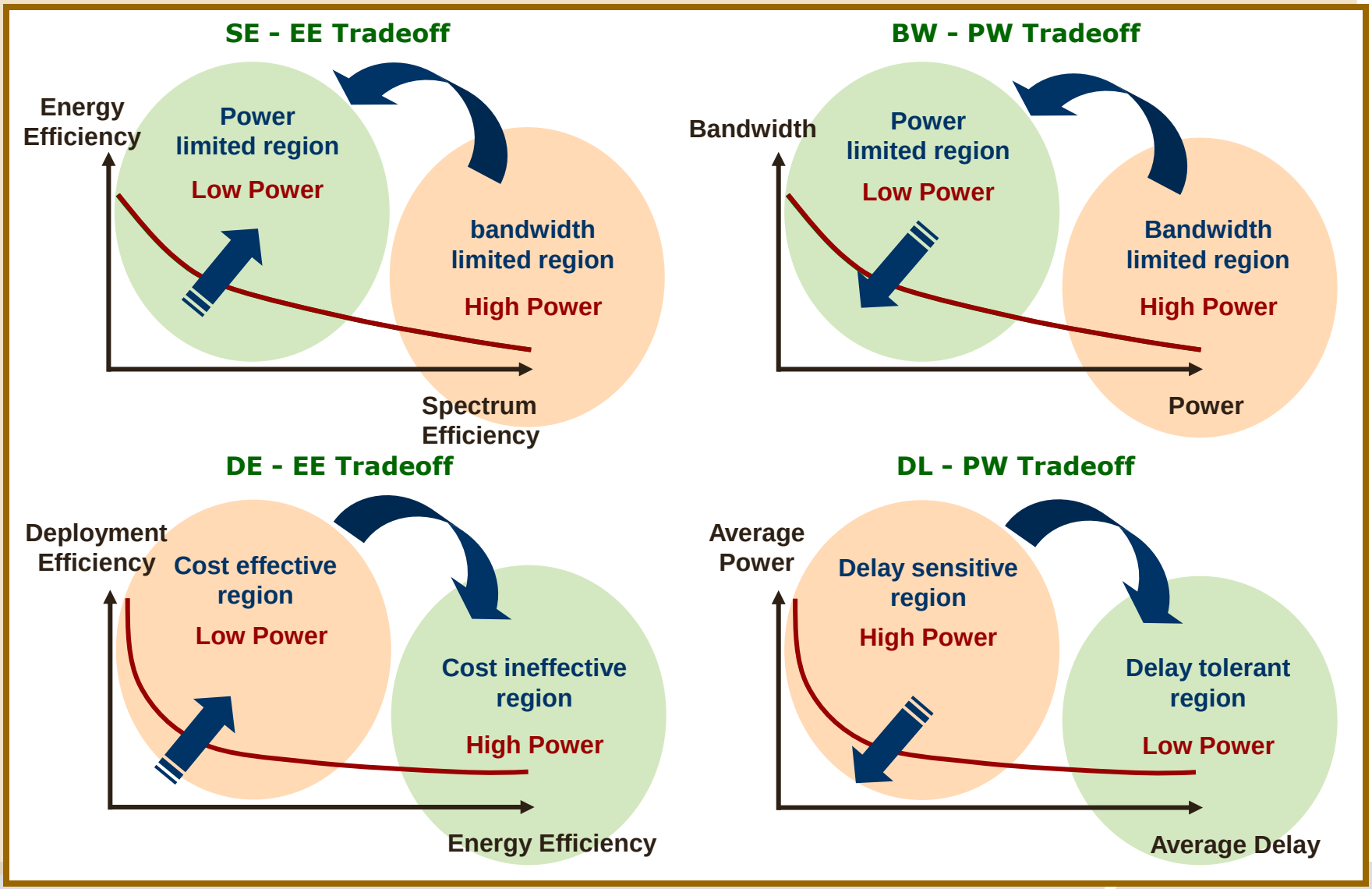
- Research Framework
- Energy Efficiency Evaluation (3E) Framework
- **Fundamental Tradeoffs on Green Design**

Fundamental Tradeoffs



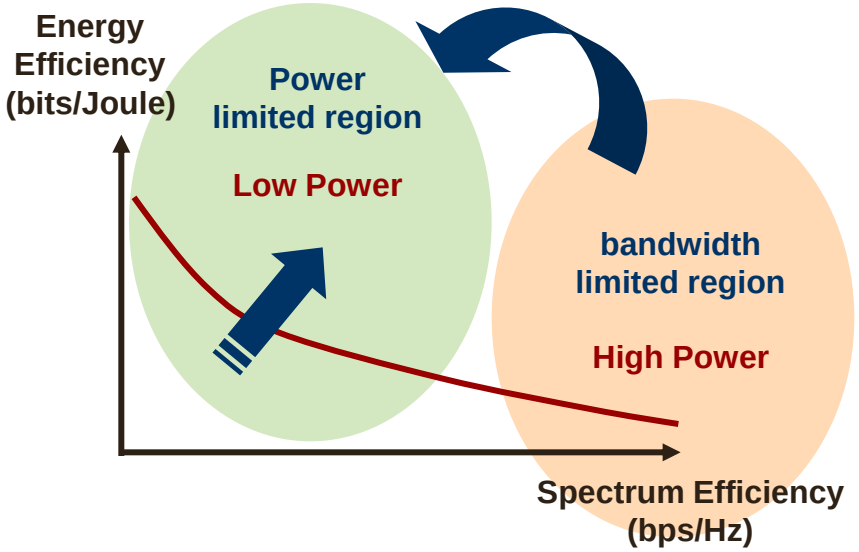
- We identify four fundamental tradeoffs in green wireless network design to improve energy efficiency while guaranteeing satisfactory quality-of-service/ cost
- We have got one paper about the four fundamental tradeoffs accepted by IEEE Communications Magazines, http://arxiv.org/abs/1101.4343

Insight from Shannon



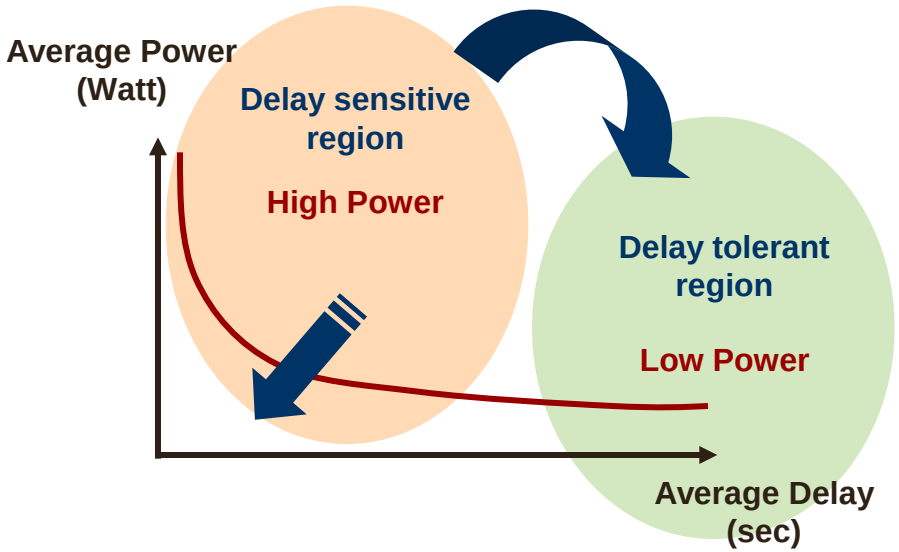
Leading GTT Project in GreenTouch

SE-EE Tradeoff



- **Expanding** the channel bandwidth at given rate requirement (i.e., trading bandwidth for power) ;
- **Reducing** the transmission rate at given bandwidth (i.e. trading rate for power)
- **Developing** novel radio transmission technologies and architectures to push the tradeoff curve outwards (i.e. improving spectrum efficiency and energy efficiency simultaneously).

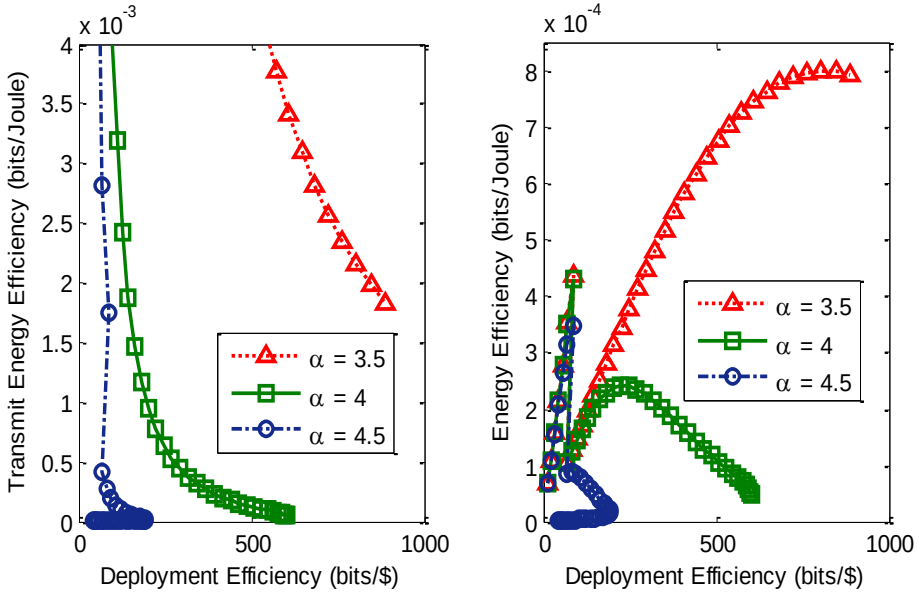
DL - PW Tradeoff



- **Prolonging** the service/transmission time but without deviating the user's QoS requirement by developing novel resource management and scheduling algorithms (i.e., trading delay for power) ;
- **Developing** novel radio transmission technologies and architectures to make the service more efficient (i.e. reducing energy consumption and reducing delay simultaneously).

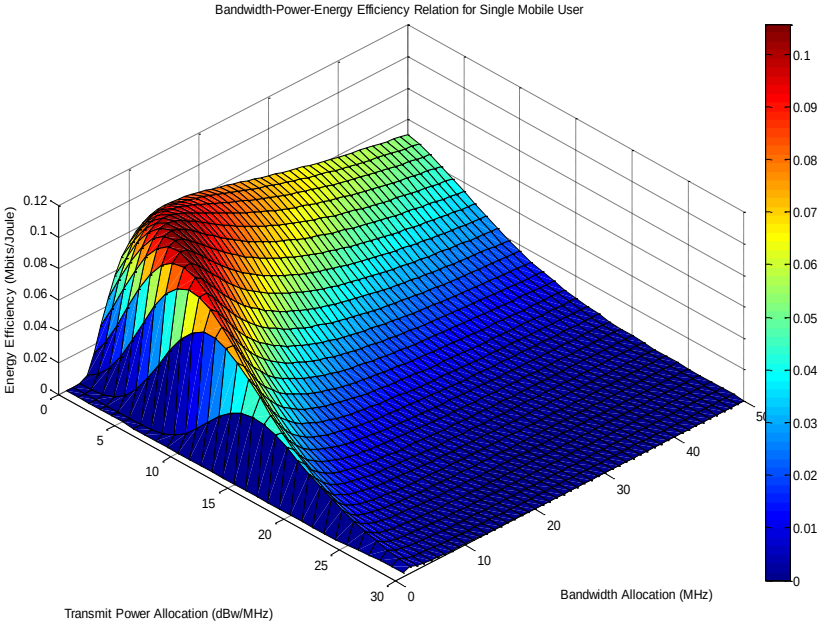
However, in Practice

Example of DE-EE Curves under practical constraints



- **Only Tx power considered, the tradeoff curve matches our intuition**
- **Static power and circuit power also considered, the tradeoff curve deviates our intuition**
- **Be careful when embracing smaller cells**

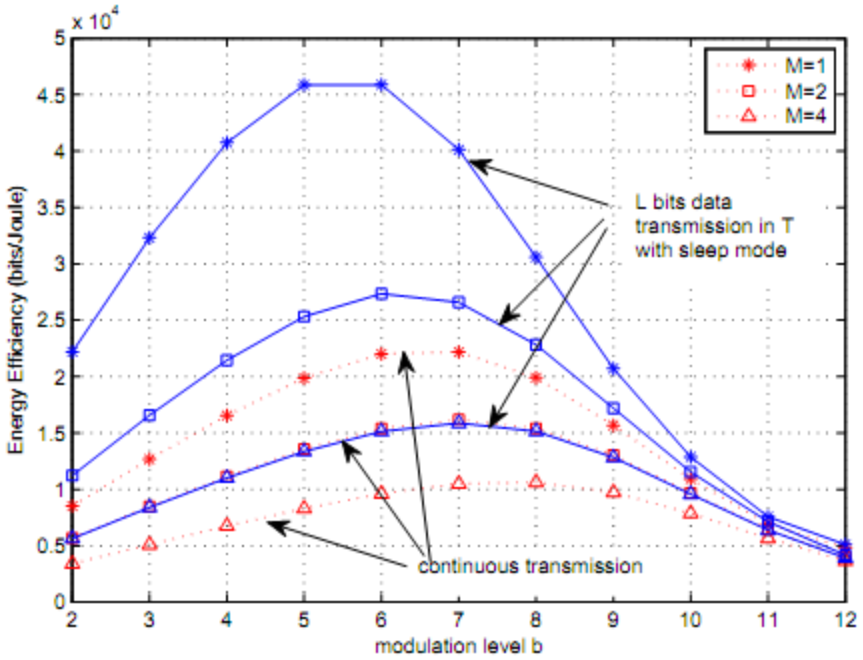
Example of BW-PW-EE Curves under practical constraints



- **Full utilization of bandwidth-power resource may not be most energy efficient**
- **Given target EE, the BW-PW tradeoff relation is not monotonic**

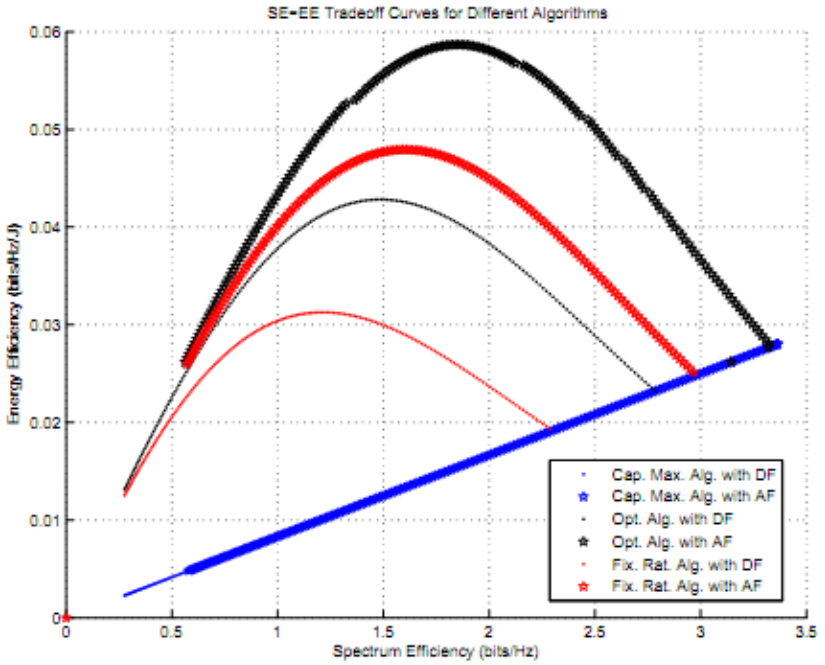
However, in Practice

Example of DE-EE Curves under practical constraints



- **The SE-EE curve under practical power model is no longer monotonic**
- **Sleep mode helps reduce circuit power**
- **Given the traditional way of RF architecture, increasing antenna does not always help increase EE**

Example of SE-EE Tradeoff in single relay system under practice constraints



- **When circuit power for both source and relay are considered, the SE-EE curve is no longer monotonic**
- **Optimized resource allocation between source and relay always helps increase EE**

Reference

- Shunqing Zhang, Yan Chen, and Shugong Xu, ", Energy Efficient Resources Allocation for Relay-Assisted Networks," in Proc. WWRF, Penang, Malaysia, Apr 2010.
- Yan Chen, Shunqing Zhang, and Shugong Xu, "Impact of Non-ideal Efficiency on Bits per Joule Performance of Base Station Transmissions," in Proc. IEEE VTC Spring, Budapest, Hungry, June 2011.
- Shunqing Zhang, Yan Chen, and Shugong Xu, ", Improving Energy Efficiency through Bandwidth, Power, and Adaptive Modulation," in Proc. IEEE VTC fall, Ottawa, Canada, Sept 2010.
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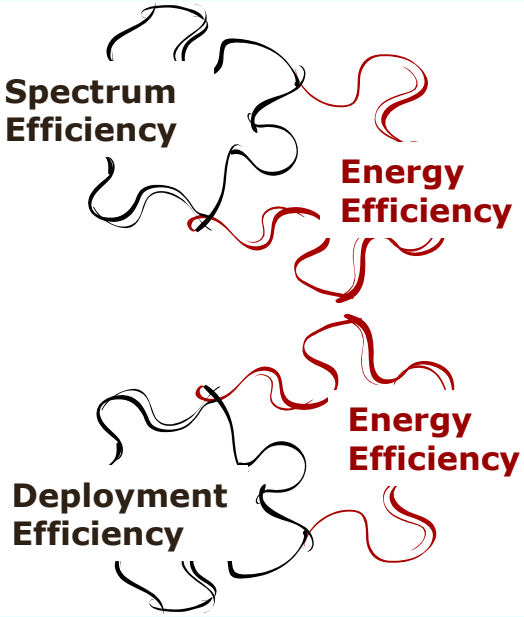
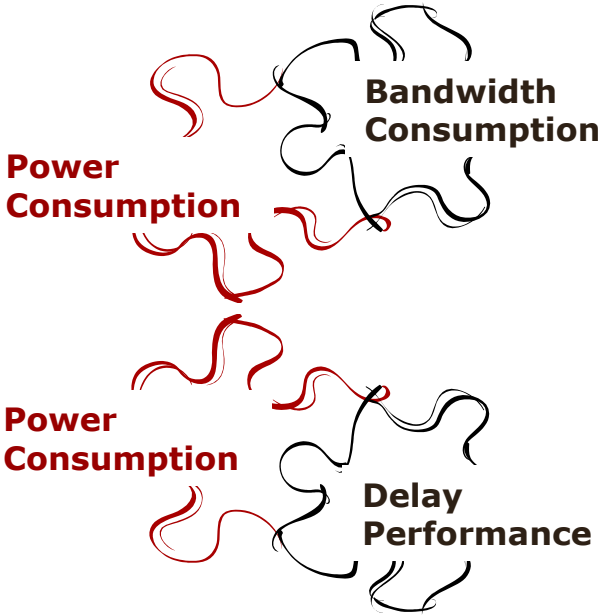


- Yan Chen, Shunqing Zhang, Shugong Xu, and Geoffrey Ye Li, "Fundamental Tradeoffs on Green Wireless Networks," to appear in IEEE Communications Magazines, Special Issue on Green Communications, 2010.



- Yan Chen, Shunqing Zhang, and Shugong Xu, "Characterizing Energy Efficiency and Deployment Efficiency Relations for Green Architecture Design," in Proc. IEEE ICC E2NET Workshop, Cape Town, South Africa, May 2010.
- Yan Chen, Shunqing Zhang, and Shugong Xu, "Improving Power-Delay Tradeoff via Traffic-Based Adaptive Modulation Scheme under Practical Power Consumption Model," submitted to IEEE ICC, Kyoto, Japan, June 2011.

Fundamental Framework

Design Guidance

- Theoretical Limits & Achievable Regions
- Gaps between boundaries and practical systems
- Directions for EE improvement

BW - PW Tradeoff

DL - PW Tradeoff

SE - EE Tradeoff

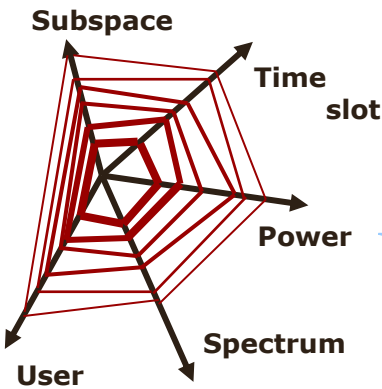
DE - EE Tradeoff

Green PHY Techniques

- Interference Management Techniques
- SDR-based Techniques
- Smart Antenna Techniques

Joint design

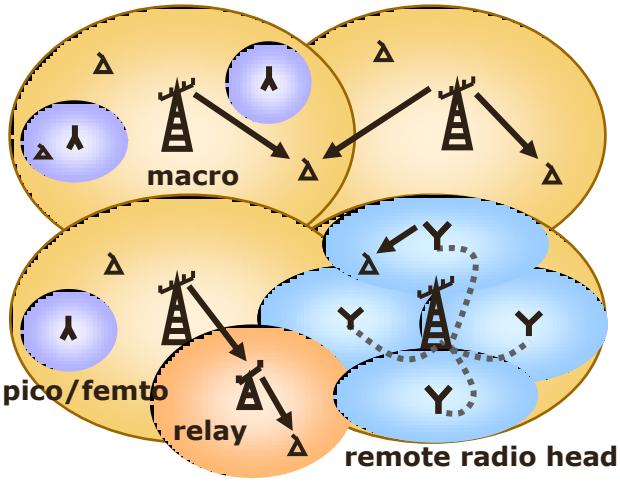
Green Resource Management



Throughput-Oriented Resource Allocation

Shift to

EE-Oriented Resource Management

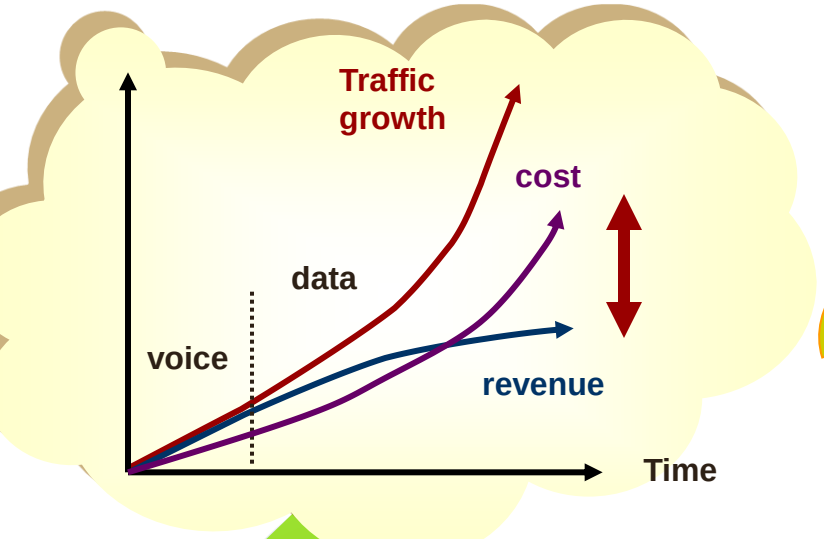


Green Network Planning

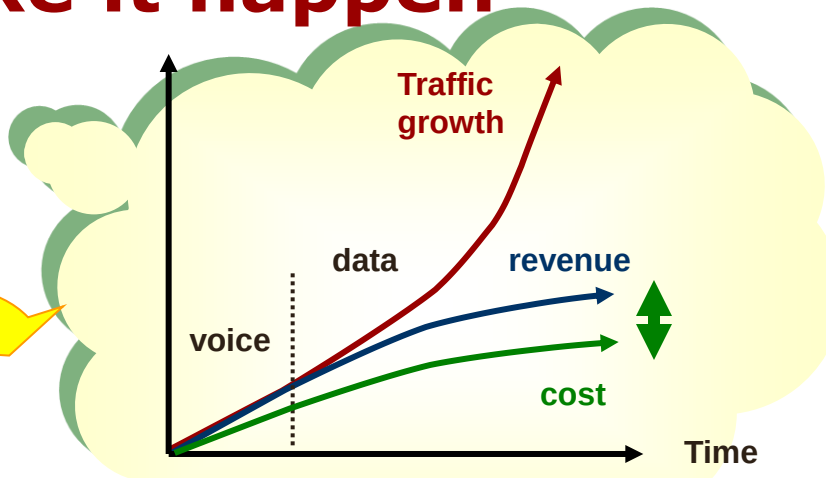
- Network architecture design
- Cell size optimization
- Dynamic Cooperation & Management

- **Huawei is currently leading the GreenTouch project – Green Transmission Technologies (GTT), which is based on the fundamental tradeoffs**

Green Vision – let's make it happen



Network EE Increase



Device -Level

Site -Level

Network -Level

Green Radio

An Enabler of This Change

Thank You!