Key Enablers for Green Radio – Results of EARTH Project

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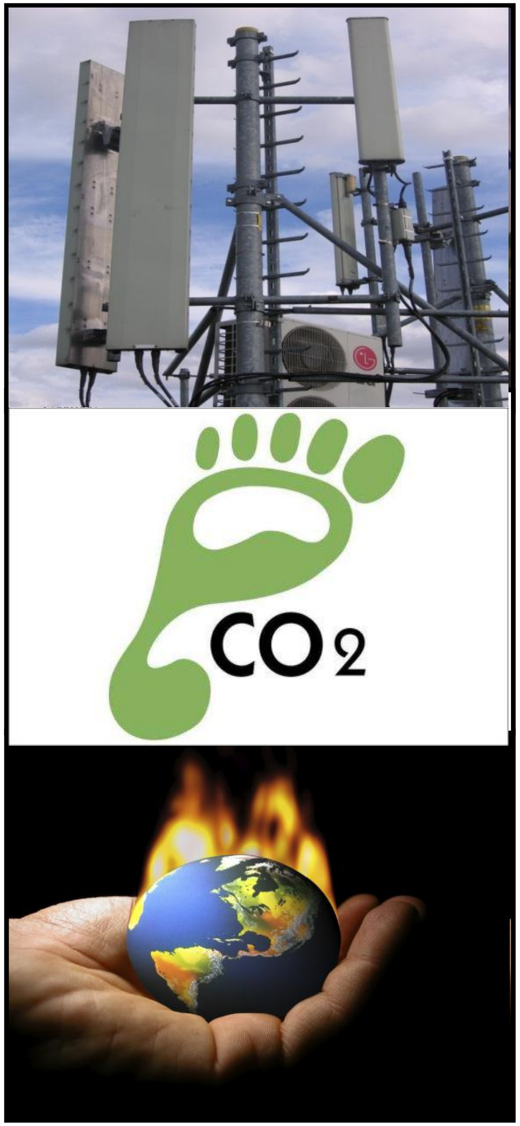
by courtesy of Gunther Auer and Hauke Holtkamp

Motivation

- Today ICT CO_2 contribution equals global air traffic contribution.
  Wireless communication: 15% of ICT.
- Mobile Broadband traffic is “exploding” and entering new markets
  - Densification of mobile networks /additional roll-out
  - High costs and long lead time for power infrastructure
  - Higher ratio of off-grid and weak grid BS
  - Increasing network operational costs due to increasing energy costs
- Increase in energy consumption should not explode as well



Outline

- Challenges for GreenIT
- Green Radio Key Enablers
  - Scaling Network Power Consumption with System Load
- Energy Efficiency Trade-offs
  - Power Control vs Discontinuous Transmission (DTX)
- Conclusions

Carbon Footprint Model

Objective:

- Assess the impact of **future** wireless systems on the **global carbon footprint**

Methodology:

- Historical trends are the basis for a forecast on the future growth of wireless communications until 2020
  - Assess power consumption per site
    - Consider various RAN technologies (GSM, WCDMA, LTE)
  - Anticipate deployment trends

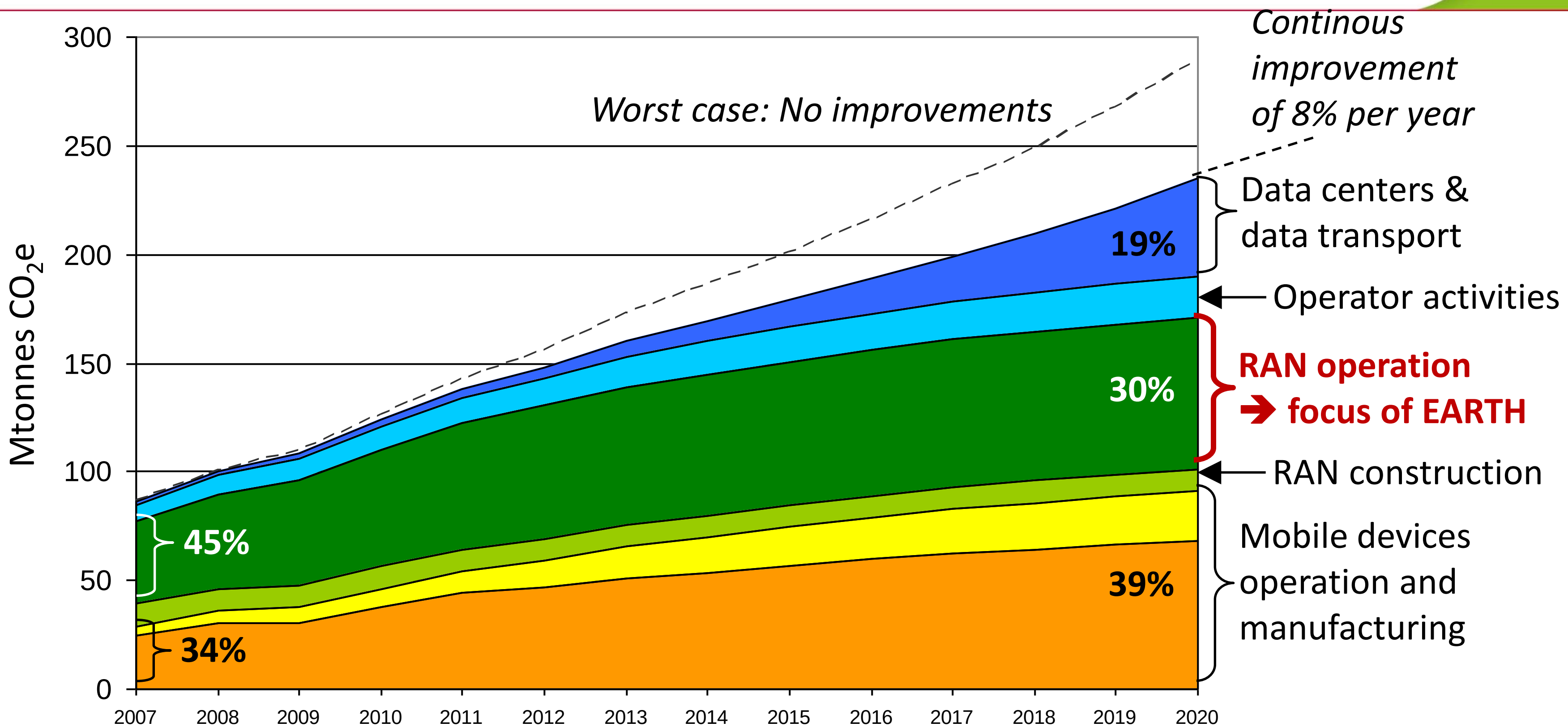
    → Number of required sites (for mix of RAN technologies)

  → Total power consumption of the network

  ➔ Carbon footprint

* A. Fehske, et al., "The Global Carbon Foot-print of Mobile Communications – The Ecological and Economic Perspective", IEEE Communications Magazine, to appear 2011

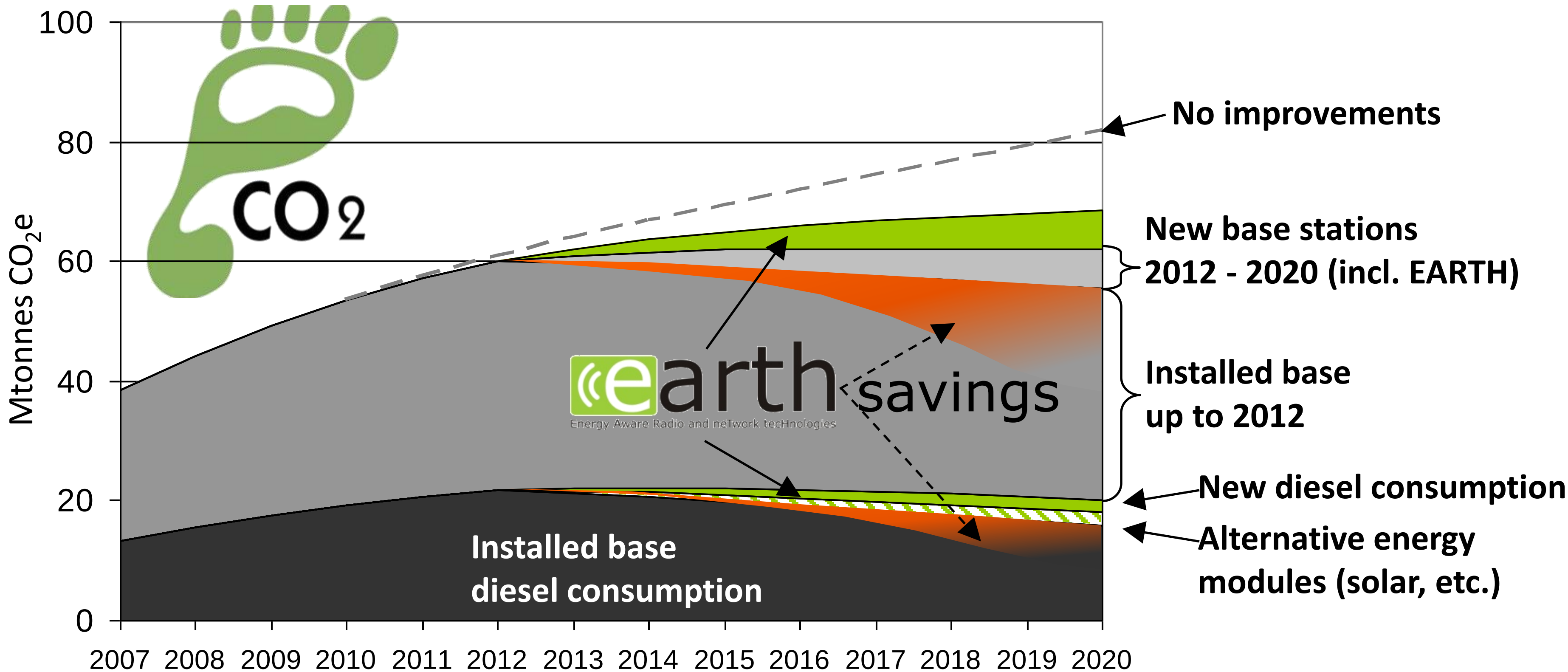
Cellular Networks
Global Carbon Footprint 2007-2020



2008:
0.3% of global direct CO_2
0.2% of total global CO_2e
1.6% of global economy [GSMA]

2020:
0.6% of global direct CO_2
0.4% of total global CO_2e

Impact of EARTH on ***all*** (**new & installed**) base stations



- ➔ Energy savings on already installed base stations (e.g. through software updates) may yield further CO_2e reduction
- ➔ Potential for reduction in carbon footprint

Major findings:

- Served data rates have grown by about a factor of 1000 over the last 15 years
- The carbon footprint of mobile communications has only increased by a factor of 3 in this period
- Potential impact of EARTH on reducing the carbon footprint :
  - New sites that consume only 50% energy (EARTH target):

    → No further increase in the RAN carbon footprint
  - EARTH innovation implemented in installed sites:

    → Potential for significant carbon footprint reduction
- To further reduce RAN carbon footprint, diesel generators for off-grid sites may be replaced by alternative energy modules

  → Indirect EARTH impact

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High loads → sustainable growth challenge

- Squeeze **more bits** through an already busy network ***without*** an increase in energy consumption

➔ Improve energy efficiency [Joule/bit]

➔ Already thoroughly investigated

→ Improvement : 300 times over the last 15 years

➔ Challenge to keep up with this trend in a subject well understood

Low loads → scale power consumption to **network load**

- On average more than 90% of radio resources are idle
- Yet only modest reduction in energy consumption of about 20% with respect to maximum load

→ Energy efficiency severely degrades at low loads

➔ **Vast potential** for energy savings in particular at low loads

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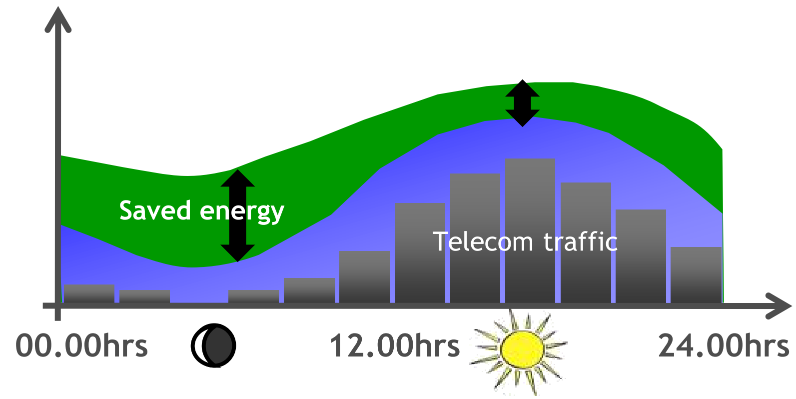
Components

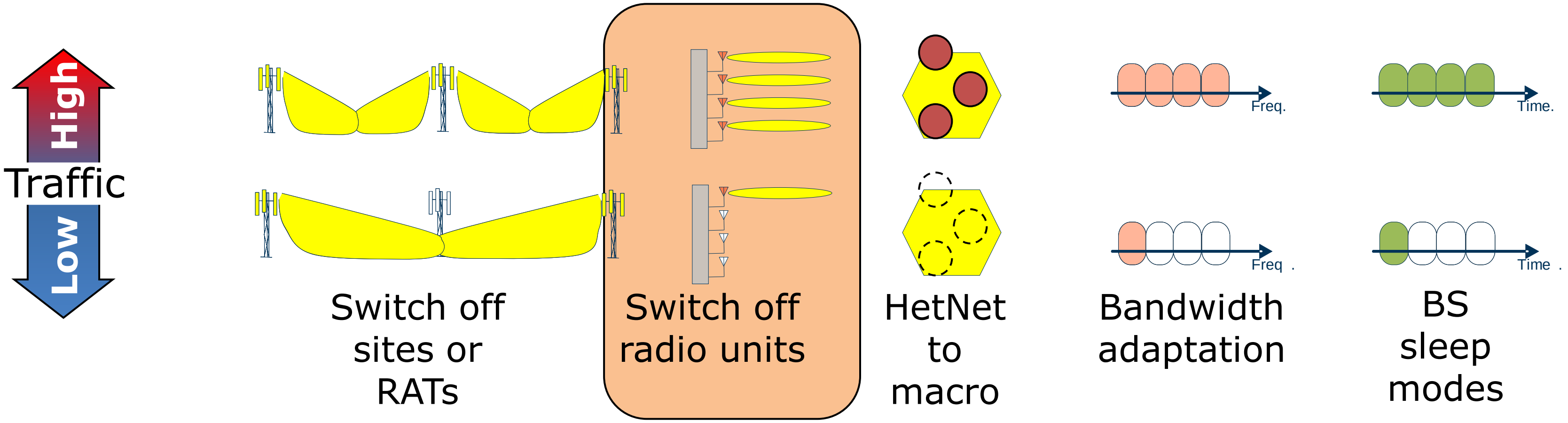
- Improve power efficiency at low loads of power amplifier (macro-cell) and baseband engine (small BS types)

Adaptive network reconfiguration

- Capacity gains of MIMO, carrier aggregation (CA) and heterogeneous networks (HetNets) do not come for free



➔ Reconfigure system to long and/or short-term traffic variations



*L. Correia, *et al.*, "Challenges and Enabling Technologies for Energy Aware Mobile Radio Networks," *IEEE Communications Magazine, vol. 48, no. 11, pp. 66 –72, 2010.*

Application of EARTH E^3F: MIMO Energy Efficiency in LTE

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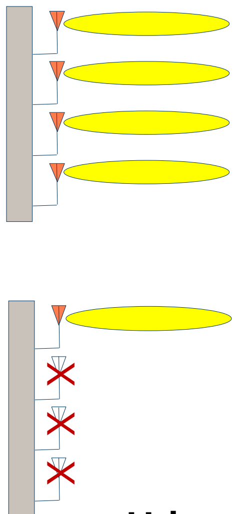
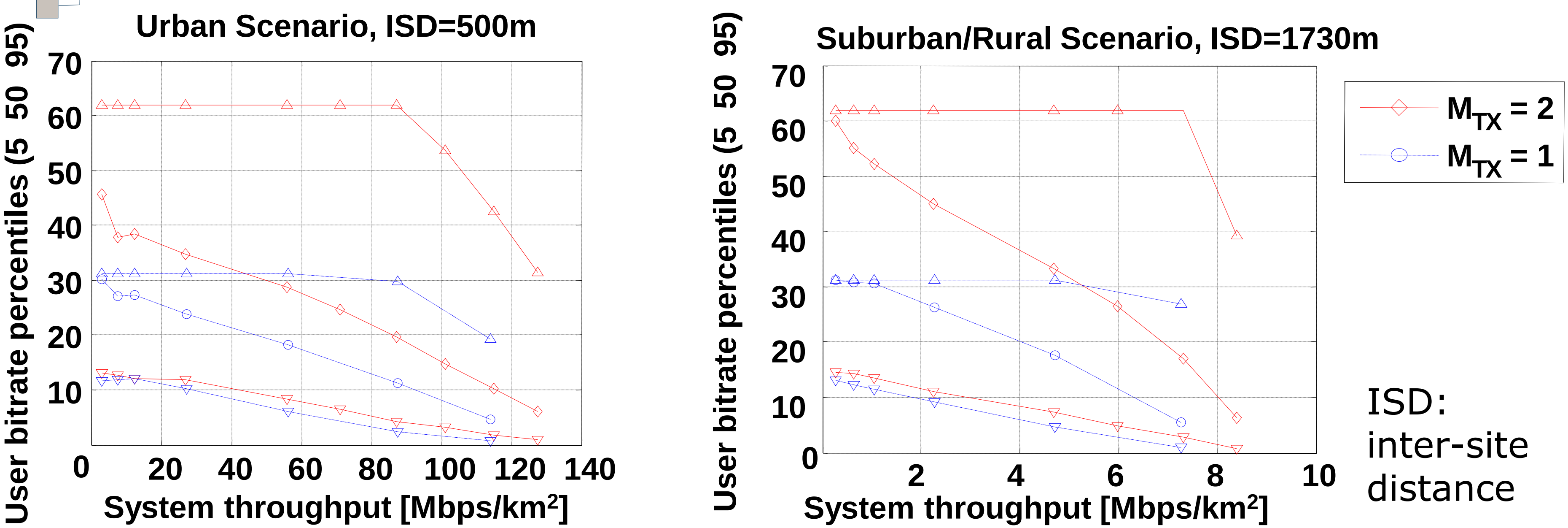


- Compare energy efficiency of LTE Rel-8 with different number of Tx antennas
- Number of Rx antennas is kept constant

➔ MIMO benefits from enhanced directivity & spatial multiplexing

➔ In particular cell-centre users benefit from MIMO



Application of EARTH E^3F
MIMO Energy Efficiency in LTE

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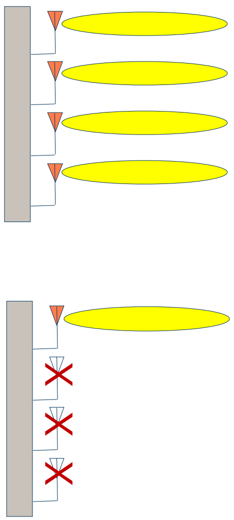
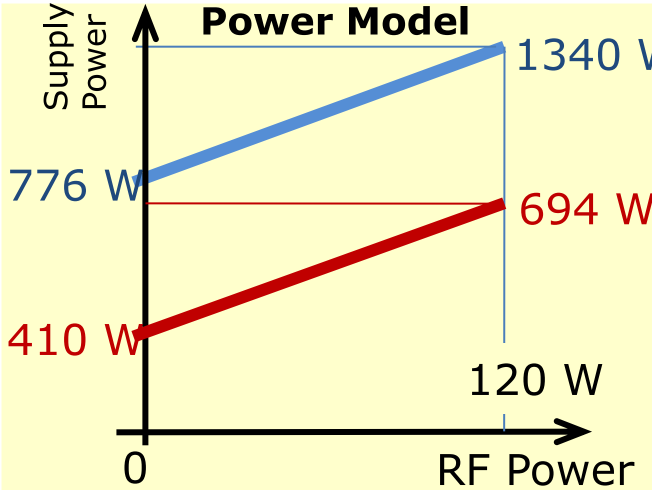
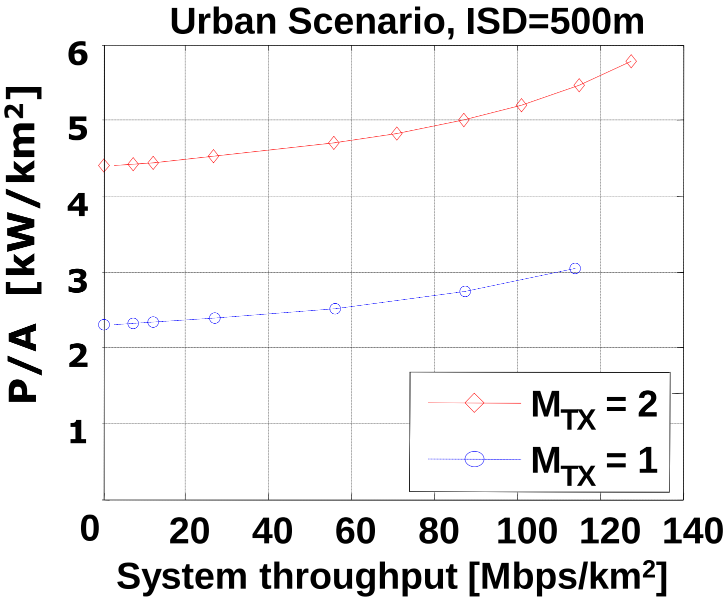
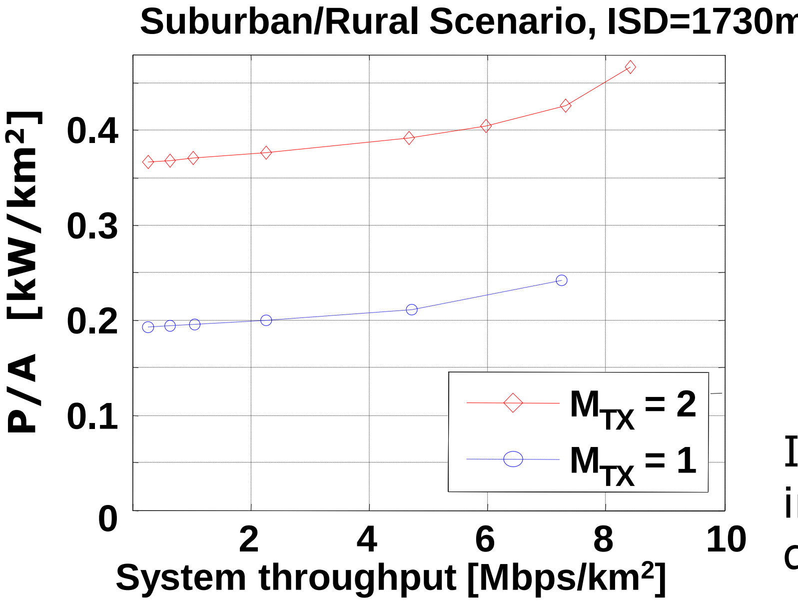


- ➔ MIMO leads to higher power consumption due to additional radio unit
- ➔ Trade-off between spectral efficiency and energy efficiency
- ➔ Results suggest to only activate additional Tx antennas on demand

Note: MIMO may greatly benefit from improved hardware and sleep modes







ISD: inter-site distance

Key Enablers for Green Wireless Networks*
➔Scaling Power Consumption to Network Load

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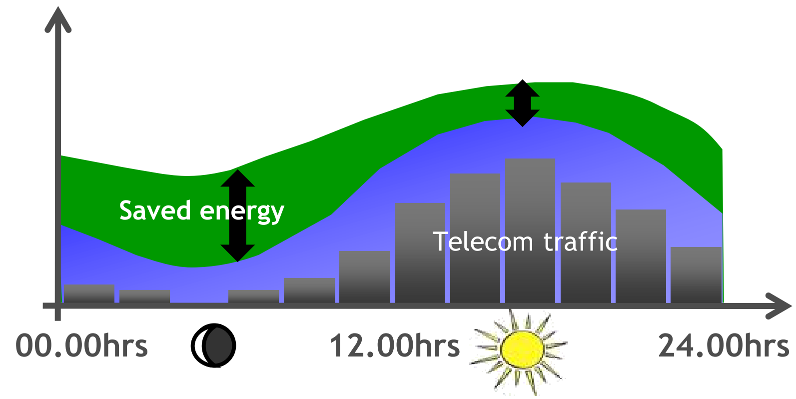

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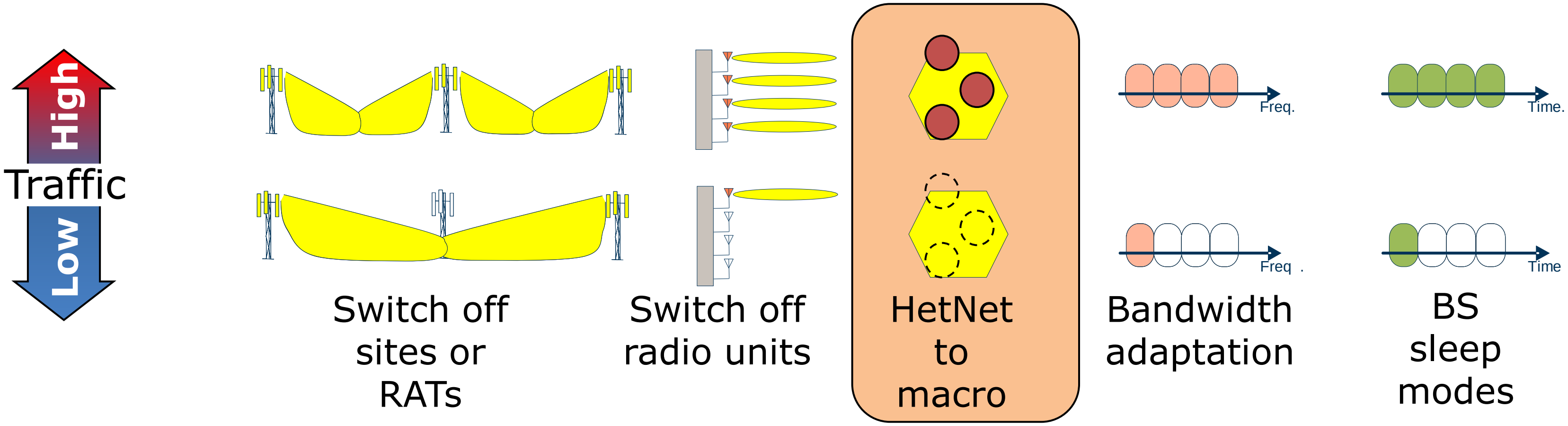

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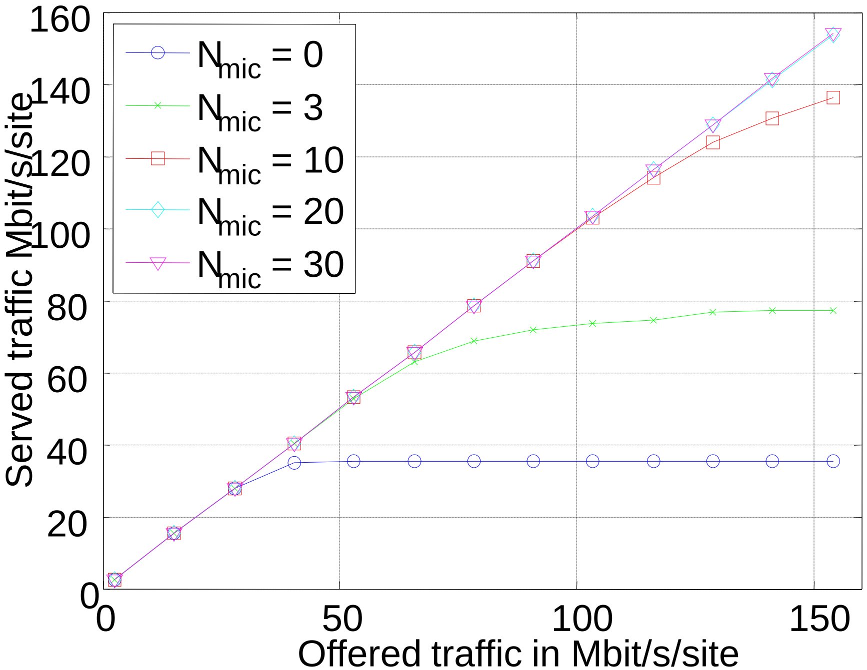
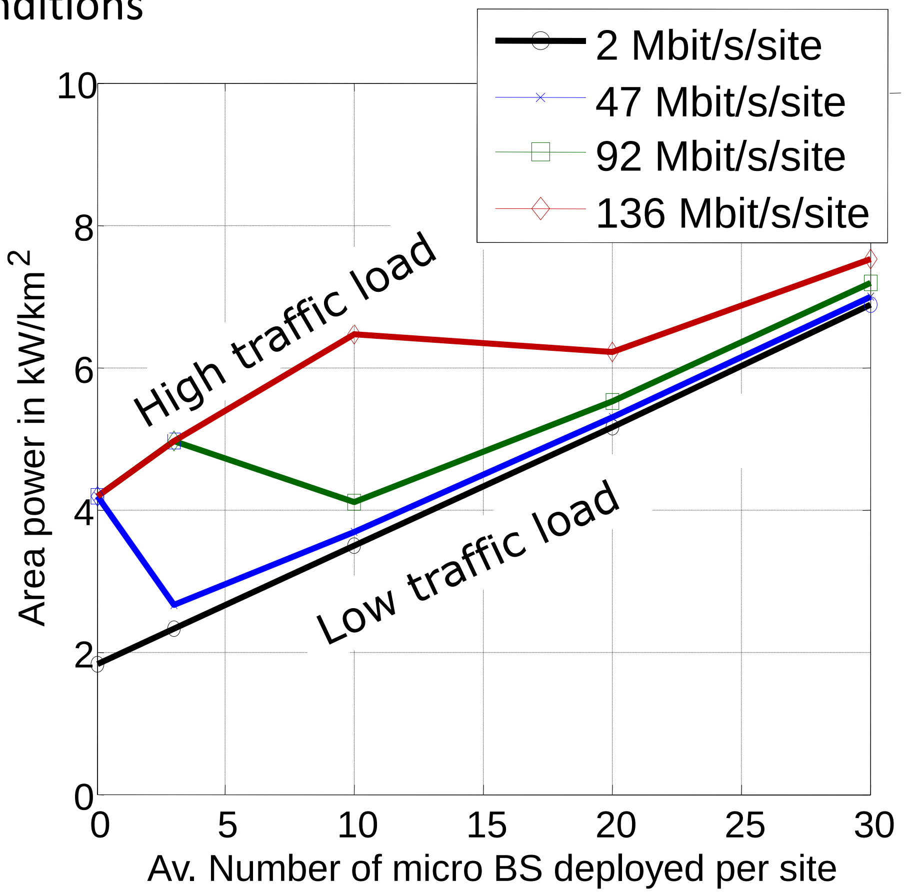
Results

- Complimentary deployment of small cells boosts capacity
- *Additional* small cells deployment can *reduce* network energy consumption for certain load conditions





Key Enablers for Green Wireless Networks*
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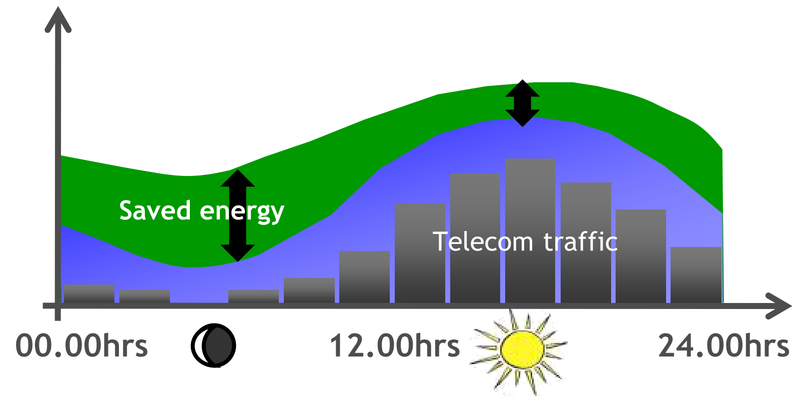

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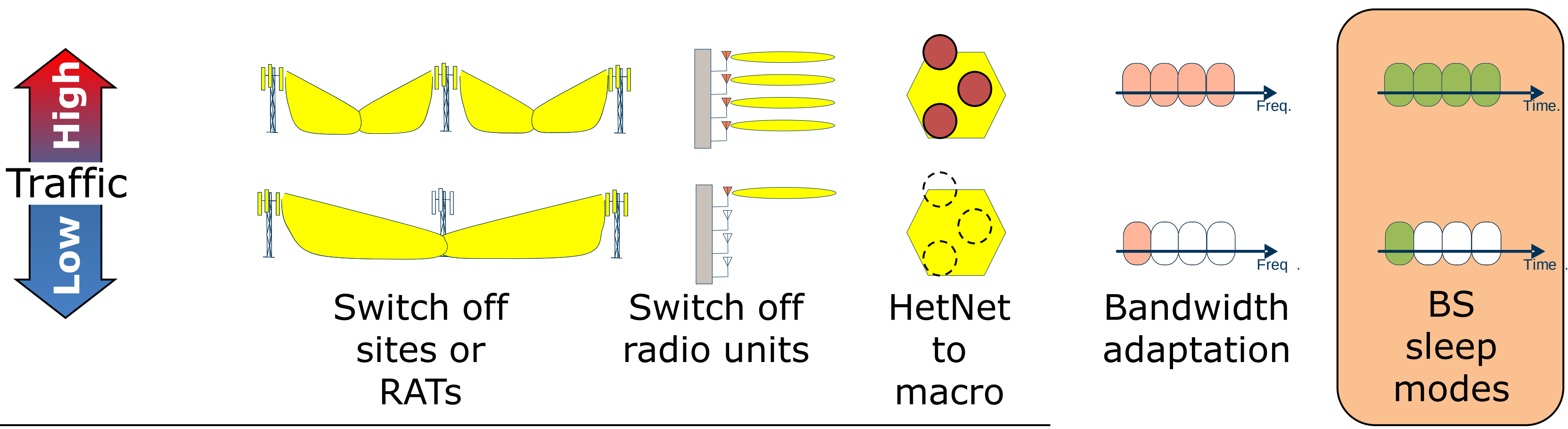

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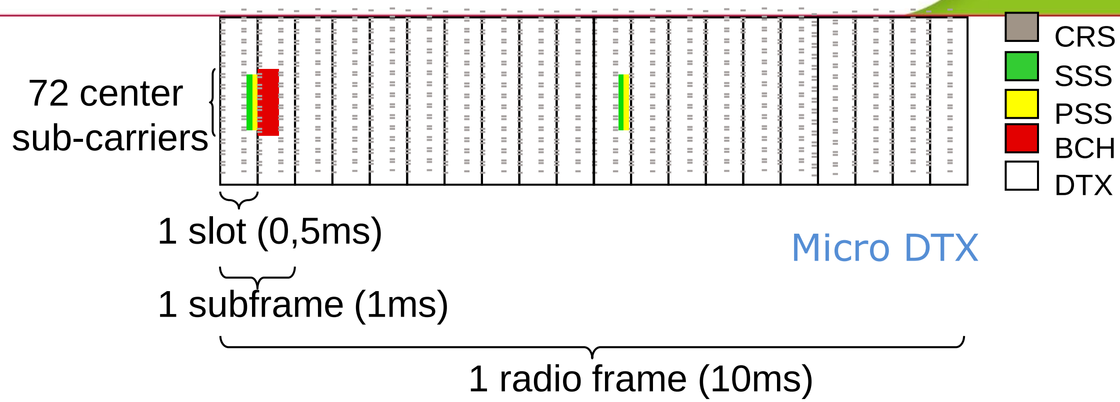
Key Enablers for Green Wireless Networks: Discontinuous transmission (DTX) in LTE

Deactivate radio components when not transmitting

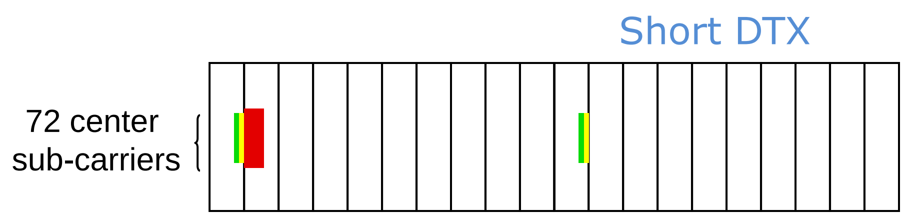
Micro DTX (<1 ms)

- Possible in LTE Rel-8



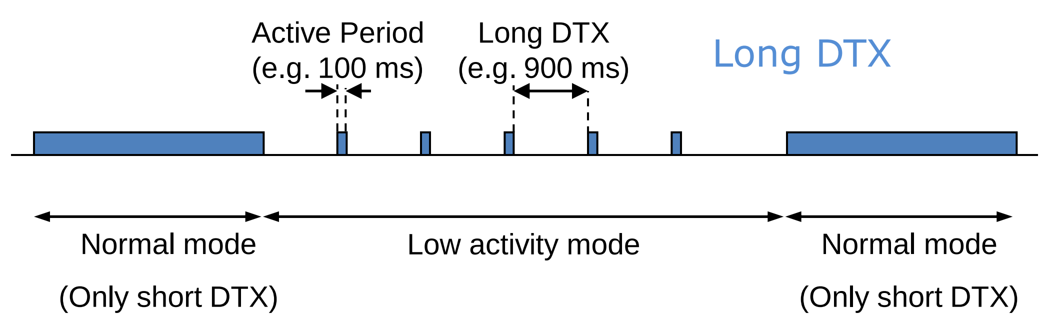
Short DTX (<10 ms)

- UEs perform mobility measurements on synchronization signals
- Standardization impact:
  → Remove CRS; Only PSS/SSS and PBCH transmissions in empty cells



Long DTX (>10 ms) → Low activity mode:

- Active period: Transmission of SSS/PSS and PBCH (short DTX)
- Idle period: No transmissions at all
- Standardization impact:
  → cell search alternatives needed



DTX in LTE: Technology Potential

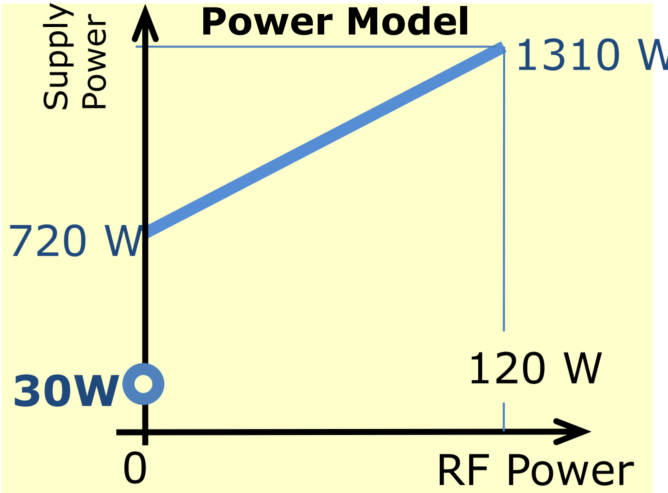
- Explore technology potential for cell DTX in LTE
  - Assume very low sleep power consumption

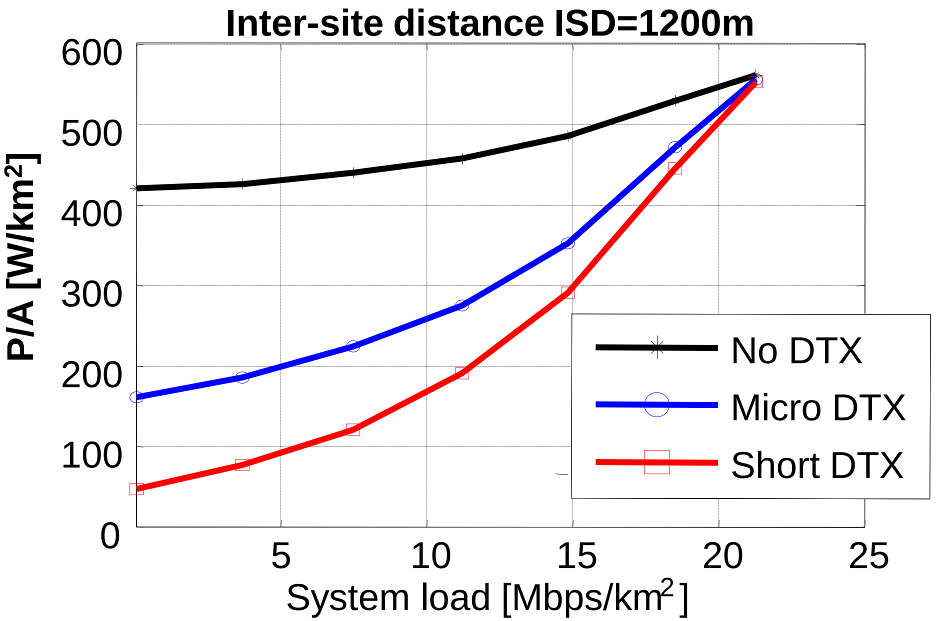
➔ Without cell DTX the power usage scales badly due to high power consumption in idle mode

➔ Significant energy savings of DTX at low load, due to high probability of empty (sub)frames

- By not transmitting CRS (short DTX) further energy savings are achieved

- Very high saving potential as according to the EARTH E3F, more than 90% of resources carry no data

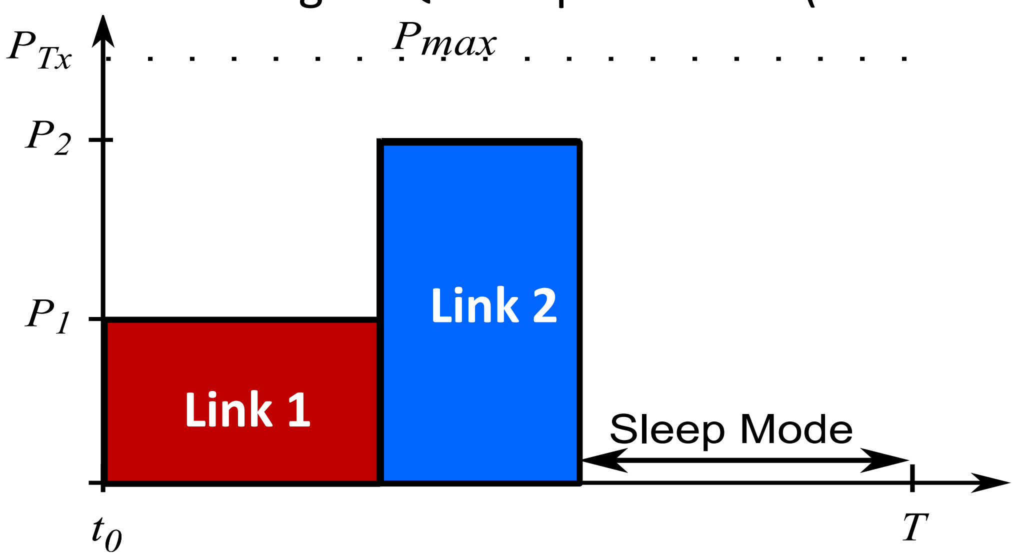


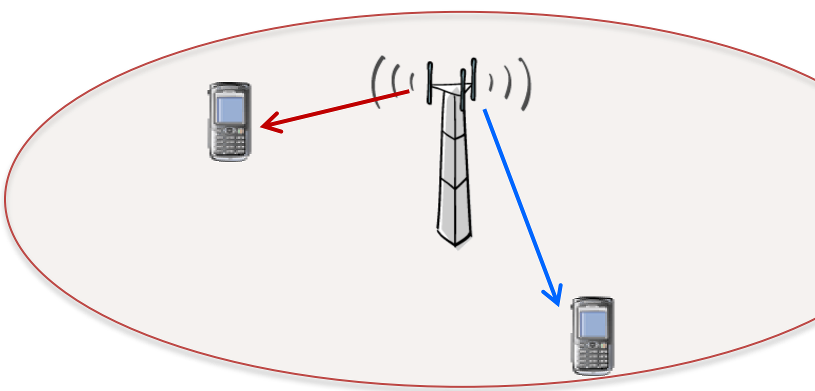


- Investigate the theoretical limits of energy efficient resource allocation algorithms*
- Find lower limit of base station power consumption by combining

Resource Sharing (TDMA) | Power Control (PC) | Sleep mode (DTX)

- Adhering to QoS requirements (minimum rate)





*H. Holtkamp, G. Auer, H. Haas, "On Minimizing Base Station Power Consumption," IEEE Vehicular Technology Conference (VTC), 2011 fall, San Francisco, USA.

Energy Efficient Resource Allocation
Considered Power Models

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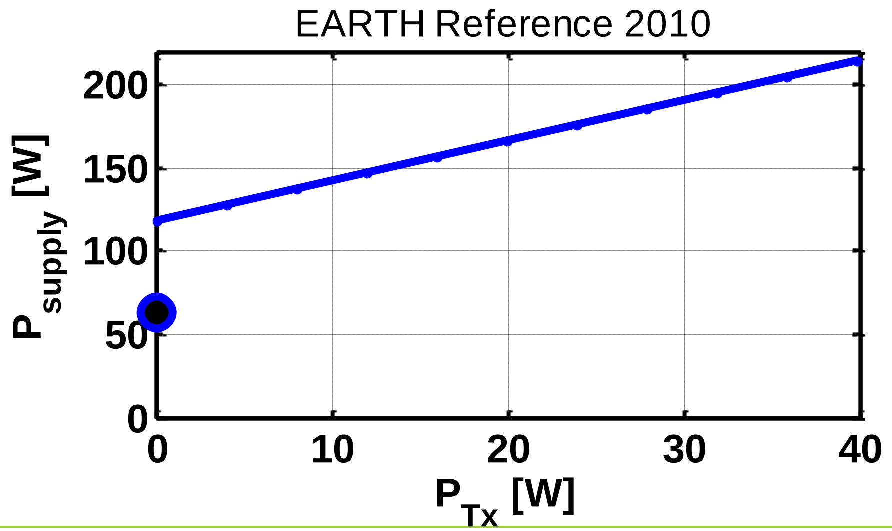
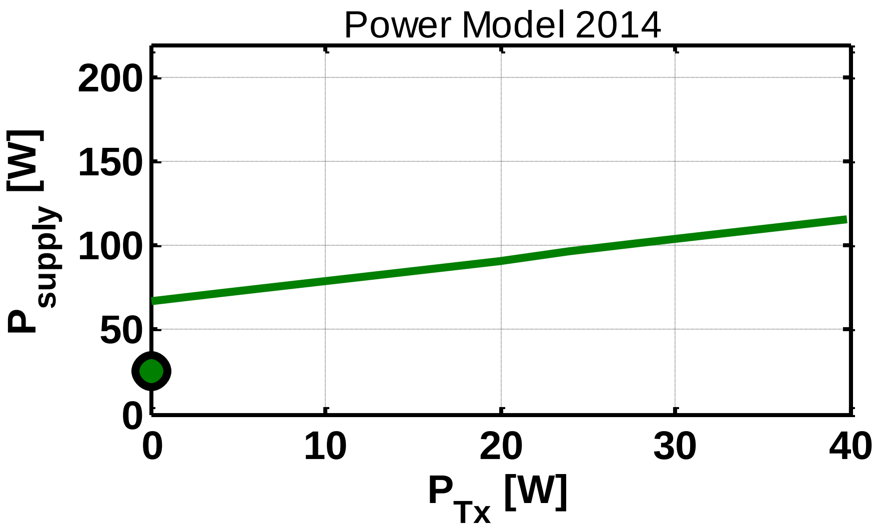


Examine performance with different power models

1. LTE macro base station as deployed in 2010
   - Including sleep mode
   - Only one sector considered



2. Base stations expected to be available on the market in 2014*
   - Improved power efficiency
   - Reduced sleep mode consumption

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Energy Efficient Resource Allocation Results

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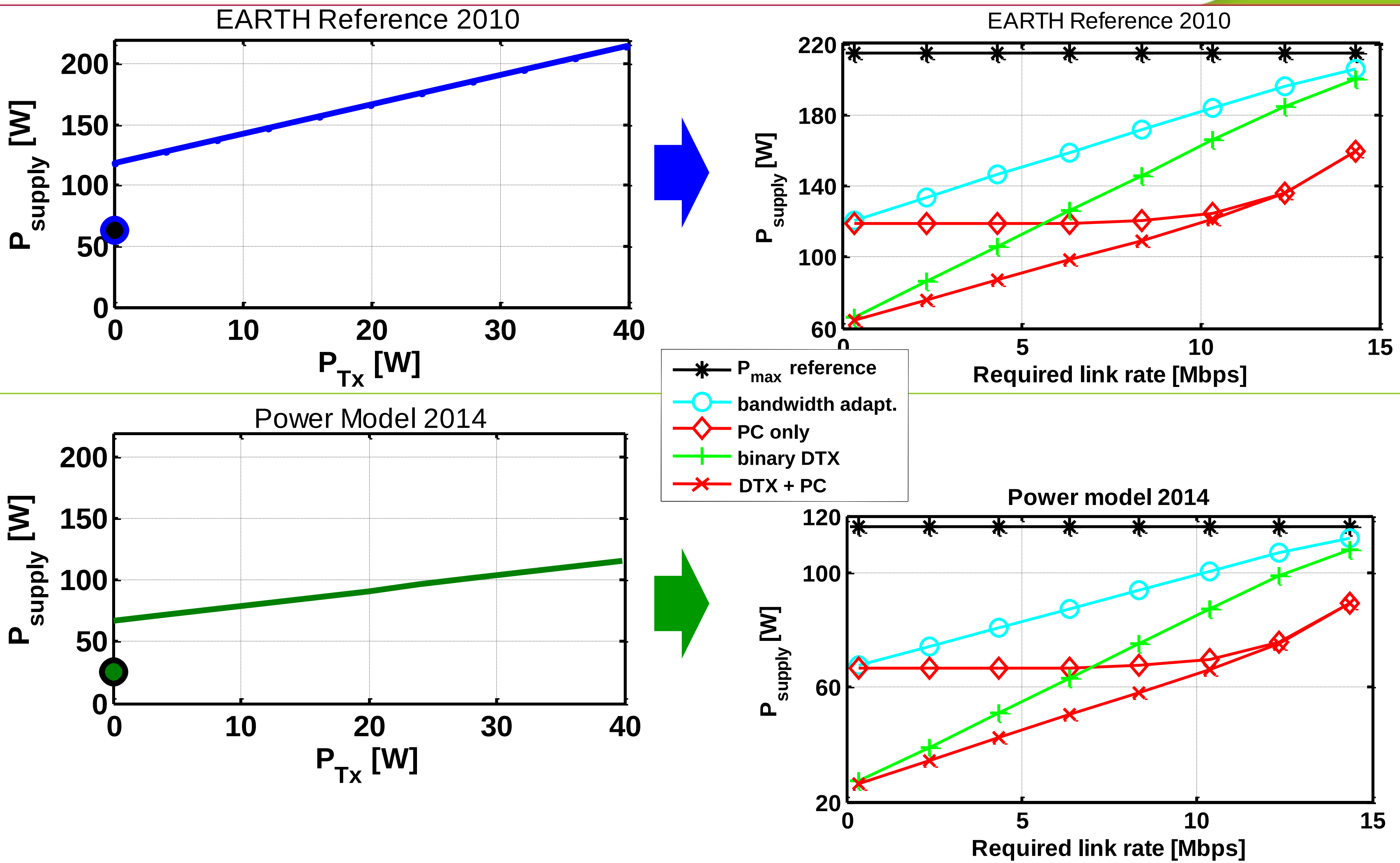

Energy Efficient Resource Allocation Results

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Low traffic loads

- Discontinuous transmission (DTx) is most efficient to save energy

High traffic loads

- Power control (PC) yields significant gains

Mid traffic loads

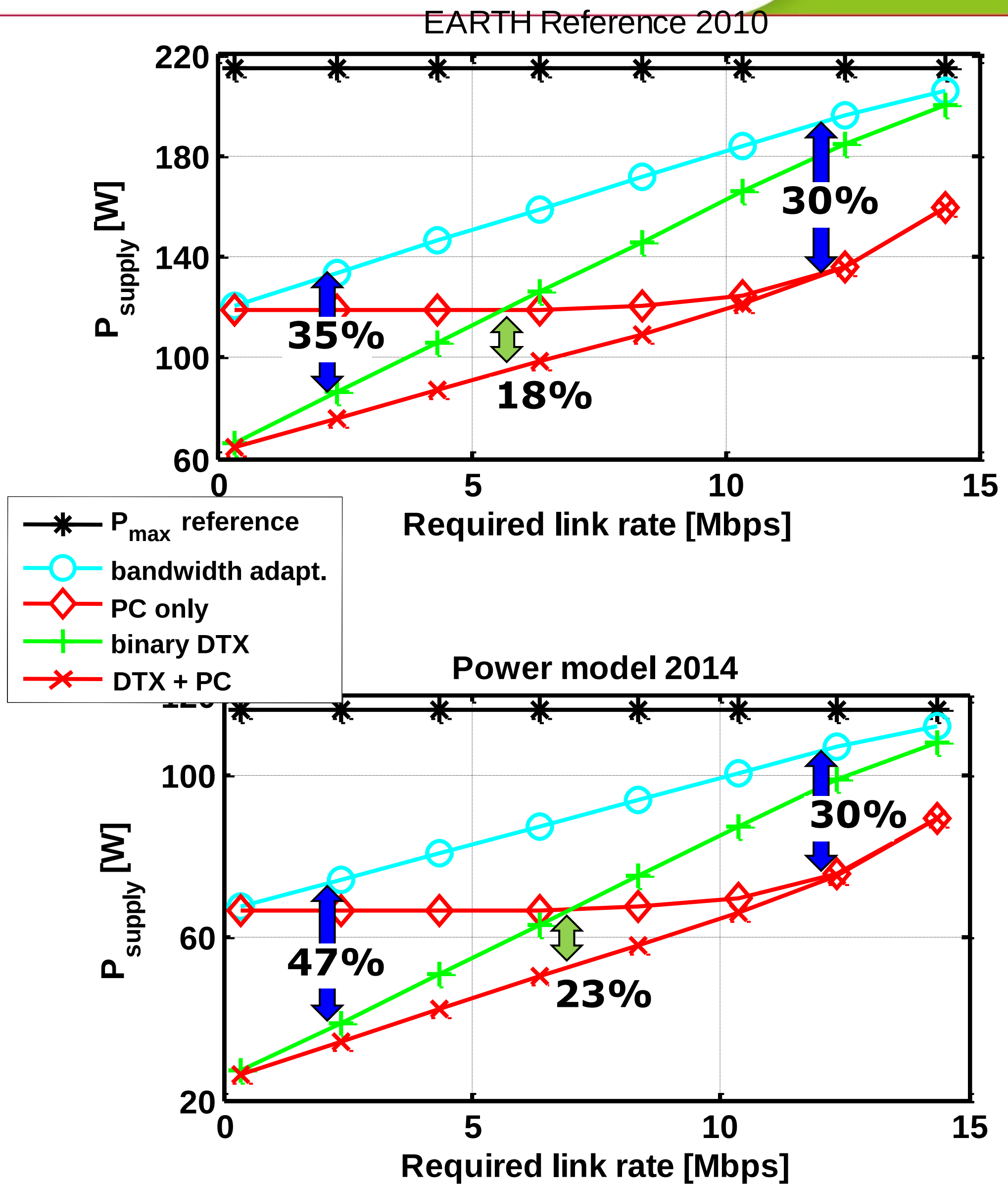
- Both DTx and PC attain comparable gains
- Cross-over point depends on used power model

➔ Combination of DTx and power control (DTx + PC) provides additional gains

➔ Compared to bandwidth adaptation (P_{supply} is scaled by amount of used resources), DTx + PC achieves significant gains (30—50%) **for all loads**

BUT, in LTE

- Gains of DTX are compromised by control signaling
- No downlink power control



- Challenges for Green Radio
  - maintain or reduce current Carbon footprint while satisfying the heavily increasing demand for mobile communication
  - high throughput for peak hour, low energy for low traffic times

- Key enablers
  - sleep modes on all time scales
  - switching of sites, RATs, antennas, etc.
  - adaptive transceiver

- Energy efficient resource allocation
  - without DTX: utilize all resources to minimize power consumption
  - with DTX: trade-off between long sleep time and high-energy transmissions
  - mixture of power control and DTX achieves lowest energy

Harmonize Social contribution beyond borders, across generations

Evolve Evolution of service and network

Advance Advance industries through convergence of service

Relate Creating joy through connections

Trust Support for safe, secure and comfortable living

HEART

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