# ComGreen: Increasing the Energy Efficiency of Heterogeneous Wireless Access Networks.

Workshop der ITG Fachgruppe 5.2.4 „Green IT in wireless access networks“ am 29.11.2012.

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Life’s for Sharing

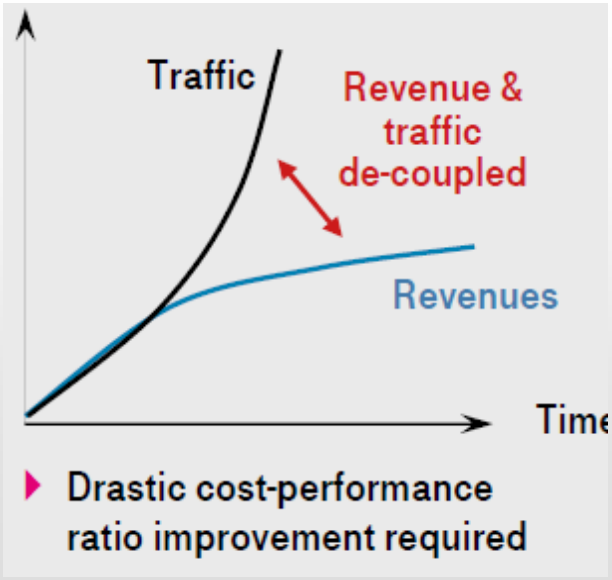
# Agenda.

- Motivation
- Load adaptive network operation to save energy
- Evaluation framework and results
- Conclusions

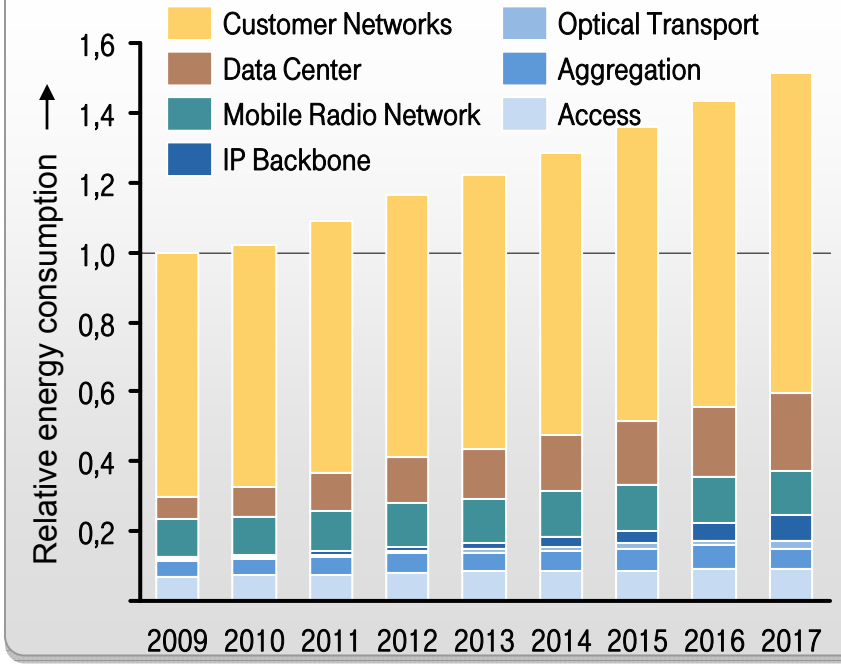
# Motivation.

# Energy consumption of telecommunication networks.
# Traffic demand increase and energy consumption forecast.

## Global IP traffic forecast




## Network's energy consumption, business as usual




**Increasing energy efficiency is one way making the network production more efficient.**

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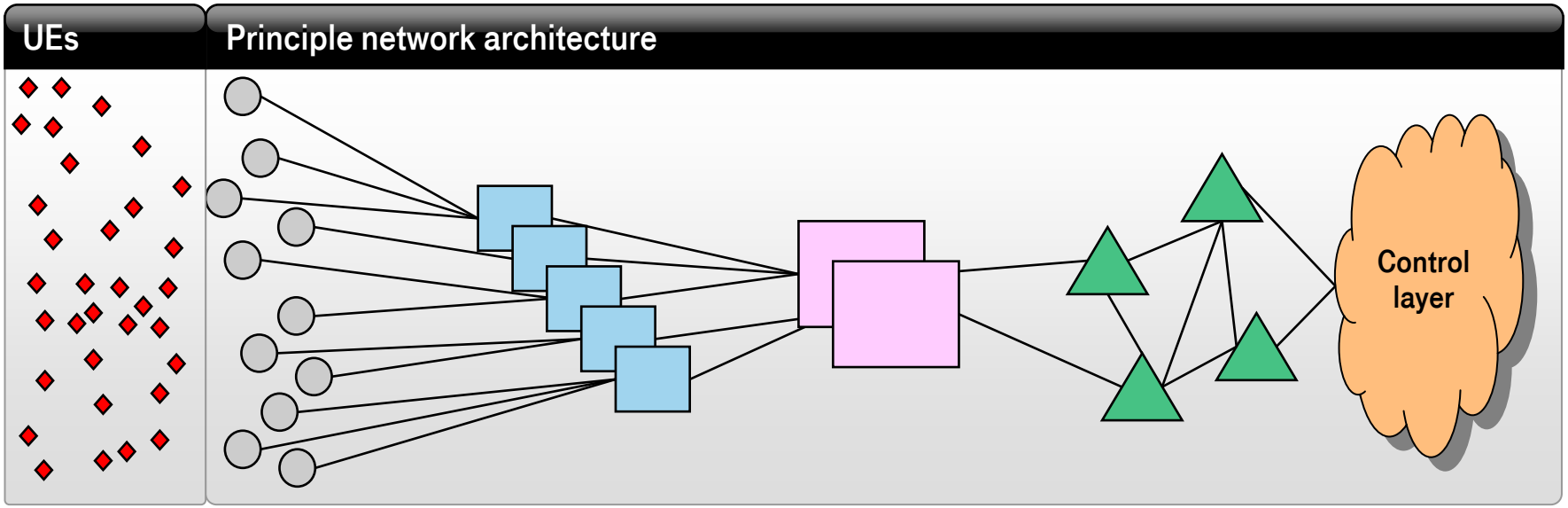
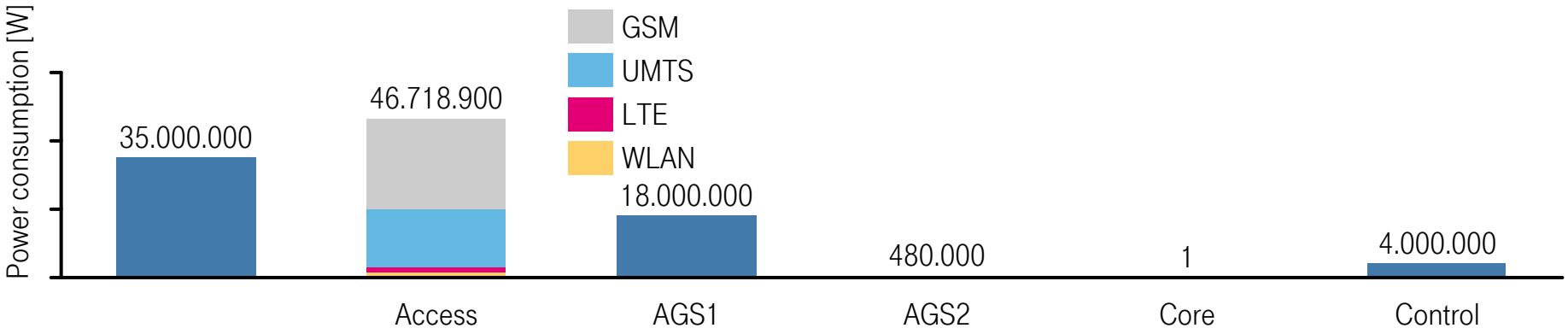
# Cellular network architecture.
# Most of the energy is consumed in the wireless access network.

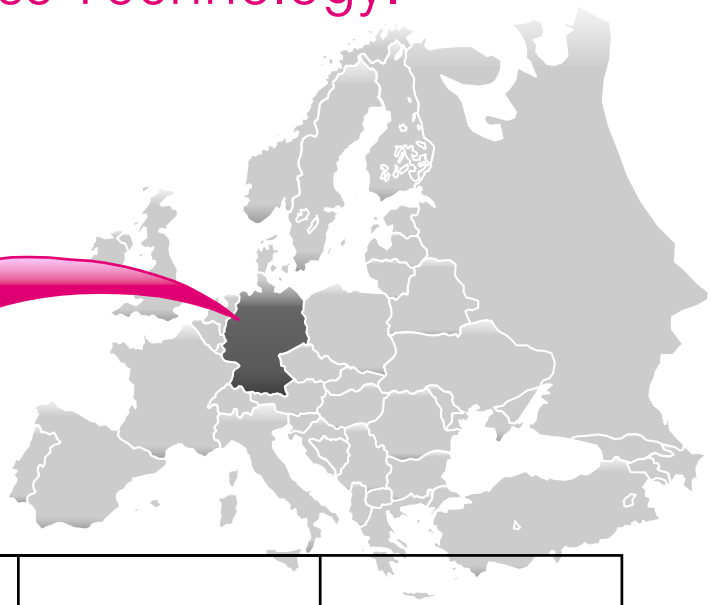


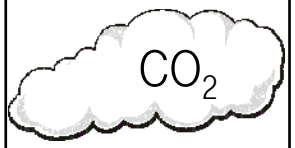
# on for energy optimisation in Radio Access Technology.
# consumption of Base Stations.

- In Germany Deutsche Telekom operates...
  - ...20.000 GSM base stations (av. power consumption: 1.200W)
  - ...10.000 UMTS base stations (av. power consumption: 1.000W)
  - ...2.200 LTE base stations ((av. power consumption: 800W)
  - ...11.000 HotSpots (av. Power consumption per site: 140W)

→ Total energy consumption: 410 GWh p.a.

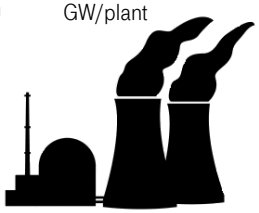


**CO2 emission**
- 178.000 tons
  - Assuming 0.59 kg/kWh




**CO2 binding**
- 28.000 trees
  - Assuming 6412 kg/tree

**Power plant**
- 5%
  - Assuming 1.5 GW/plant



**Solar power**
- 4,5 Million $m^2$
  - Assuming 10,52 $W/m^2$

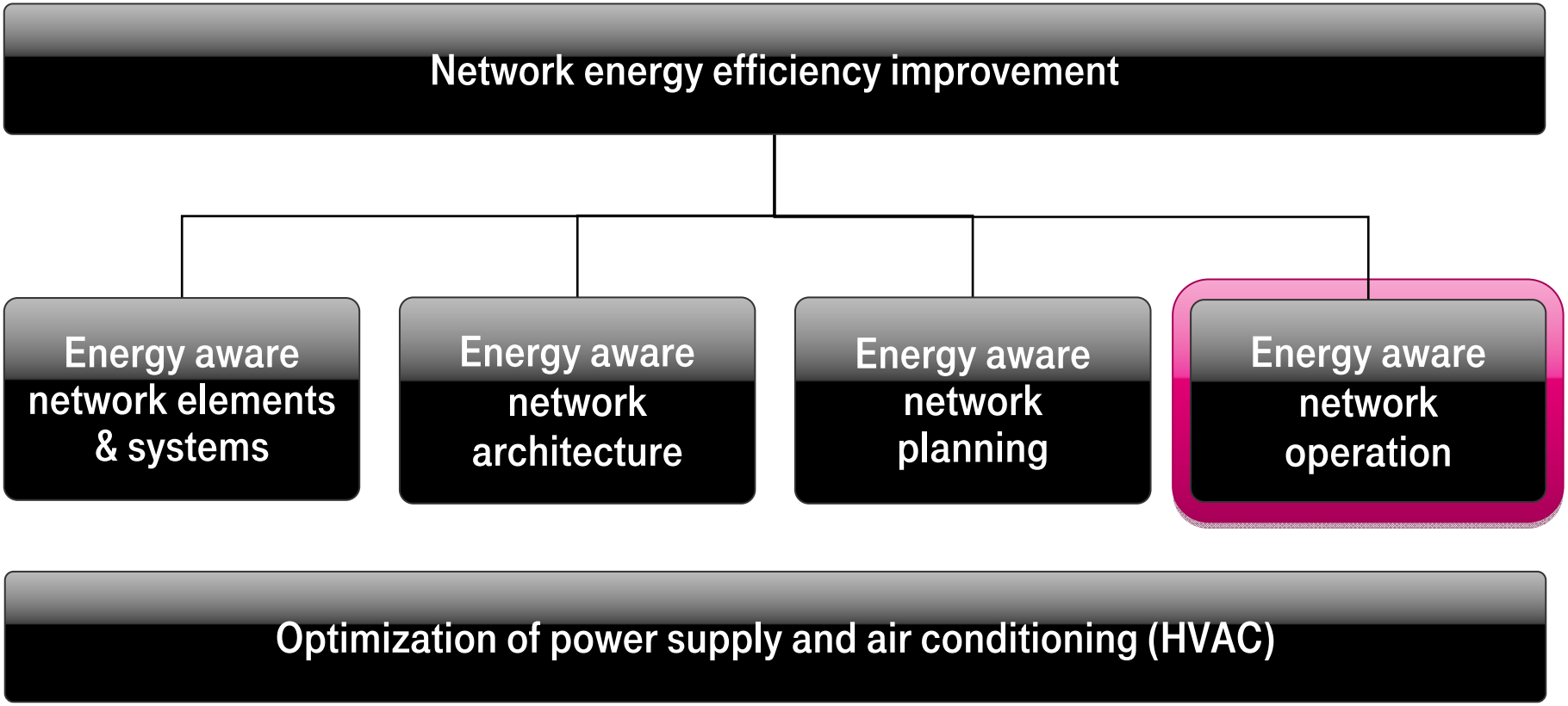
**Wind power**
- 37 sites
  - Assuming 1.25 MW/site

**Costs**
- ≈ 41 Million €
  - Assuming 0.1€/KWh

**High potential for energy optimisation**

Load adaptive network operation to save energy.

# Opportunities for reduction of the network's energy consumption. Classification of options.

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# Energy aware operation.


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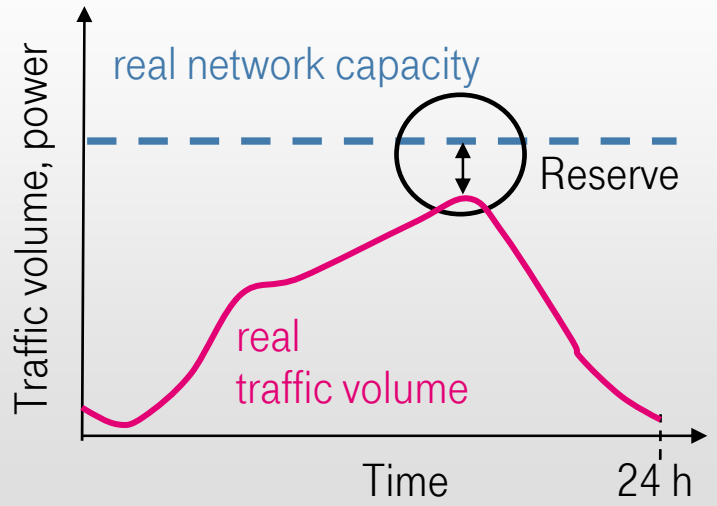
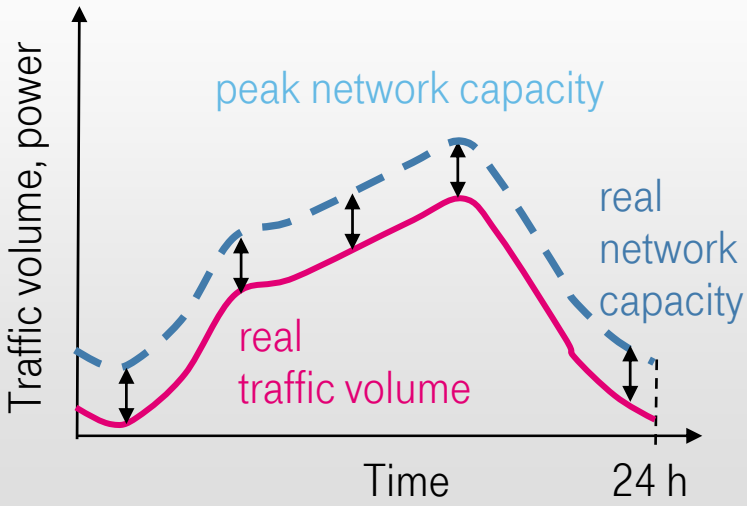
# Opportunities for reduction of network's energy consumption. T-Labs proposal: Load adaptive network operation.

**Conventional network operation**




**Peak network capacity determines the network's power consumption.**

**Load-adaptive network operation**




**Actual traffic load determines the network's power consumption.**

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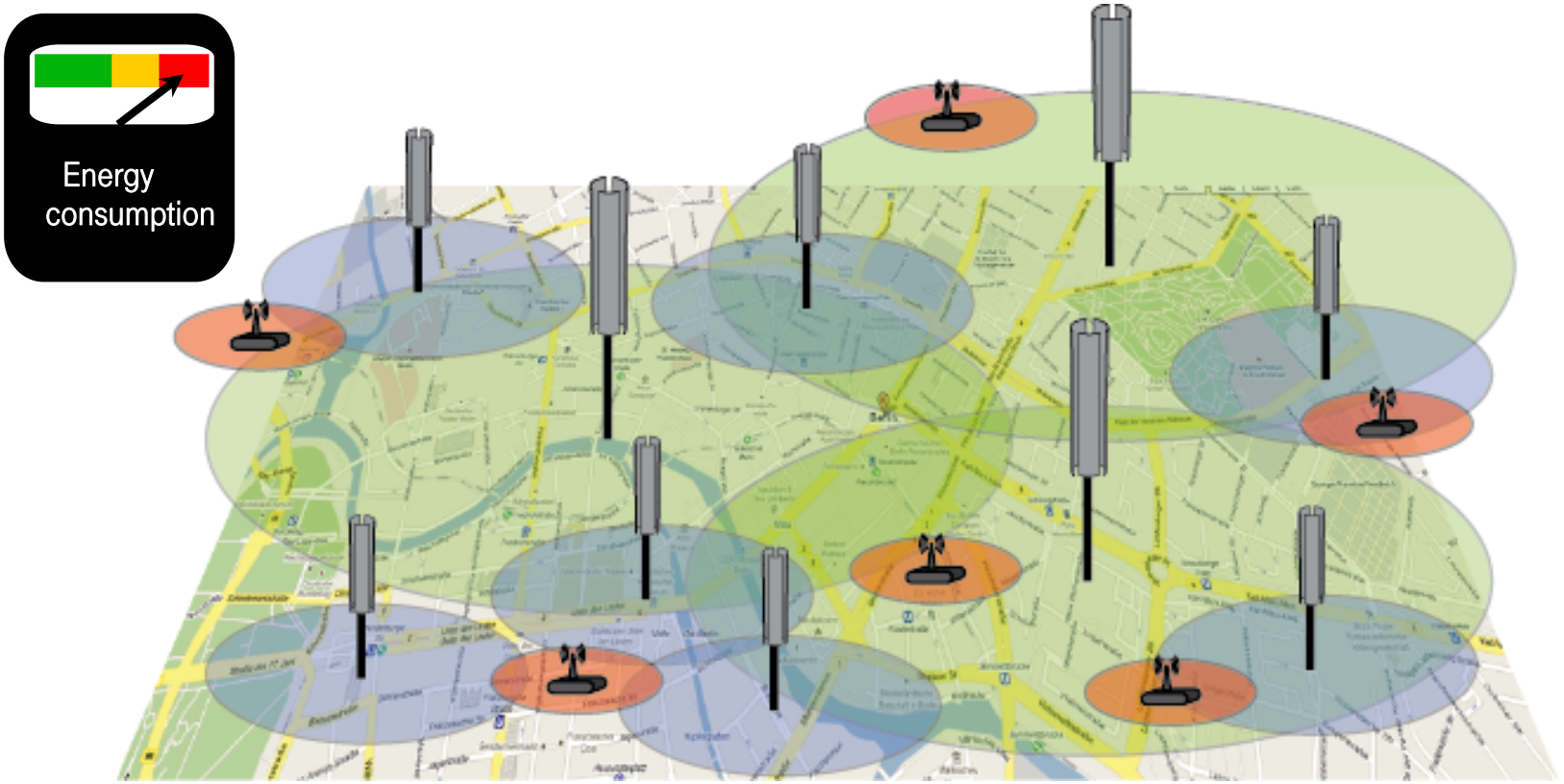
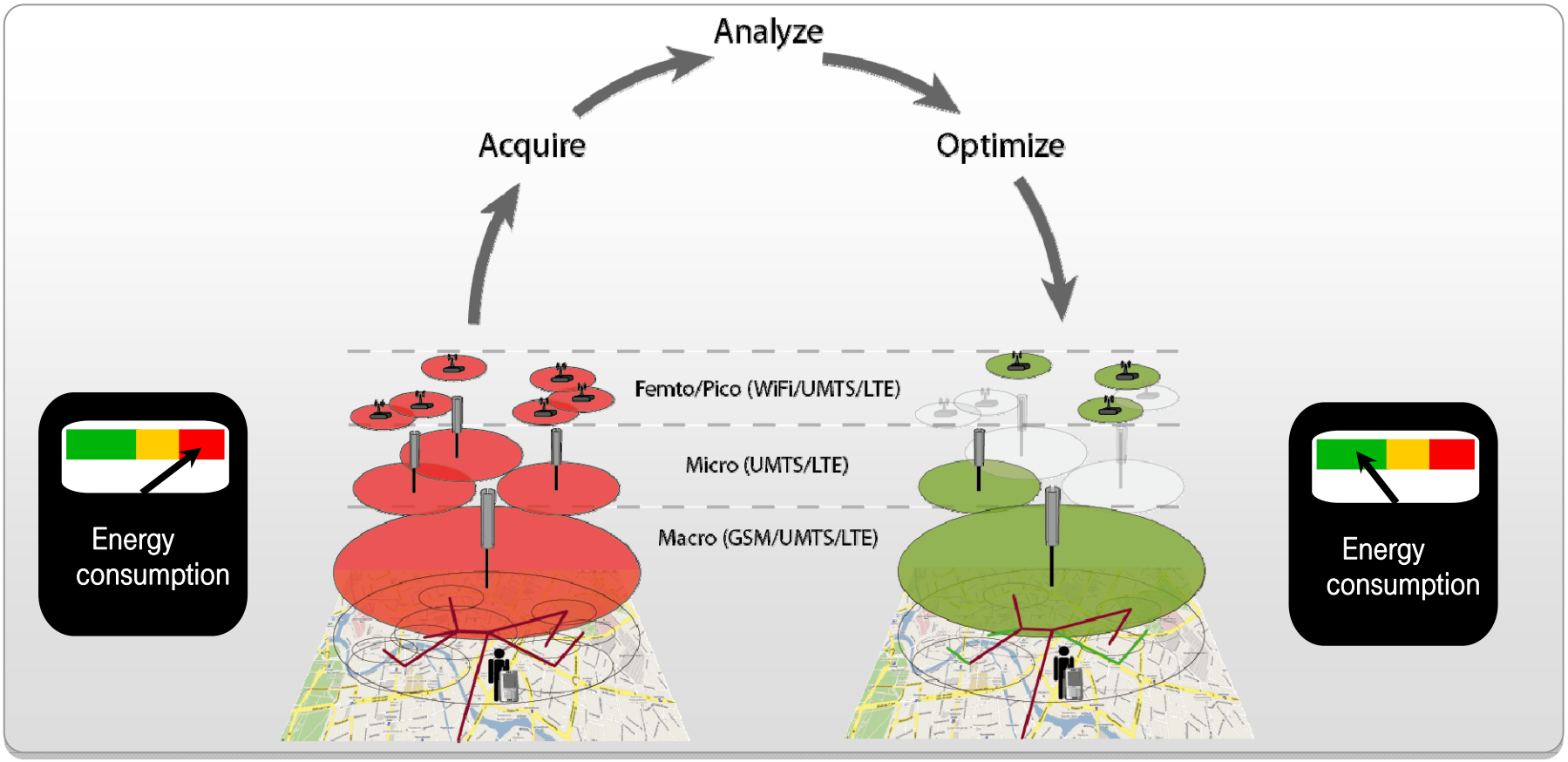
# Energy-efficient optimisation of Multi-RAT (Radio Access Technology) networks – available network topology.



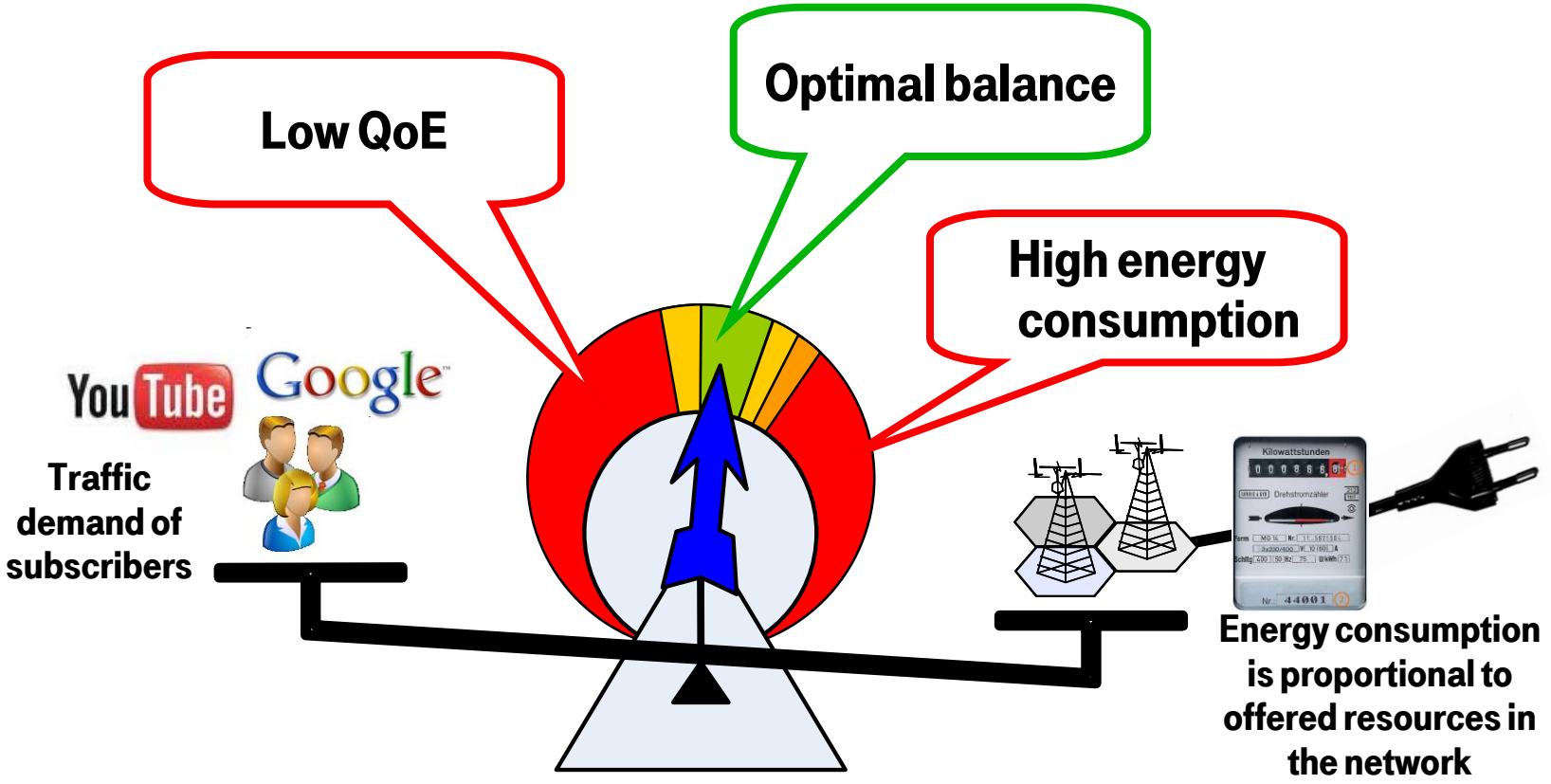

**Currently networks are designed for peak traffic demands.**
**Energy-consumption of multi layered networks is high.**

# Radio Access Networks (RANs).
# ComGreen: Load-adaptive network operation with QoE awareness.




**Expected energy savings of 20-30% in the RAN.**

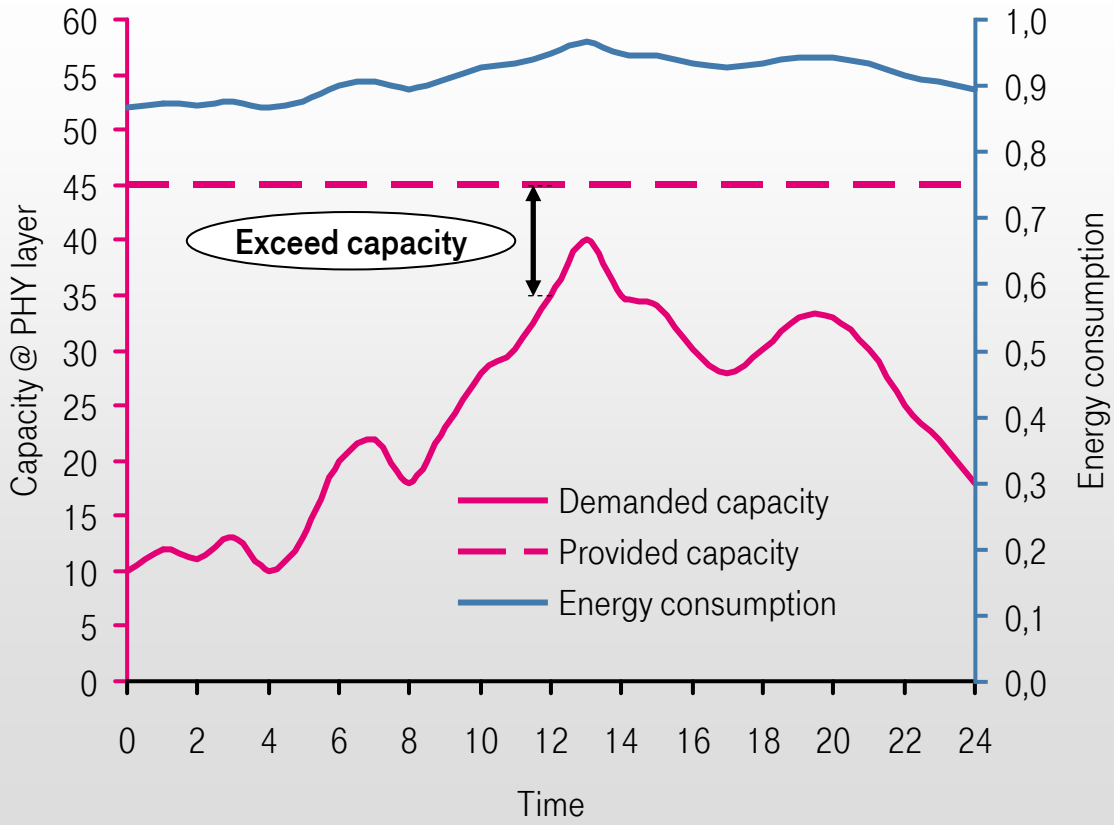
# Overarching goal of iAccess 2.5.
# Reduce energy-consumption in networks with the same user QoE.




**Project goal: develop a system enabling optimal tradeoff between provided Quality-of-Experience (QoE) and energy consumption.**

# Optimisation approaches.
# Reducing exceed capacity to reduce energy consumption.

**Capacity vs. time of day**

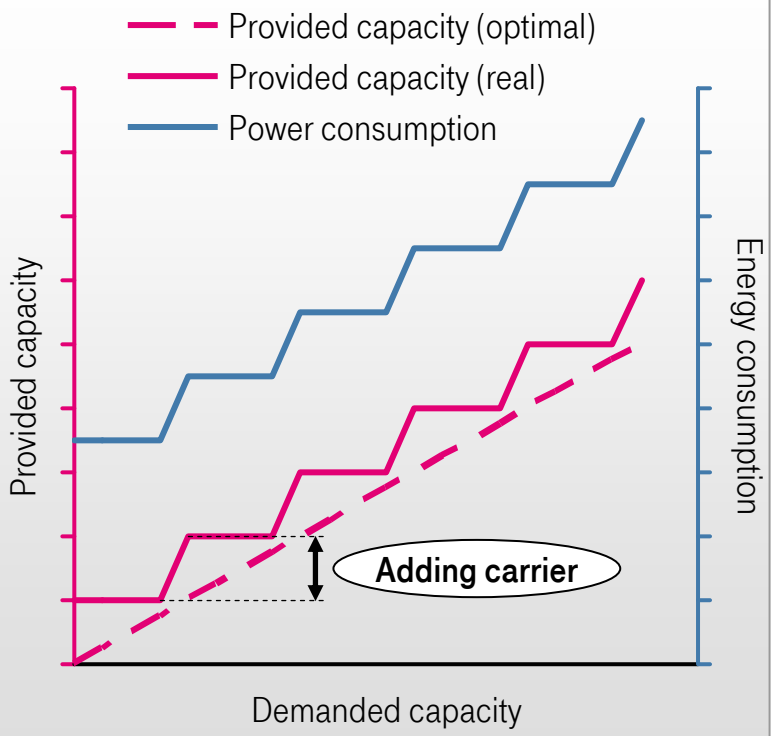



- Categories
  - Switching on/off hardware components (Category A)
    - E.g. carriers, sectors, base stations
    - Goal: Decreasing provided capacity
  - Trading SINR for energy (Category B)
    - E.g. TX-power modifications
    - Goal: Decreasing provided capacity and increasing capacity demand

# Optimisation approaches.
# Category A mechanisms.

## Switching on/off hardware components

- Normally each BS has three sectors
  - With multiple carriers per sector
- According to the power model used each carrier consumes energy
  - → Switching on/off carriers based on capacity demand improves energy consumption
  - → Granularity is low, e.g. +/- 200 kHz for a GSM carrier



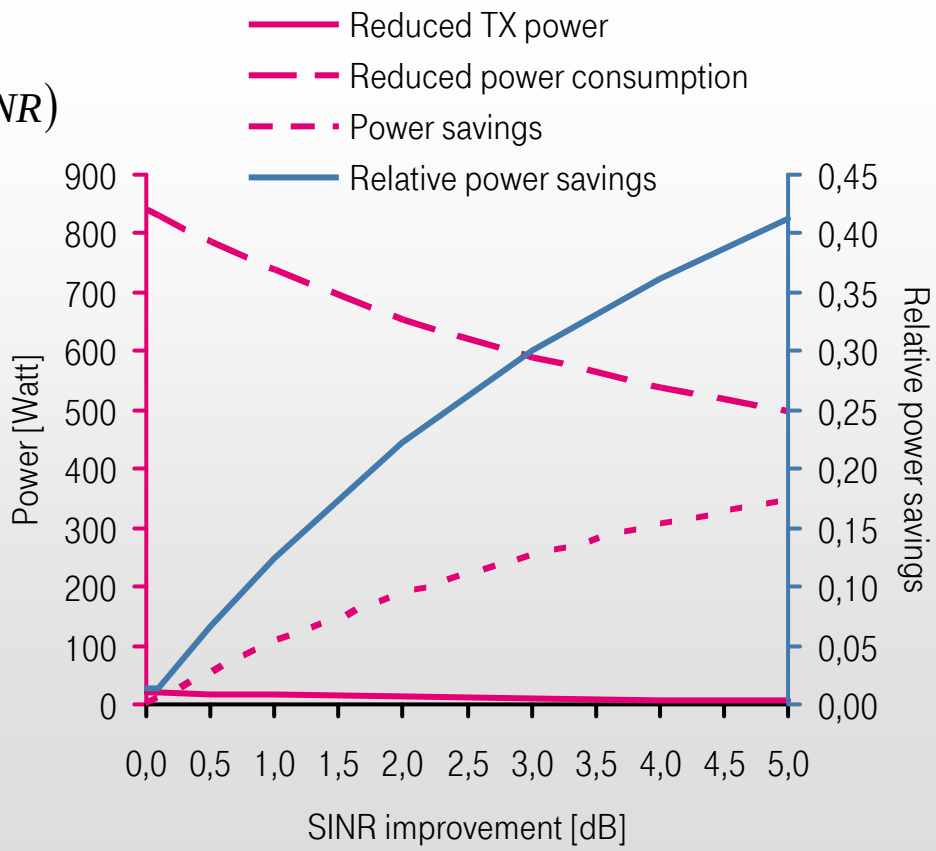
# Optimisation approaches.
# Category B mechanisms.

## Trading SINR for energy

- Based on the Shannon capacity formula:

$$R = B * \log_2\left(1 + \frac{P}{B * N_0 + I}\right) = B * \log_2(1 + SINR)$$

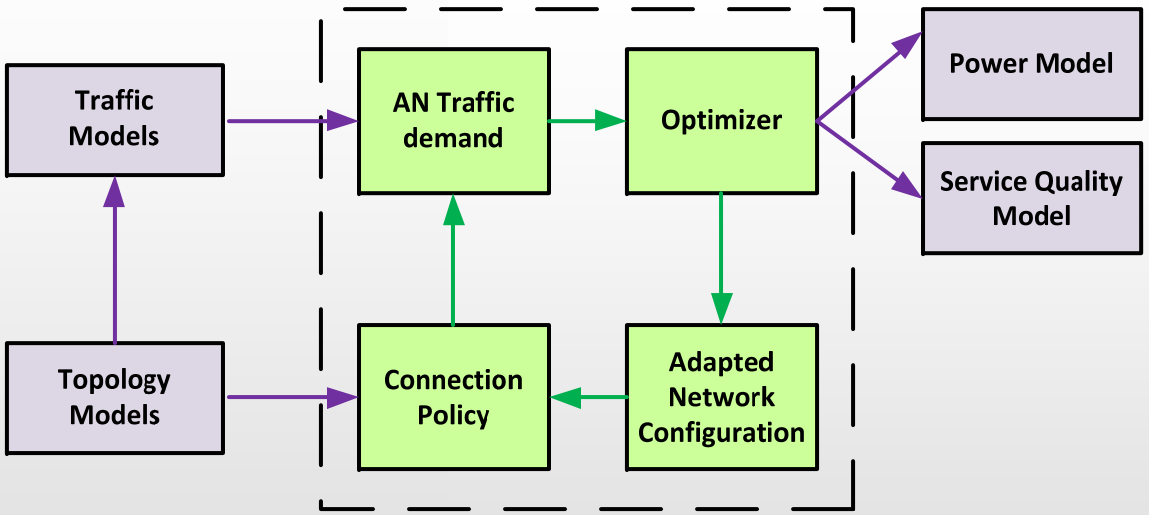
- Two approaches
  - (1) Keeping R constant
    - All mechanisms improving SINR can also be used to reduce energy consumption
    - Keeping R constant by reducing P
  - (2) Reducing R - bandwidth expansion mode (BEM)
    - In case resources are not fully utilised P can be reduced in order to increase R
    - As R is logarithmic in P energy can be saved



Evaluation framework and results.

# Simulation environment.

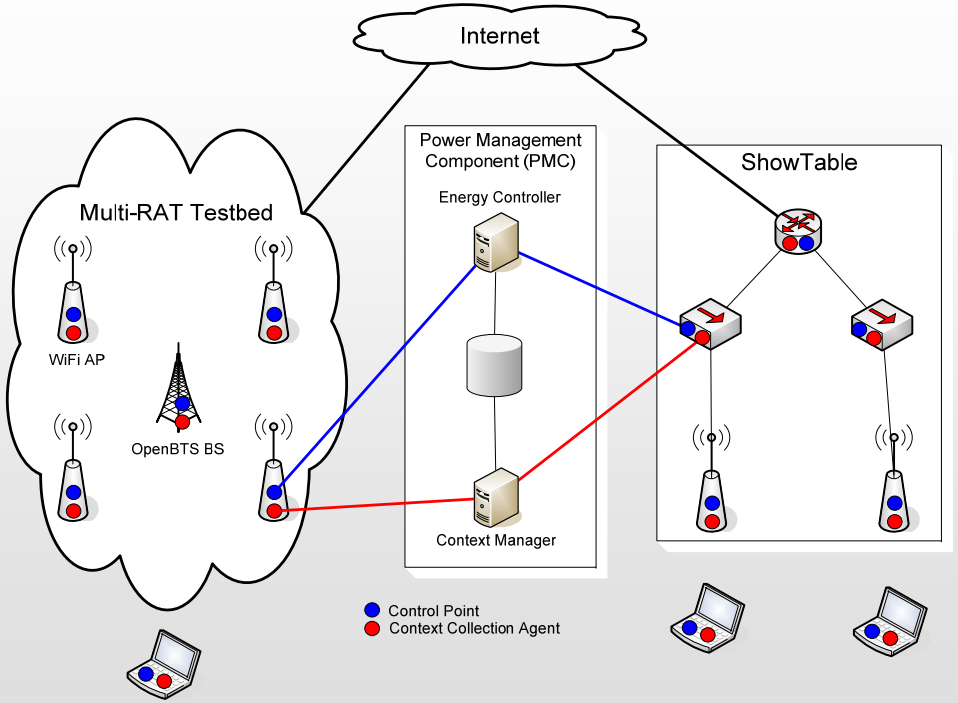
**System level simulator to investigate energy efficiency in heterogeneous multi RAT networks**



# Testbeds environment.
# MultiRAT testbed to investigate heterogeneous access networks.

## Multi-RAT Testbed approach

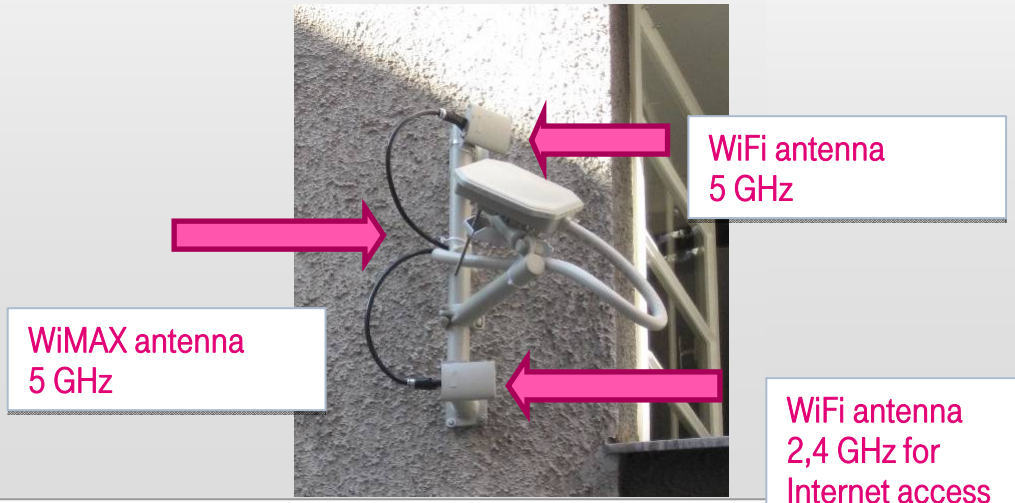
- Multi-RAT Testbed
  - Field-trials, performance measurements and demos
- ShowTable
  - Mobile demos to highlight the key ideas of the project → demo to come later
- Power Management Component as the core of the testbed
  - Context Manager
  - Energy Controller
  - Control Point
  - Context Collection Agent

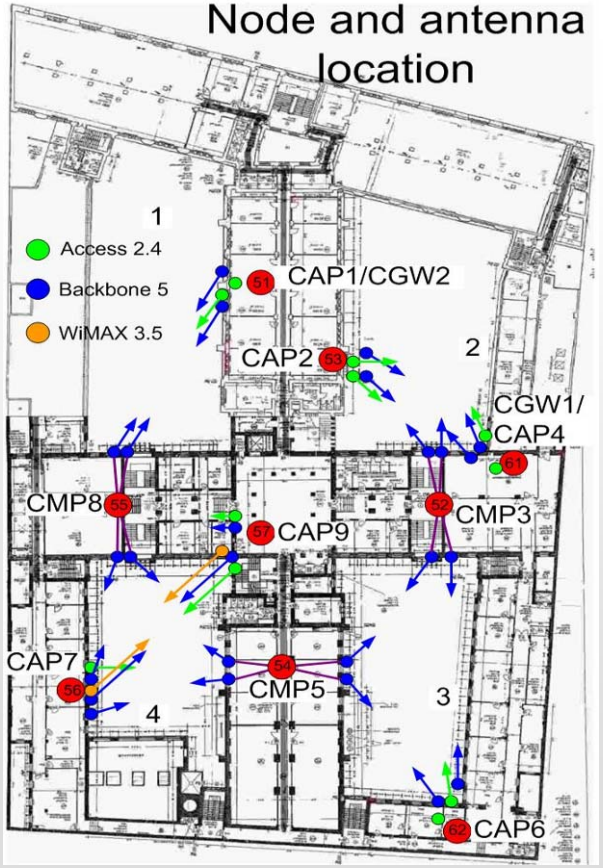


# Testbed environment.
# MultiRAT testbed to investigate heterogeneous access networks.

**Mixture of different access technologies deployed indoors and outdoors**

- Testbed comprises 9/30 outdoor/indoor
  - max. 4 WLAN Interfaces (802.11a/b/g/n)
- WiMAX base station and CPE
- 2G and 4G base station – in preparation
- OpenEPC as control layer
- Electronic power controller for each node

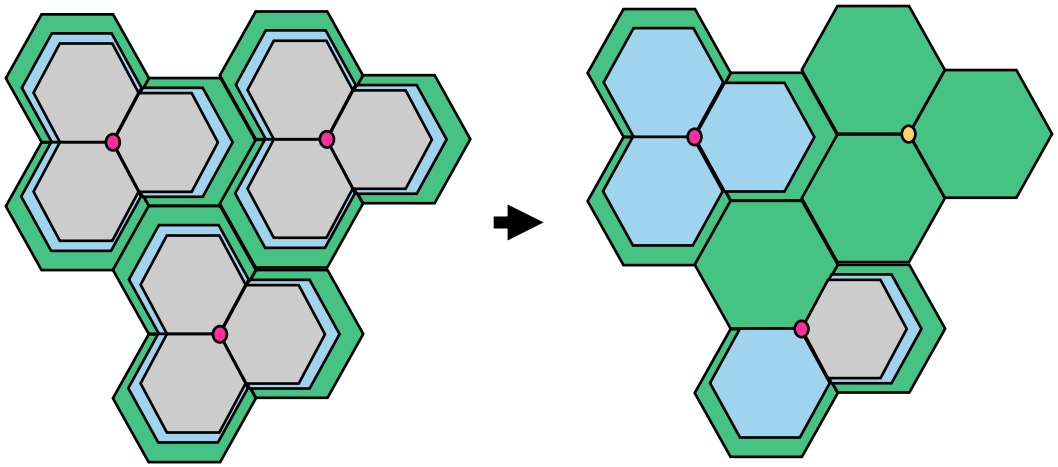


# Macro cell sleep mode.

## Approach

- Based on the capacity demand single BS are re-configured, e.g. parts of the BS are switched on/off
- Switching on/off ...
  - ...carriers → local decision
  - ...sectors → per site / global decision
  - ...BSs → per site / global decision

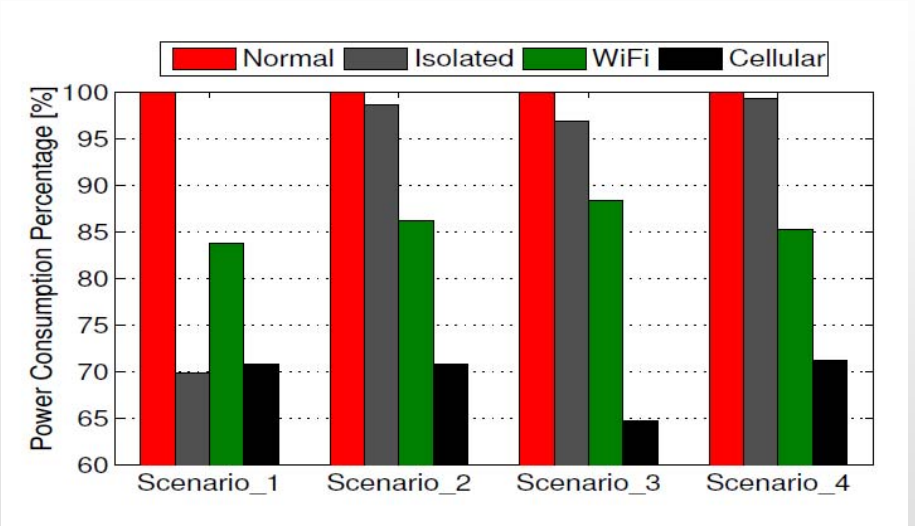


# MORFEO - Energy Optimizer Algorithm @ Multi-RAT testbed. Testbed results.

## Scenarios

- Four different scenarios under investigation
  - Scenario 1: The network is working without users
  - Scenario 2: The network is working with users without traffic
  - Scenario 3: The network is working with users and UDP traffic
  - Scenario 4: The network is working with users and TCP traffic

## Results

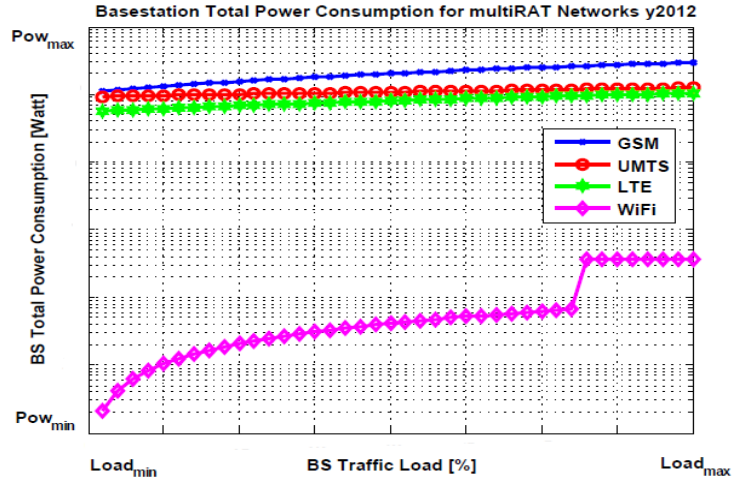


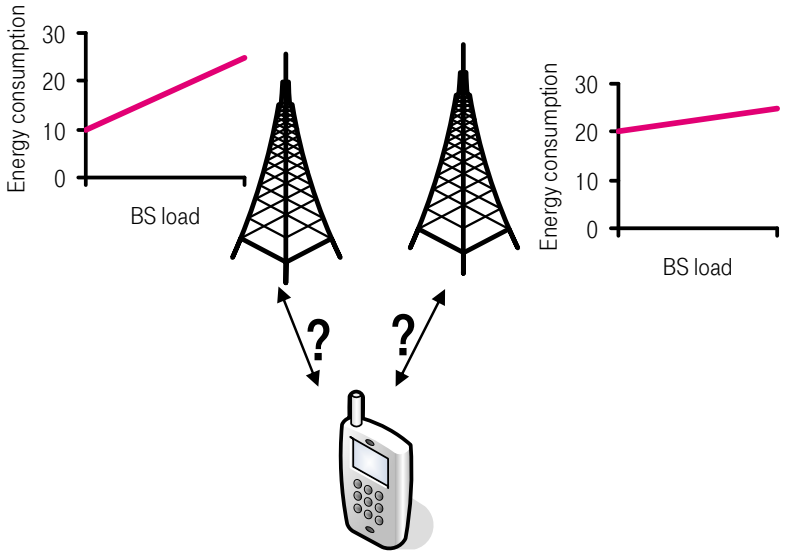

**Proof of concept and proof of simulation results.**

# Energy efficient connectivity management.

## Approach

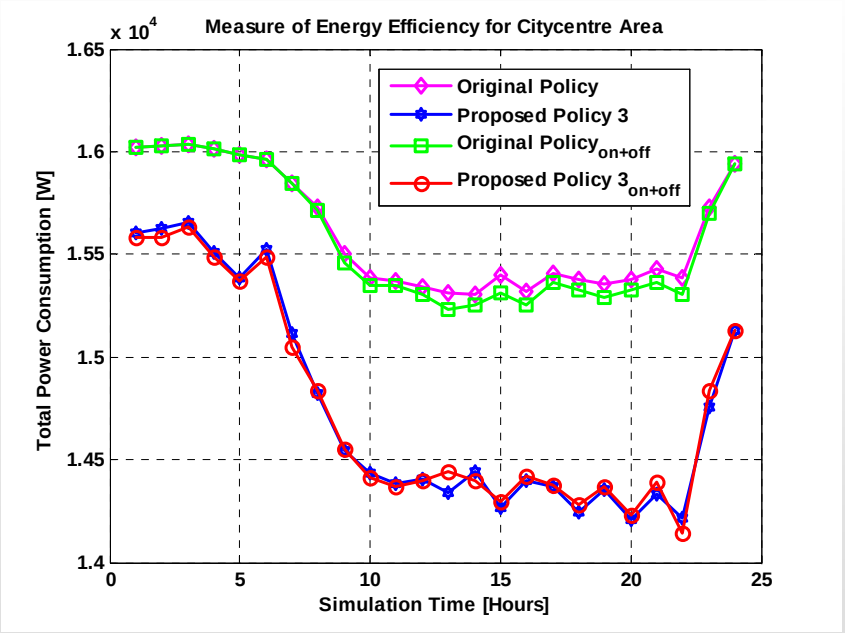
- Energy efficient connection policy
  - Single-RAT environments
    - Different HW ages and power models
    - Different BS types (macro, micro, etc.) with different power models
  - Multi-RAT environments
    - Different technologies with different power models
  - Requires load balancing mechanisms

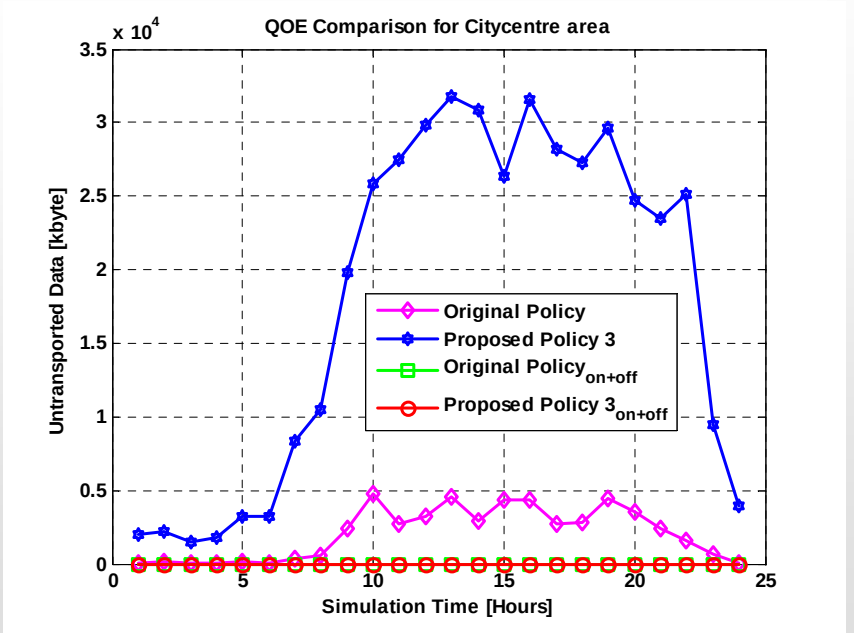


# Energy efficient connectivity management.
# Simulation results.

## Energy consumption and QoE for the city-centre scenario



# Example simulation results.
# Summary.

**asdfsdsdf**

| | High demand | City centre | Suburban | Rural | GER |
|---|---|---|---|---|---|
| Connectivity management | 7% | 5% | 6% | 9% | 8% |
| Macro cell sleep mode | 46% | 38% | 43% | 9% | 27% |
| Bandwidth expansion mode | ? | ? | ? | ? | ? |

# Conclusions.

# Conclusions.

**Load adaptive network operation to improve energy efficiency of wireless access networks**

- Bandwidth requirements are increasing while revenues are decreasing
  - → Network production needs to become more efficient
  - → Increased energy cost strengthens the problem
- Load-adaptive network operation is one way to improve to reduce energy consumption
  - Several mechanisms have been developed
  - Performance as been investigated in simulator and testbed
  - Overall savings from 20 to 35%

# Thank you for your attention.

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