Dynamic Bandwidth Management for Energy Savings in Wireless Base Stations

Ulrich Barth
Anton Ambrosy, Michael Wilhelm, Wieslawa Wajda, Oliver Blume

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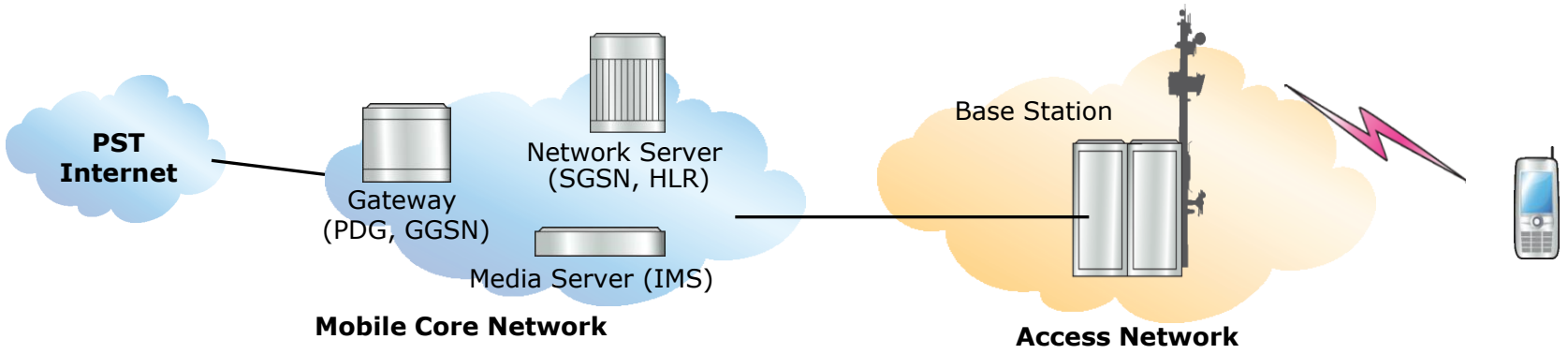
Alcatel·Lucent

EC FP7 project EARTH



Energy Consumption

(CO_2-contribution)

10-20%

70-80%

2-10%

reduce
by 50%

Green Networks

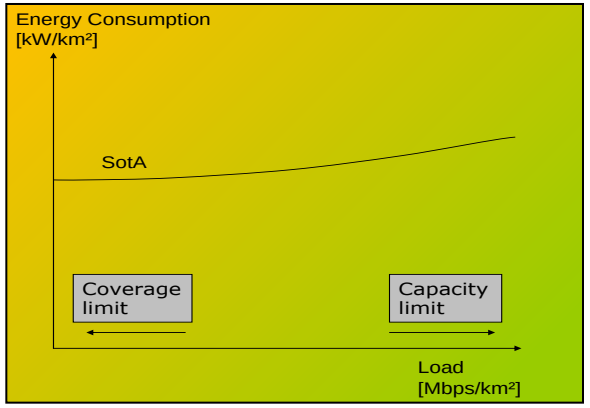
Green Radio

earth
Energy Aware Radio and neTwork tecHnologies

Focus on present and future mobile cellular networks (LTE-A,…)

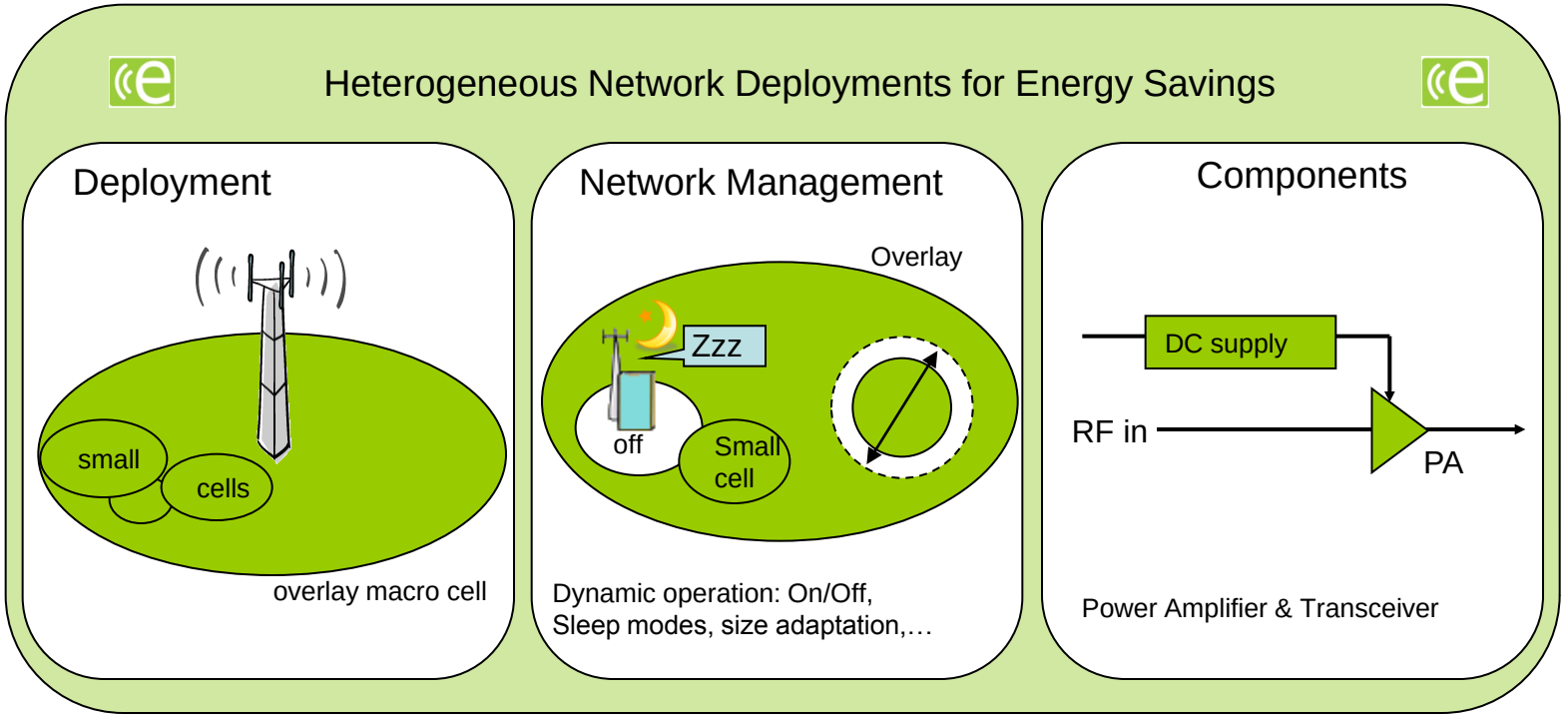
Green Wireless Network

"Power follows load"



Improving Load Dependence of BS Power Consumption

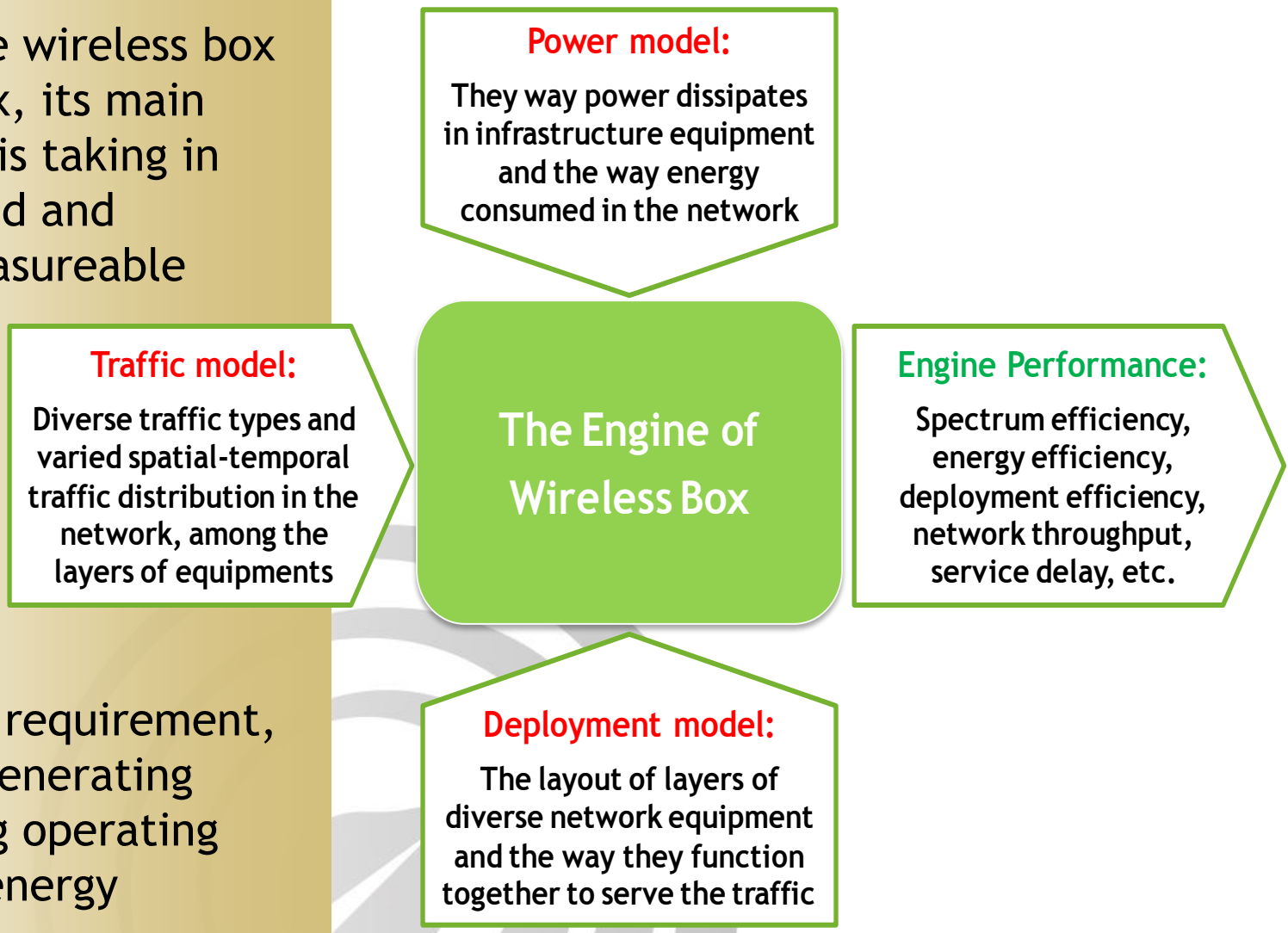
- Integrated solution of TRX hardware and RRM
- Combination with other hardware improvements
- System level simulation of energy saving



The Wireless Box

- If we take the wireless box as a black box, its main functionality is taking in traffic demand and providing measureable performance

to satisfy the requirement, meanwhile, generating corresponding operating cost such as energy consumption.

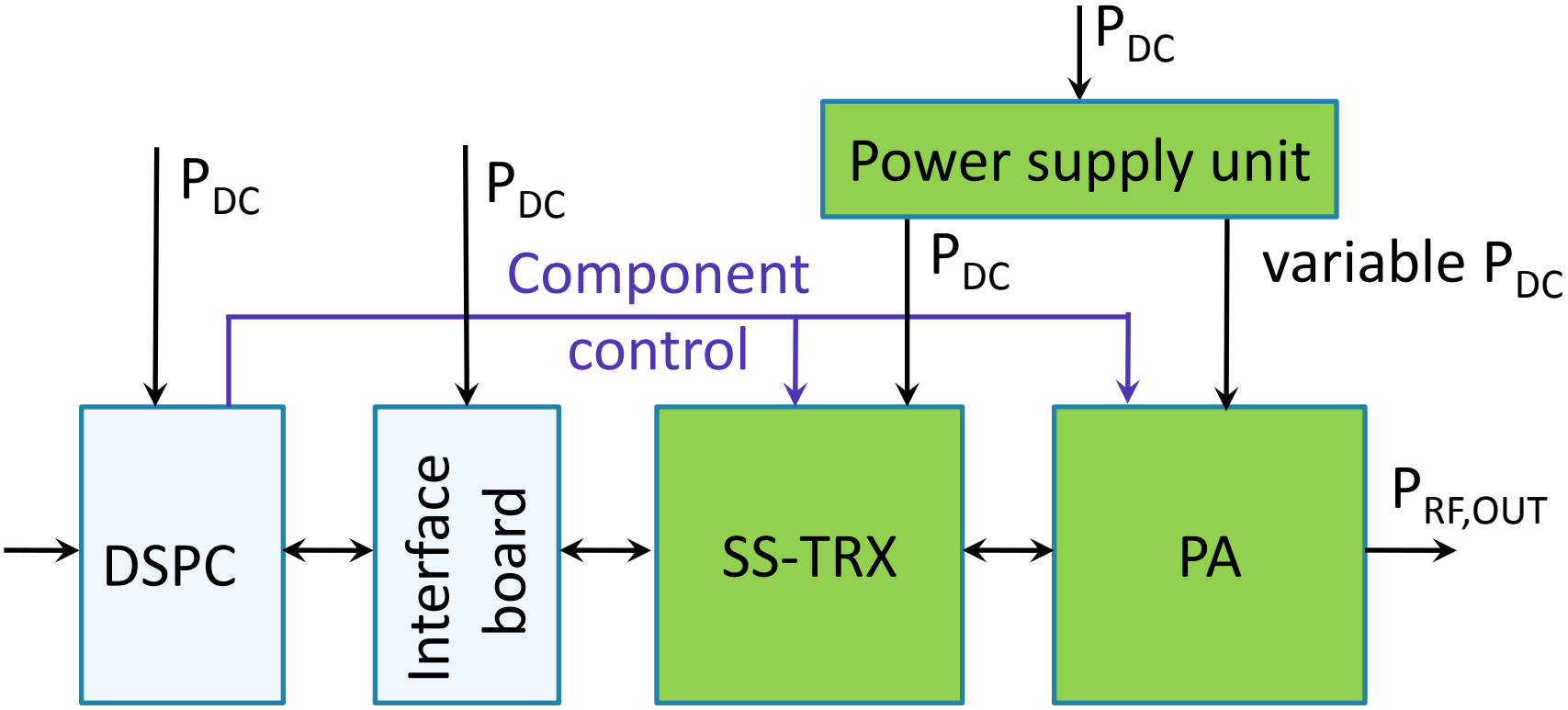


Adaptive Transceiver for Macro-Cell BS

Energy Adaptive Power Amplifier

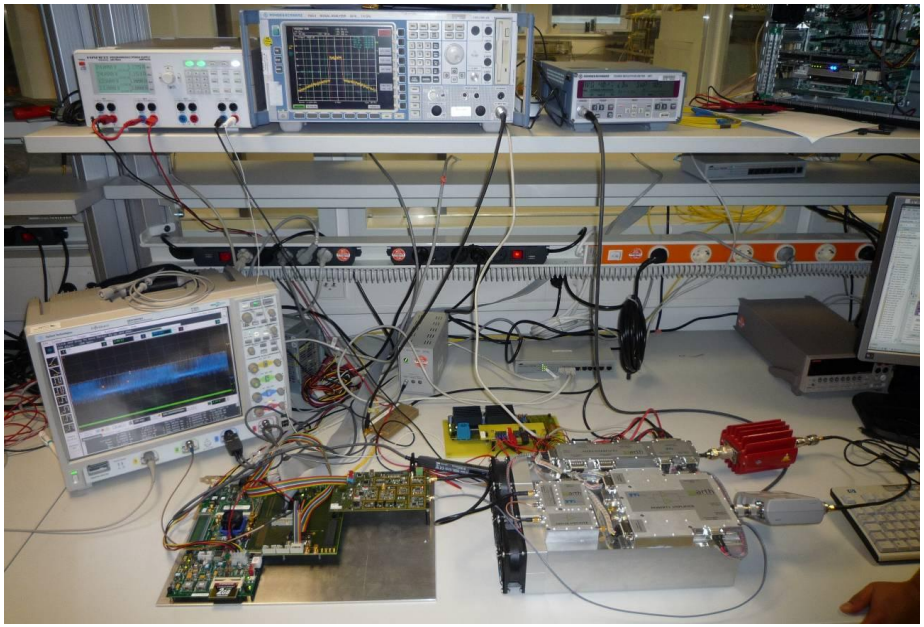
Features for enabling EE solutions

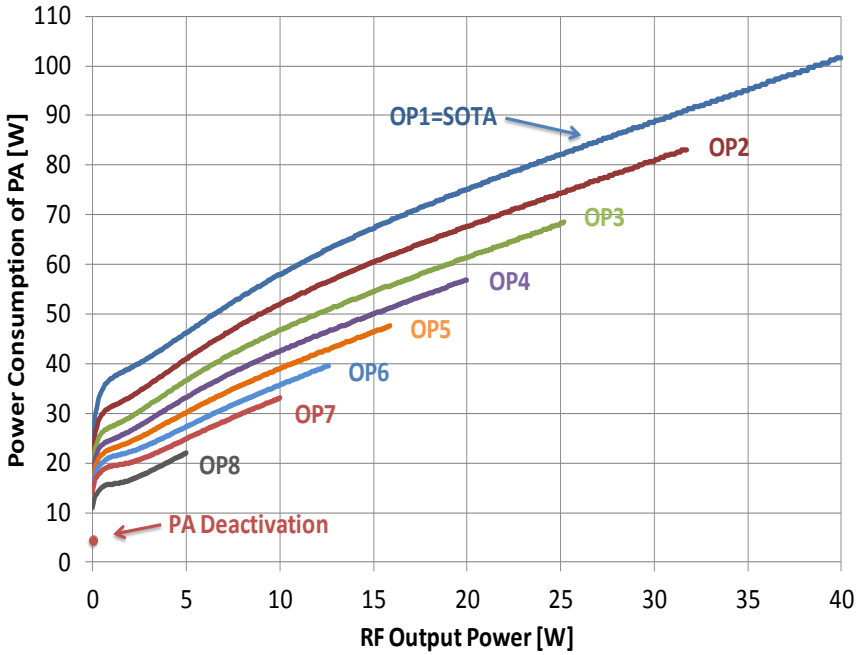
- Operating point adjustment (OPA)
- Component deactivation (CD)



Adaptive Macro TRX Hardware Prototype

Measurement results of power modes

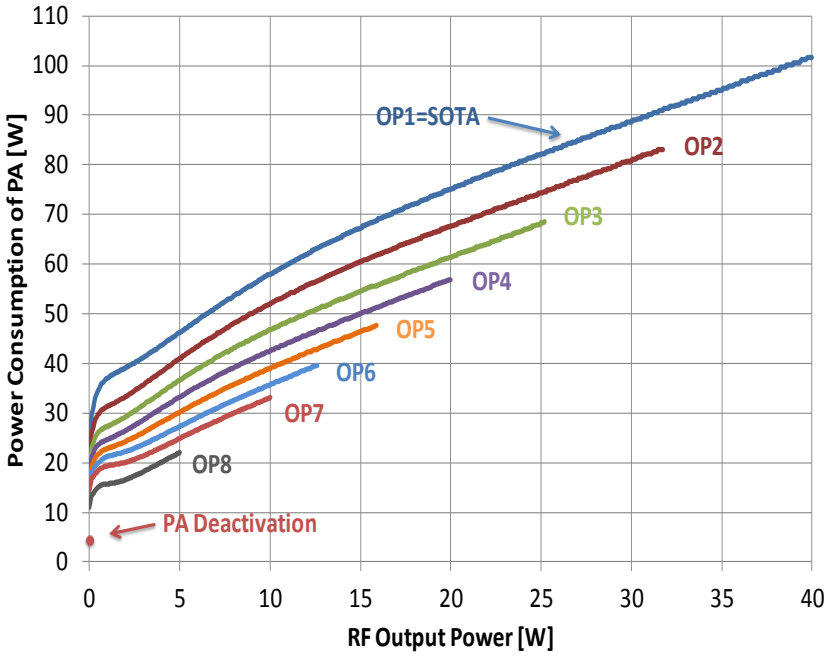


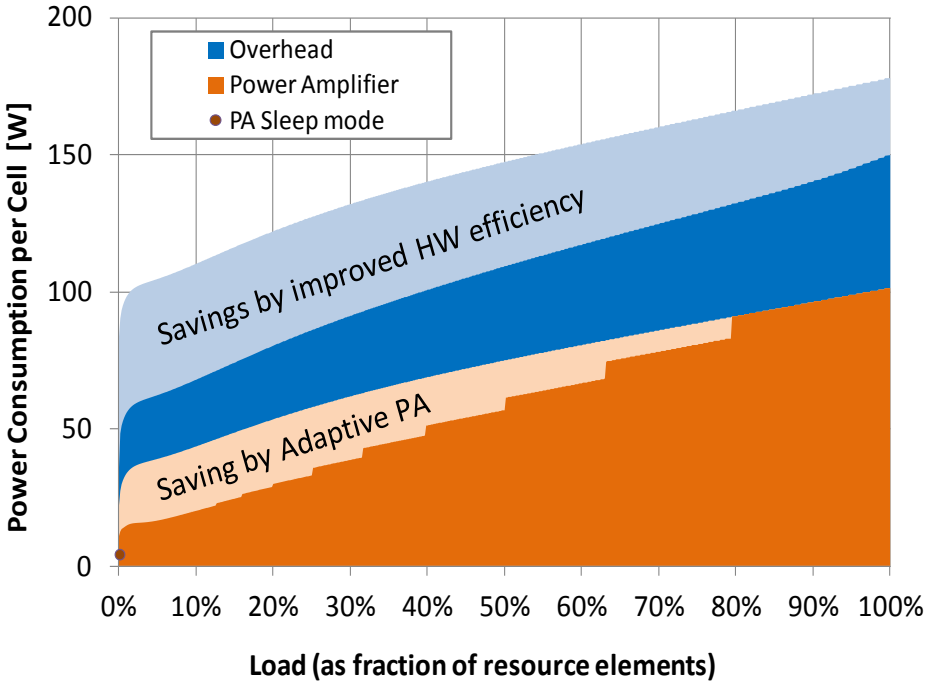


- Proof-of-concept for energy saving by adaptive
  - operation point (OP) adjustment and
  - component deactivation (CD) on OFDM symbol level

Power Amplifier improvements

Realising saving potentials at low load



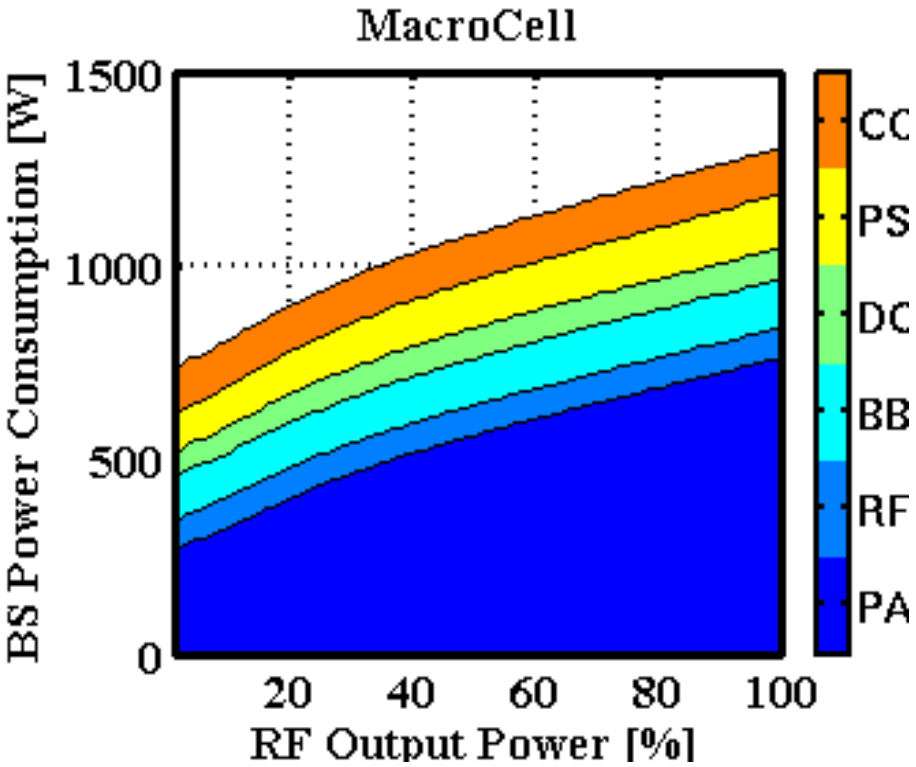


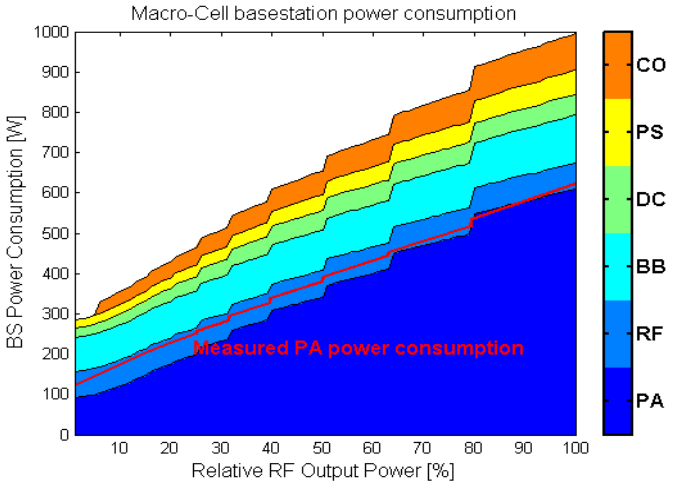
Adaptive TRX (EARTH project)

→ Multiple operational states of the power amplifier (changing bias voltage)
→ Fast Sleep mode on OFDM symbol granularity
→ Complemented by adaptive BB processing, cooling,…

Power Amplifier improvements

SotA and EARTH power model





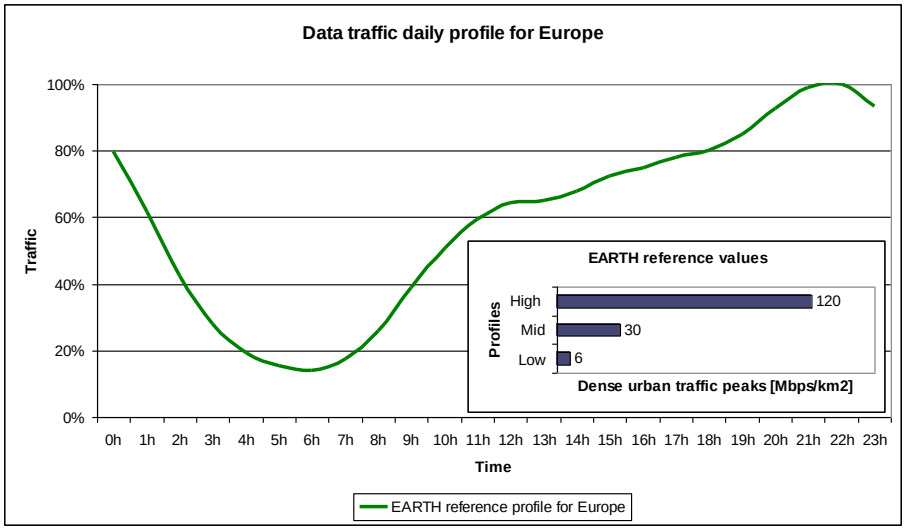
Resulting EARTH Macro BS power model

→ Still significant offset power consumption

→ **Resource Management** has to leverage the adaptive hardware

Daily traffic profile

Deployment area	High traffic profile
Dense urban	120 Mbps/km^2
Urban	40 Mbps/km^2
Suburban	20 Mbps/km^2
Rural	4 Mbps/km^2



- Busy Hour Traffic demand from user density and monthly rate
- Note : this is already on the high end!

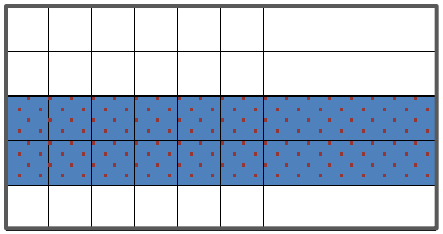
  Latest EARTH D2.3 scenarios:

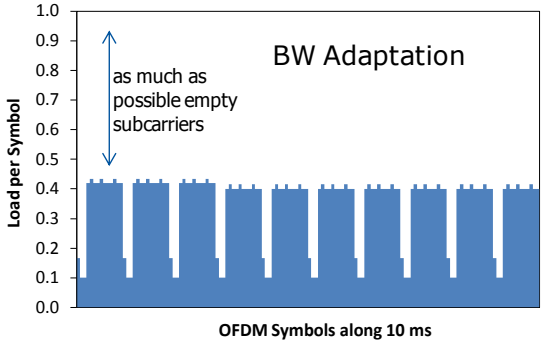
Deployment area	20% heavy users	50% heavy users	100% heavy users
Dense urban	28 Mbps/km^2	52 Mbps/km^2	92 Mbps/km^2
Urban	9 Mbps/km^2	17 Mbps/km^2	31 Mbps/km^2
Suburban	5 Mbps/km^2	9 Mbps/km^2	19 Mbps/km^2
Rural	1 Mbps/km^2	2 Mbps/km^2	3 Mbps/km^2

- Busy hour is 60% above daily average
- At night time traffic is 7 times lower than in Busy Hour

Impact of Scheduling Strategy on Power Level
with adaptive TRX hardware

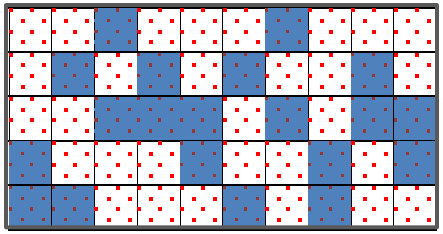
Bandwidth Adaptation

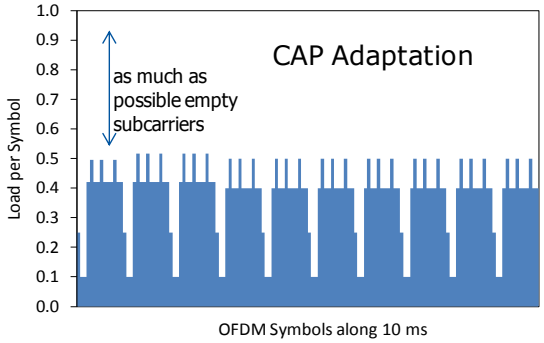




- Avoids pilot overhead
- Not standard compliant
- Uses Operation Point adjustment

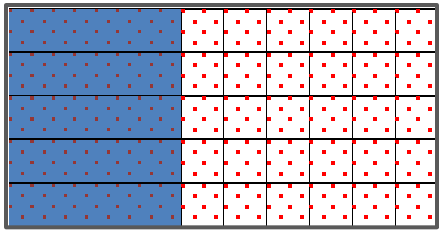
Capacity Adaptation

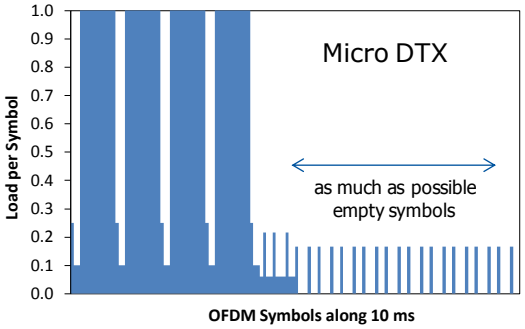




- Channel diversity maintained
- 3GPP compliant
- Uses Operation Point adjustment

Micro Sleeps

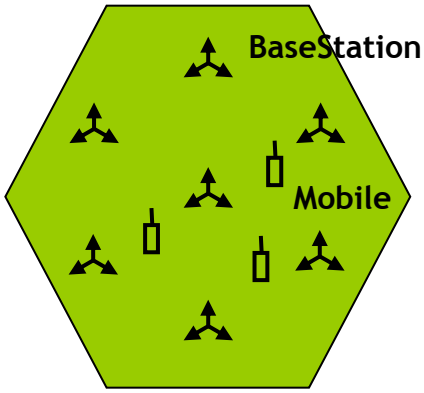


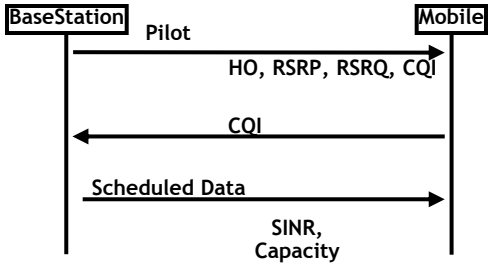


- Fastest adaptation
- Limited by switching transients
- Uses Component Deactivation

Dynamic System Level Simulator

- Dynamic system level simulator
  - User distribution, movement
  - Video traffic model, scheduling
  - Power modell, efficiency

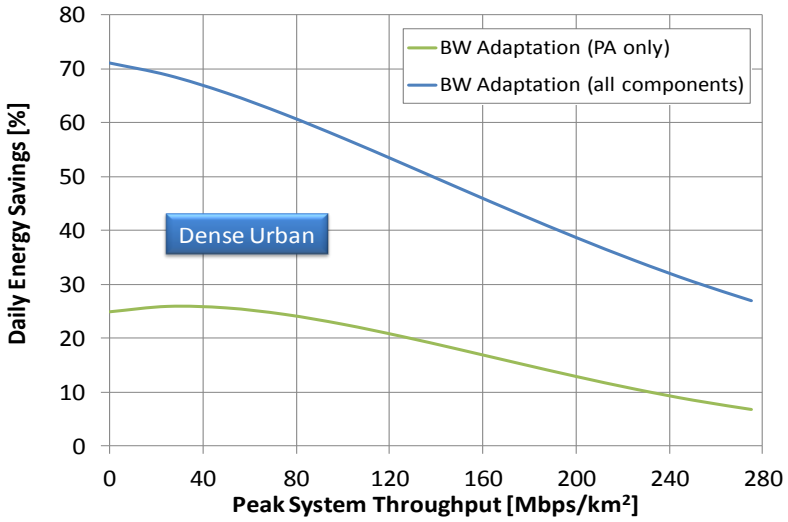


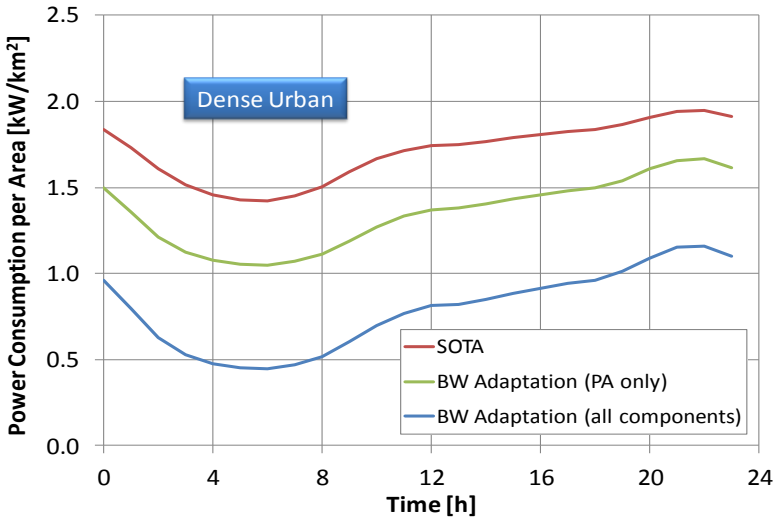


Available Features (SON)	State	New Features (EE)	State
Flexible Playground, wrap around		Power Model	
BaseStation Transceiver		User Traffic Model [video]	
Mobile		Non-uniform user distribution	
User Traffic Model [full queue]		Heterogeneous Cells	
Handover [best connected]			
Pilot Signals		EE Scheduler (BW adaptation)	
Scheduling		Interference coord. (Reuse)	
SINR calculation			
Capacity calculation			

Energy Aware Scheduling
Dense Urban Scenario

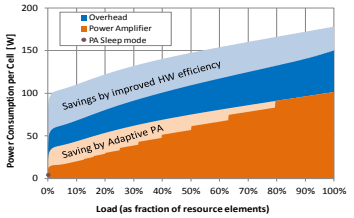
500m Inter Site Distance, 3x40W RRH, SISO configuration, 120Mbps/km² in Busy Hour





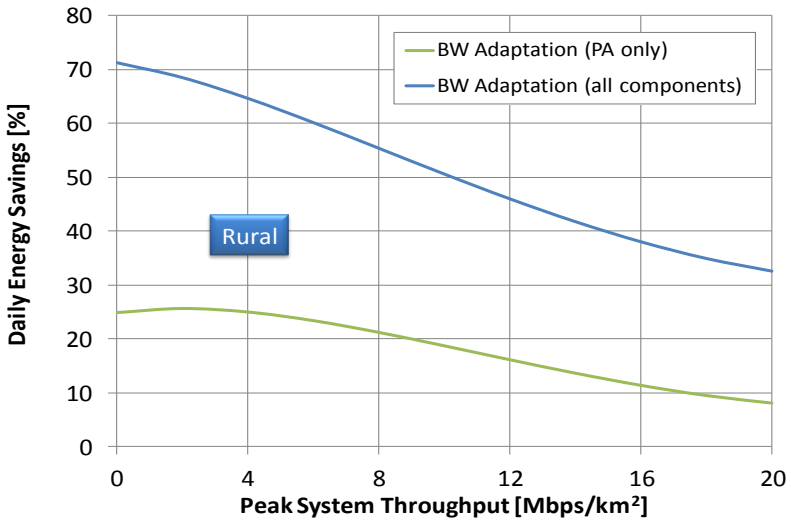
Daily energy savings

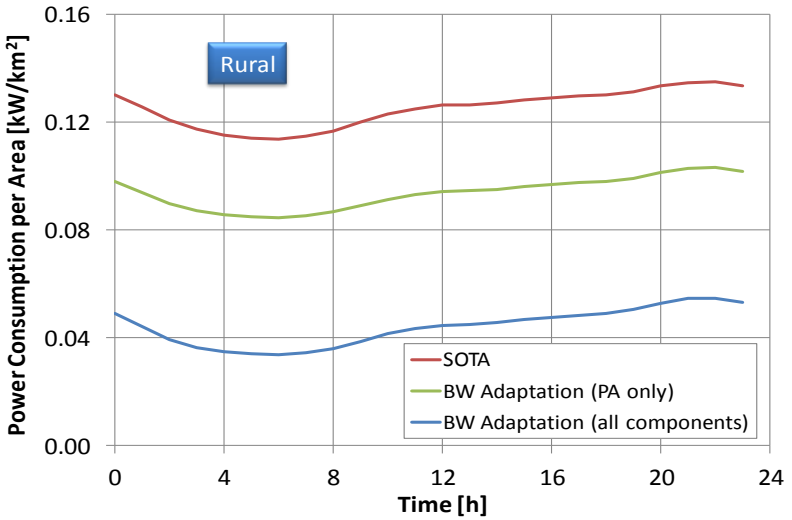
- 20.9% from adaptive TRX & BW adaptation
- 53.6% with additional load adaptive overhead



Energy Aware Scheduling
Rural Scenario

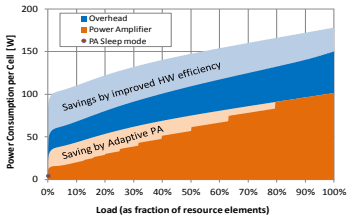
1732m Inter Site Distance, 3x40W RRH, SISO configuration, 4Mbps/km² in Busy Hour





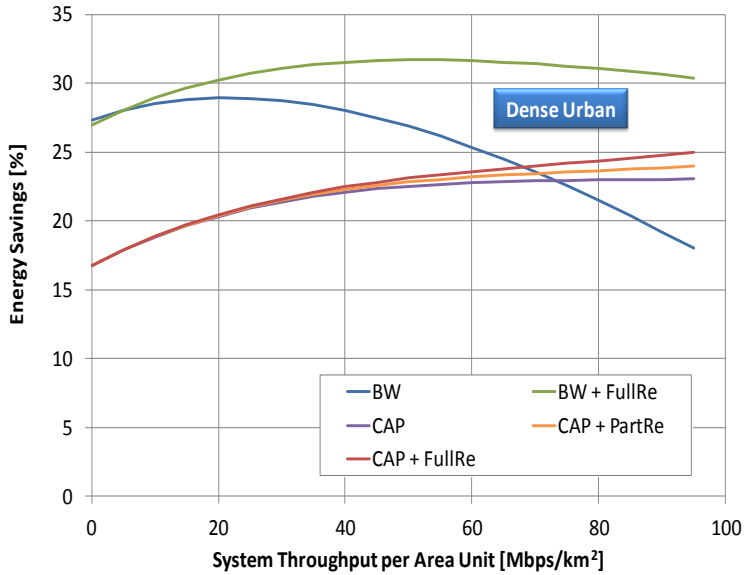
Daily energy savings

- 25.0% from adaptive TRX & BW adaptation
- 64.7% with additional load adaptive overhead



Energy Aware Scheduling
Extension to MIMO

- Simulator extended to 2x2 MIMO (2x 20W output per sector)
- Capacity Adaptation and MicroDTX
  - Partial reuse scheme: Roll-over of frequency use within 10MHz
  - Combinations of adaptation schemes with microDTX



- Significant effect of the adaptation scheme
  - Cross-over between BW and Cap adaptation
  - BW better below 70Mbps/km²
- Spectral reuse brings only minor additional savings (within 10MHz band)
- For high system throughput
  - microDTX on top of BW adapt (when highest BW is required)
  - adds significant savings (>5%)

Minor saving from interference mitigation.
More important to chose the optimum scheduling strategy for each traffic load .

Conclusion

- **No/low load situations offer potential for energy savings!**
  - Basic LTE deployments are inefficient at low load
  - In many cells only 10-20% of the resources are used for data transmission
- **Network resources should be adapted to traffic demand!**
  - RAT, cells, sectors, carriers, bandwidth, MIMO antennas, etc
- **Scalable hardware with adaptation to traffic load is key !**
  - Component de-activation, operating point adjustment, etc.
  - Facilitates bandwidth adaptation, capacity adaptation and microDTX

Integrated solutions are able to cut the energy consumption of an LTE network by ~70%, with preserved QoS!

Daily saving	Adaptive PA, reuse 1	Adaptive PA, reuse 3	Adaptive BS, reuse 1	Adaptive BS, reuse 3
Dense Urban @ 120 Mbps/km^2	20.9%	30.8%	53.6%	64.9%
Rural @ 4 Mbps/km^2	25.0%	28.5%	64.7%	68.2%

AT THE SPEED OF IDEAS™

Acknowledgements

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earth
Energy Aware Radio and neTwork tecHnologies