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Research results of the IntelliSpektrum project

Project summary

Project title:	IntelliSpektrum - Intelligent spectrum management for energy-efficient and service-optimised access in flexible hierarchical mobile networks
BMWi code:	01ME11023A
Term:	01/04/2011 to 30/09/2014
Consortium:	Alcatel-Lucent Deutschland AG
	Intel Mobile Communications GmbH (IMC)
	Fraunhofer Institute for Applied Solid State Physics
	Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute
Project director:	Dr. Andreas Wich, Alcatel-Lucent Deutschland AG
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Supported by:

Federal Ministry
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and Energy

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Research topics

The project IntelliSpektrum develops energy-efficient, highly capacitive, service-oriented and spectrally efficient mobile communication by means of:

- Scenarios for a flexible, dynamic and heterogeneous mobile network

- Utilisation optimisation by switching the small radio cells on and off using intelligent control (network management)

- Flexible, dynamic, self-organising, and highly efficient transmitters for base stations (intelligent algorithms for RF transceivers)

- New transmitter with gallium nitride circuits for high bandwidth and low power consumption

- Broadband transmission amplifier & low noise amplifier module for reception (energy-efficient transmitter)

- Energy profiler in the terminal for the analysis of the interaction between the network and the terminal (energy profiling for mobile user terminals)

- Self-powered network elements (energy harvesting)

Use of small unidirectional radio cells in combination with macro base stations

- Unidirectional (uplink only) small radio cells with Interference Rejection Combining (IRC) will improve the reception at the base station by more than 50%

- Improvement of the downlink throughput by approximately 10% on average and 97% at the edge of the radio cell

- In full operation, small radio cells have resource utilisation that is approximately 2 to 11 times higher

- This also reduces the transmission power of the terminal

Result of the measure:

- Electricity savings in network elements
- Electricity savings in terminals

Energy management in HetNet scenarios

The best results are obtained with macros with a large coverage area (IISDMacro = 1732 und 4330 m, ISDPico 130 m) and a moderate number of picocells

- Energy savings of up to 58.5%

- Idealised powering on and off of picos can be neglected in comparison with Micro DTX

- In case of a reduction of backhaul energy consumption by a factor of 2, energy savings of up to 70% can be achieved (5W was expected)

With respect to its performance, the network is oversized in scenarios with large macros and many small picos

- Low energy efficiency

- High energy consumption due to the large amount of per-link backhaul energy consumption

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Different combinations of sectored macro cells with additional pico cells (HetNet)

Macros and picos (30 dBm max.) vs. 6x sectored macros:

- Up to 80% energy savings (1x sectored macro and additional picos)
- 15% to 50% energy savings (3x sectored macro and additional picos)
- Pico cells must be activated only when the capacity limit of the scenario is reached

Macros and picos (24 dBm max.) vs. 6x sectored macros:

- 40% to 50% energy savings (3x sectored macro and additional picos)
- Pico cells can already be activated to save energy before the capacity limit of the 3x sectored macro cell is reached

Conclusion: 3x sectorisation and small pico cells are much more energy efficient than a 6x sectored macro base station!

Cooperative data transmission to the user (downlink) through multiple macro base stations

- In case of cooperative data transmission through three macro base stations, the throughput increases by about a factor of two in the sector (compared to individual transmission)

- Lower signalling effort

- Cell edge users benefit from the conversion of interference signals to useful signals

Result of the measure:

- Reduction of the transmitting power budget in the median by about 45%

- Significant energy savings

Needs-based activation and deactivation of small radio cells

With the help of user localisation using self-organising maps, small cells can be efficiently used (activation & deactivation):

- Self-organising maps provide information about:
    - Concentrations of users
    - Location-based connectivity
- Concentration detection and prediction of the user's movement based on:
    - Output of the signalling channels of the detected base stations and user positions

Cognitive interference coordination

Study of compression/reduction of signalling data:

- Using prediction of the radio channel (effectiveness is dependent on the mobility of the user as well as the quality of the knowledge of the channel)
  - Prediction can be performed using simple linear functions, that is, with low complexity
  - In this way, the signalling intervals can be extended
- Quantisation of the signalling data

Intelligent grouping of users and the supplying base station:

- In this way, the total throughput is increased in the cells

Transmission power reduction through limiting of the transmission power of the antennas involved in the joint transmission

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Energy Harvester for the operation of small network elements (repeaters)

The aim was to operate a small network element (base station repeater) on a battery-buffered photovoltaic system:

- Optimisation uses weather statistics for predicting energy generated by wind and sun

- Charging times and operating times of the batteries are controlled

- Berlin scenario with 63 base stations and 5 energy-autonomous elements

- Relays can be active 97% of the total time

- Throughput per user decreases by only 12%

- Potential energy savings per year: > 7 MWh

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New GaN-based amplifiers

The aim of the research was to develop a low-noise amplifier (LNA) and a high-power amplifier (HPA) for use in an intelligent transceiver system (TRX) for neural control in the base stations

The new dual-band HPA was:

- realised by means of gallium nitride processes (GaN)
- implemented with a circuit topology class ABJ (max. output power > 25 W and up to 60% max. efficiency)
- designed to operate in both frequency bands of modern mobile telephony UMTS (2.11–2.17 GHz) and LTE (2.62–2.69 GHz)

The new LNA was:

- realised as a linear and very broadly constructed gallium nitride MMIC (Monolithic Microwave Integrated Circuit) LNA with a very high amplification of G > 30 dB and low noise of NF < 1 dB in the wide frequency range of 0.4 to 3 GHz

Neural networks

Optimisation of the energy efficiency of mobile wireless systems by implementing neural networks:

- Neural networks resolve stochastic and deterministic problems without the need to describe them mathematically

- Neural networks enable very fast parallel data processing (such as FPGA)

- Applicable to various transceiver concepts and topologies

- Neural networks have the ability to learn and respond adaptively to different signals, scenarios and requirements

Energy Profiler for terminals

The aim of the research is to track and log the energy consumption of system components in smartphones in connection with context information such as network affiliation, device status and type of running applications

- Requirements for the Energy Profiler:

  - Low weight and good scalability of the monitoring infrastructure

  - Sufficient precision and granularity in order to detect gateways (network transitions) in heterogeneous networks

- Development of integrated flow monitors which measure the load currents on each voltage regulator

  - For the prototype implementation in the IntelliSpektrum, the SenseFET concept was recommended. The SenseFET is a dedicated MOSFET which is implemented as a current mirror in parallel with the Power MOSFET of the voltage regulator

Patents and publications

- ALUD patents
    - E-report title: "Hybrid Massive MIMO / Multi-Antenna System"
    - E-report title: "Small Cell Network Optimization for Rate Restricted P2MP Backhaul"
    - E-report title: "RAN Friendly Internet Notification Techniques"
- 22 national and international scientific publications
- Best Paper Award: Vincenzo Carrubba (FhG IAF) was awarded the "EUMC Microwave Prize" (EuMC 2012) for the paper "Dual-Band Class-ABJ AlGaN/GaN High Power Amplifier"

Presentations:

- Electronics Goes Green 2012, Berlin, September 2012
- Bell Labs Open Day, Stuttgart, November 2012
- CeBIT, Hanover, March 2014
- Bell Labs Future X Days, November 2014