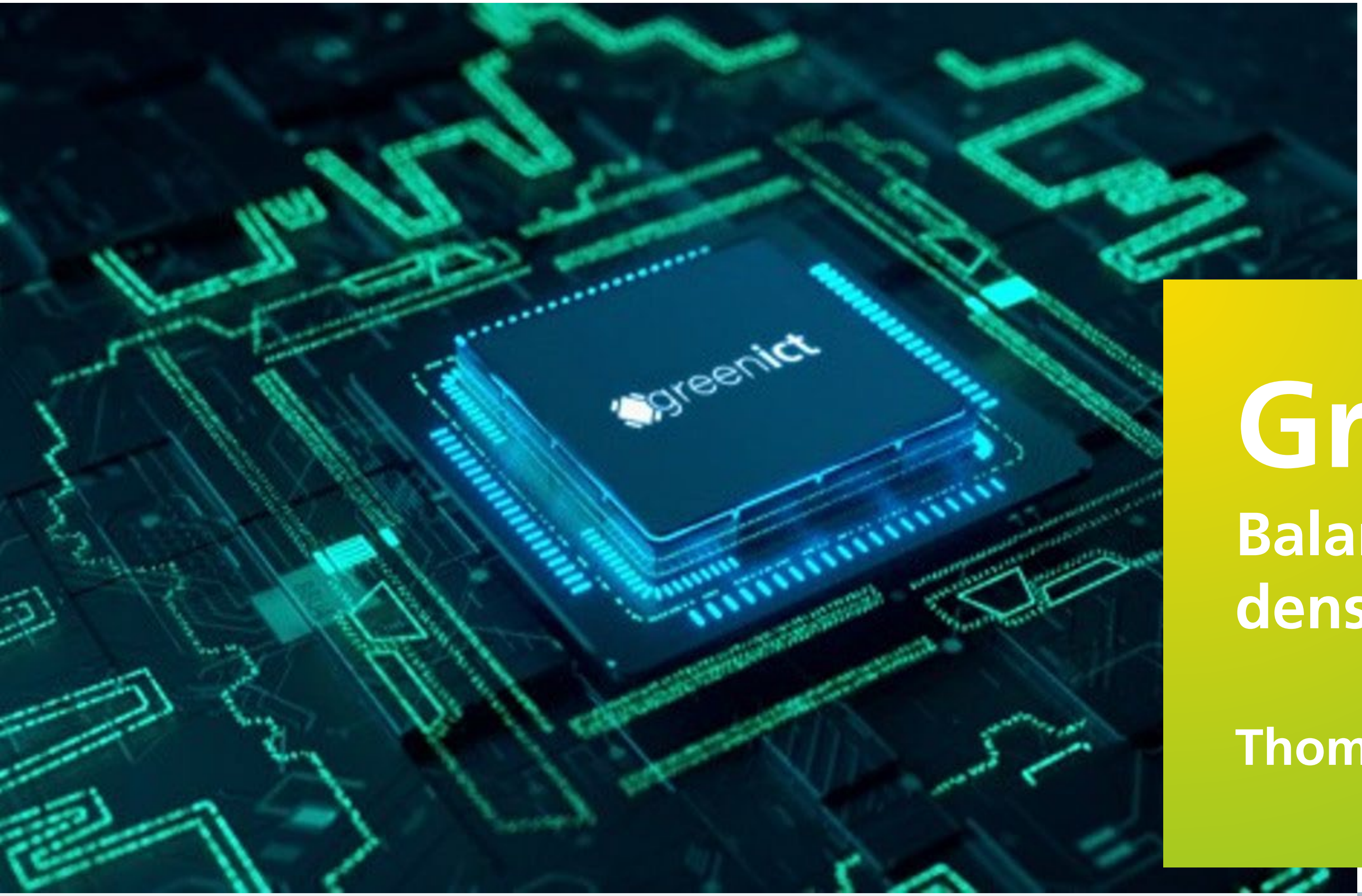
FMD.iDay²³



GreenICT EdgeLimit

Balancing the ecological footprint of dense deployments

Thomas von der Grün, Fraunhofer IIS

EdgeLimit – Two German Funded Projects

» Electronics for energy-saving information and communication technology «

Fast-growing numbers of installations of 5G/6G campus networks and dense deployments in urban hotspots: How about their CO_2-footprint?

German funded project (BMBF) in two phases

1. Competition project concluded in 2021 rank 2 of 10*: Proposal of a new concept for systematic evaluation
2. Follow-up project 2022 to 2024: Detailed technical implementation of evaluation concept with validated data and analysis of the potential of energy saving techniques

- Partners: Fraunhofer IAF (Projektlead), Fraunhofer IIS, Uni Freiburg, Nokia, United Monolithic Semiconductors (UMS), Deutsche Telekom

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* https://www.bmbf.de/bmbf/shareddocs/pressemitteilungen/de/2021/08/190821-ICT-II.html

»5K-Ökodesign-Methode« (5C) for Dense Deployments

The 5Cs in EdgeLimit

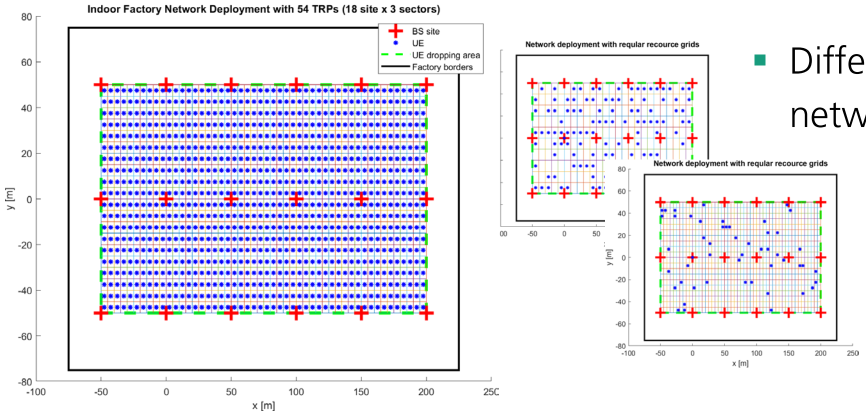
1. **Conditions:**
   - Use cases for mm-wave: 5G Campus network **indoor factory** and Smart City dense urban area
2. **Capacity:**
   - Defining load scenario over the day for the considered use cases
   - Requirements for data throughput, number of supported UEs and positioning accuracy
3. **Configuration:**
   - Multi-TRP architecture and compute network for O-RAN (RU, DU, CU, core)
   - Complete architecture of a 5G+ campus network
4. **Components:**
   - Electrical power budget considers MIMO antennas (RF chains), PAs, RFSoC FPGAs, computing resources,…
5. **Control:**
   - **Selecting energy-efficient components and architectures and MIMO-schemes**
   - **Energy management by switching off resources: computing, transceivers, panels, sites**

Multi-TRP-Simulation to assess network performance

Transmission Power

“Indoor Factory” Assumptions (aligned with 3GPP)

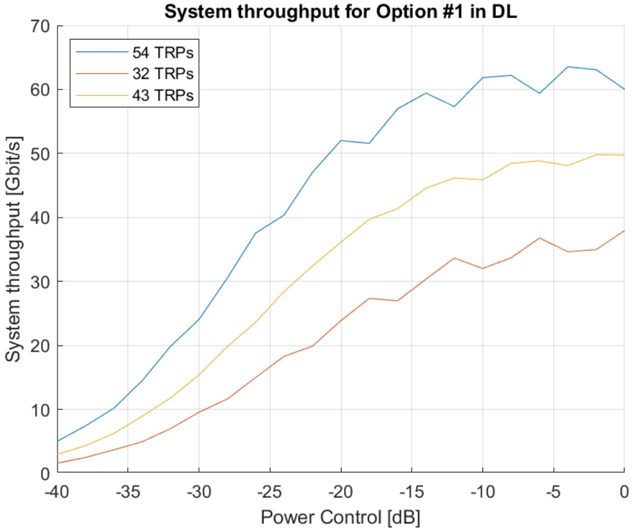
- Regular, idealistic deployments in different densities
- 3 load levels over 24h: modelled by count of UEs



- Different network load levels

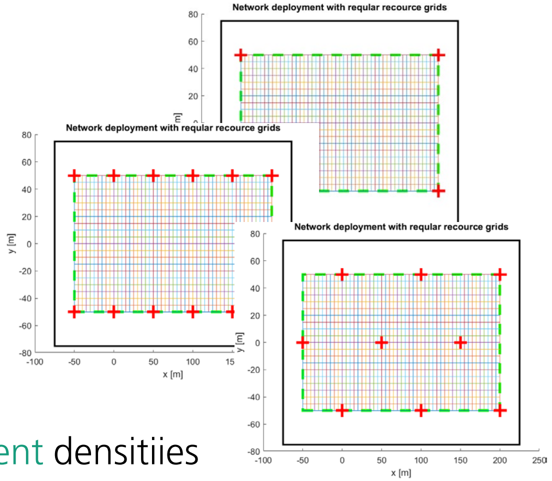
Features

- »FR2« in DL/UL
- Power control
- Interference management
- Upcoming: orchestration for positioning



KPIs

- System Throughput [bit/s]
- Channel Capacity [bit/s/UE]



- Different deployment densitiies

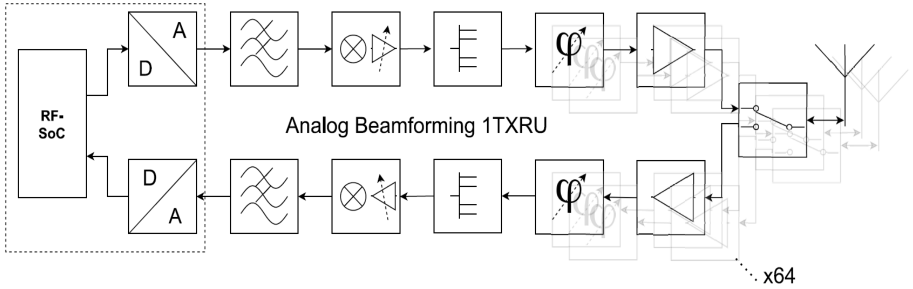
Multi-TRP-Simulation to assess MIMO-architecture options

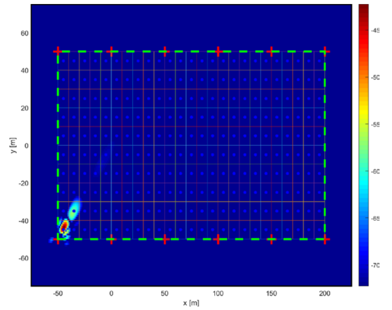
Transmission Power

Modelling of MIMO architectures

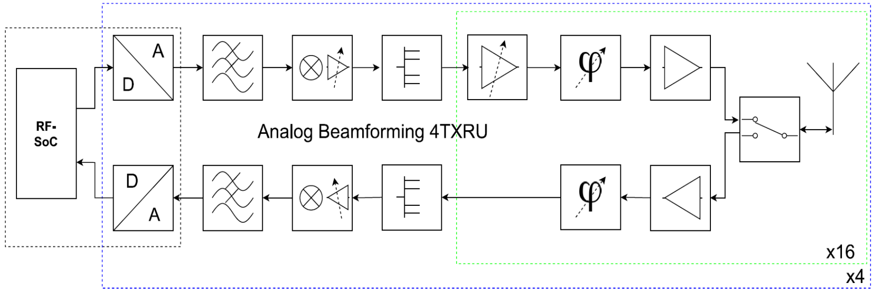
per 120° coverage:

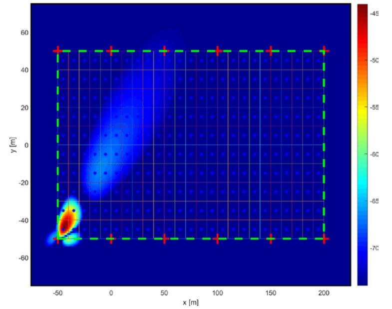
- Option **#1**: 8x8 Antenna array, 1 TXRU
  → analog beamforming



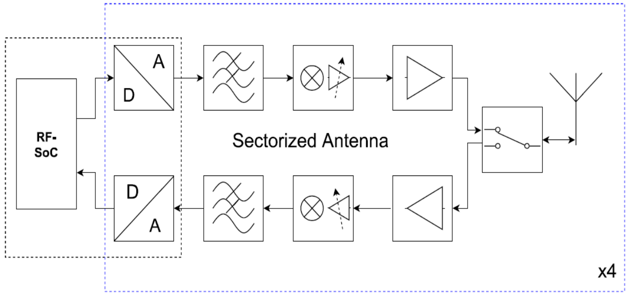


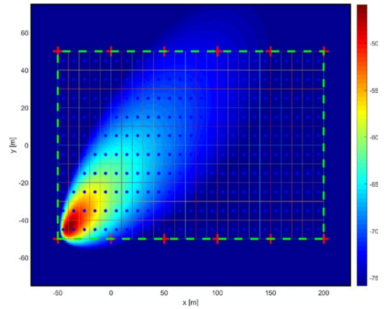
- Option **#2**: 8x8 Antenna array, 4 TXRU
  → hybrid beamforming





- Option **#3**: fixed sectorized Antenna array (30° sectors)
  → alternative with spatially fixed transmissions



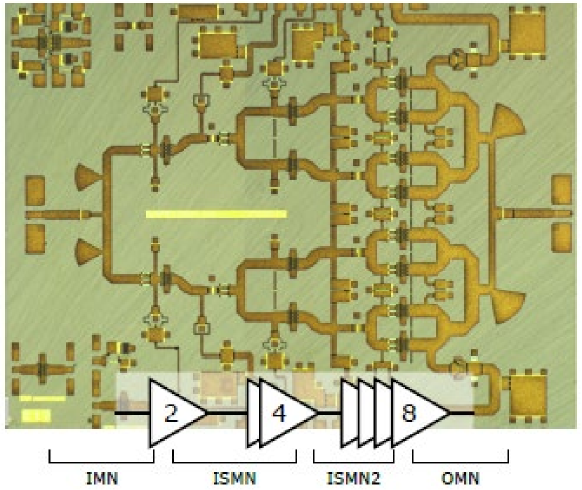


EdgeLimit – Efficient RF-Hardware

Transmission Power

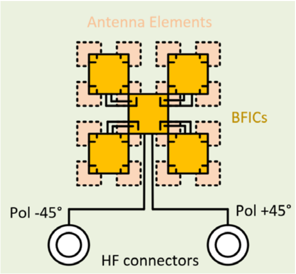
Components: PA

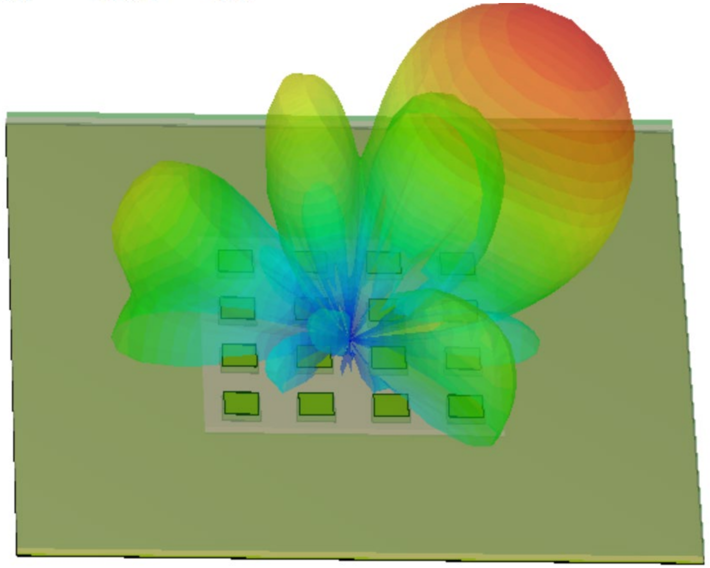
- PA by Fraunhofer IAF
  → semiconductor material/design → better efficiency
- Note: PA efficiency effect scales in massive-MIMO-setups



RF modules and antennas

- Architectural design options → efficient module design by Nokia
- RF module built around efficient PA
- Real-life antenna samples → available at Fraunhofer IIS
  - Analog beamforming: 64-elements, 1 transceiver
  - Hybrid beamforming: 256-elements, 4 transceivers
  - Fixed sectorized arrays: versions with 30° and 60° sectors
  - Own design of a scalable 16-element phased-array antenna tile

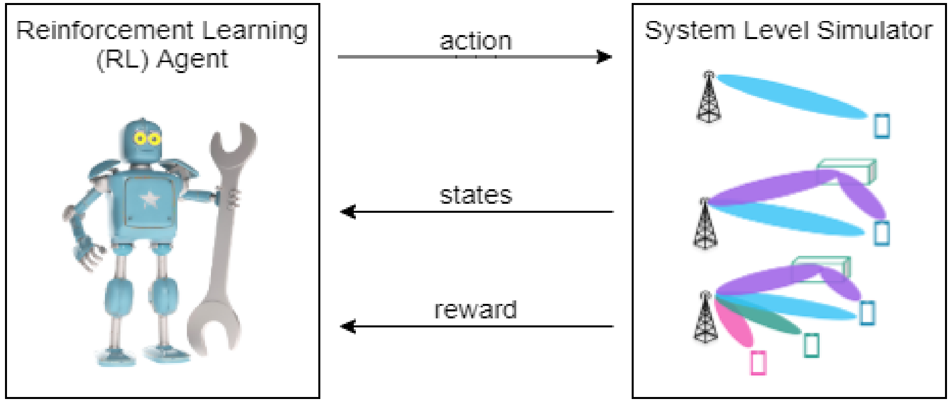


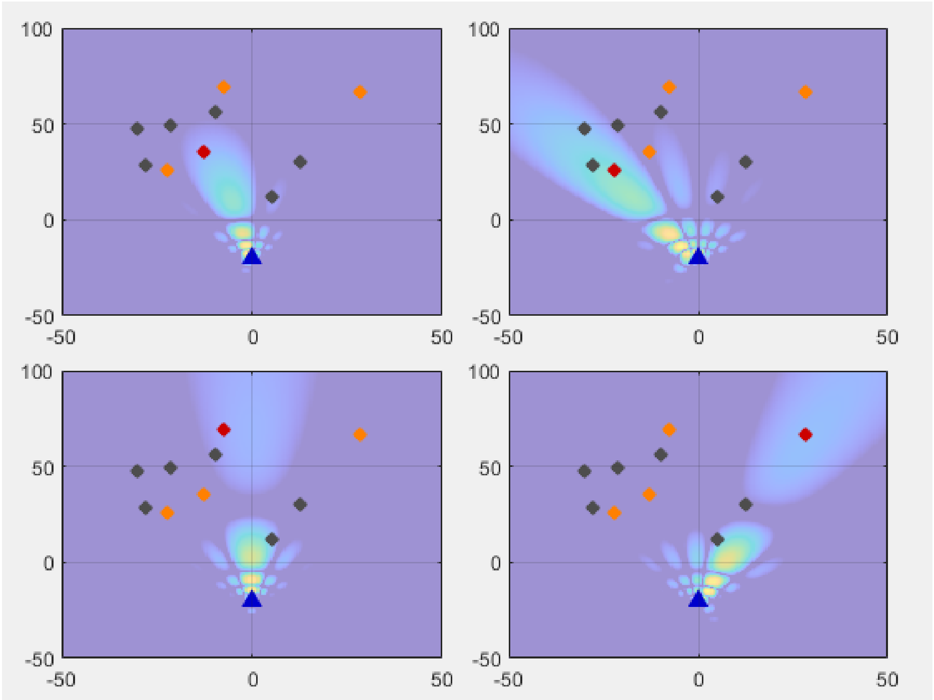


AI/ML: Reinforcement Learning (RL) for multi-TRP-Energy Savings

FMD.iDay23

Transmission Power



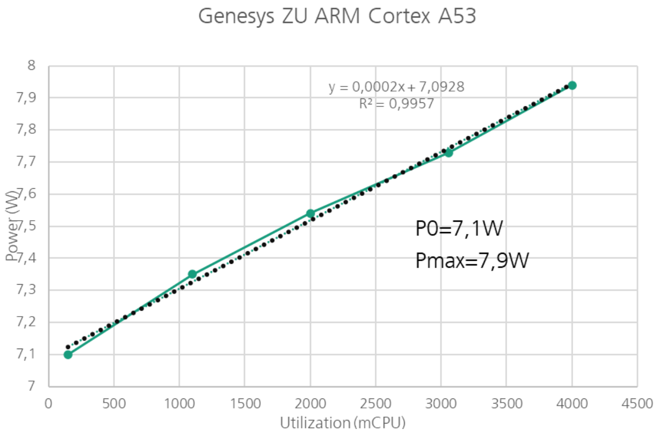


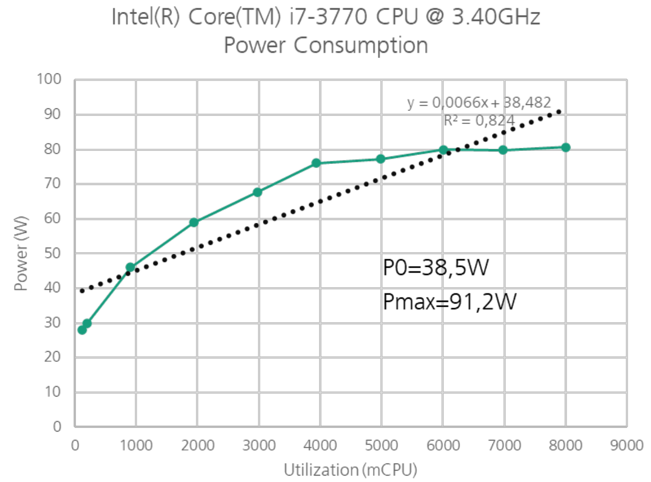
- Background at Fraunhofer IIS: RL for beam management
- Now in EdgeLimit: RL for beam management and energy savings
  - For lower network load,
    several TRPs or sites can be deactivated (or set to sleep mode)
  - Different sleep modes → smaller energy consumption,
    larger "wake-up" transition time
  - Ensure minimum QoS

Complex task in dense deployments:
→ Combination of Reinforcement Learning and Discrete Optimization

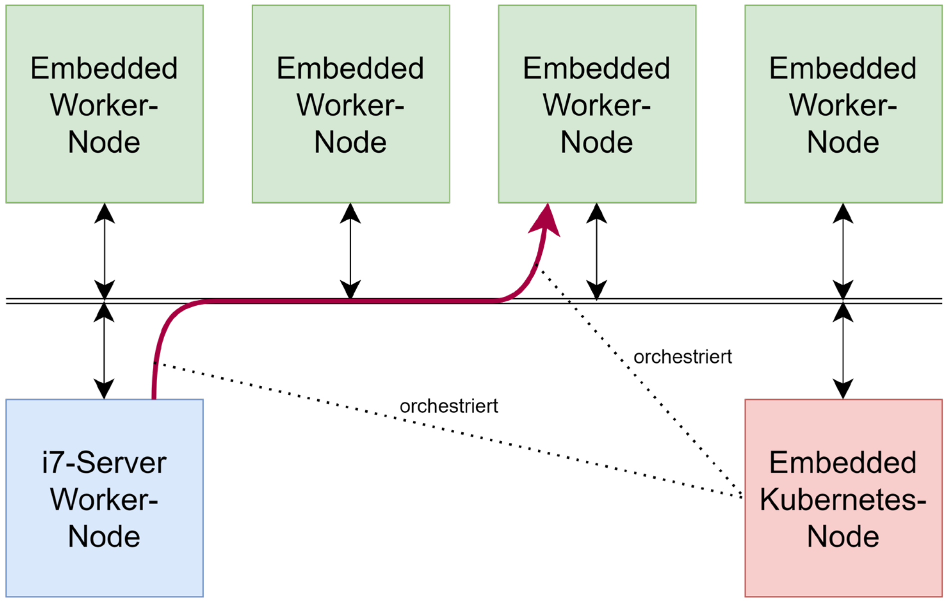
Energy-efficient virtualization and orchestration

Compute Power





Characterization of compute resources



Test and measurement cluster at Fraunhofer IIS

Goal

Exploit savings potential for edge distributed computing

Energy savings in the partial load range

Distribute software containers in the partial load range

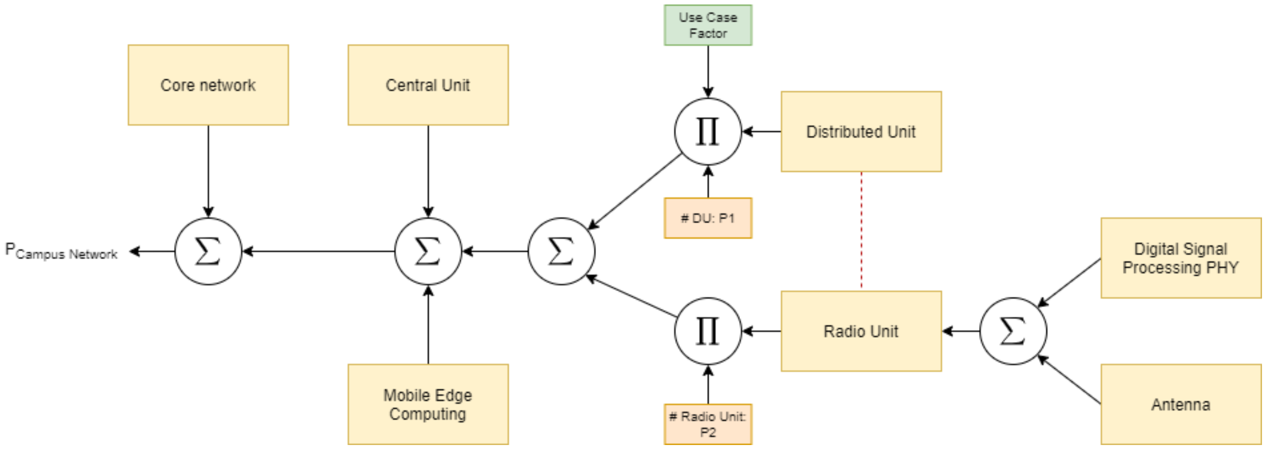
Unused components are completely shut down

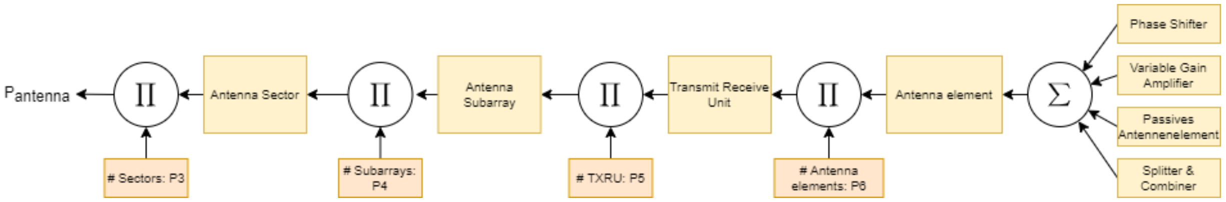
Tool "Network Energy Balance", an Excel-based simulation model

FMD.iDay[23]

Results Generation

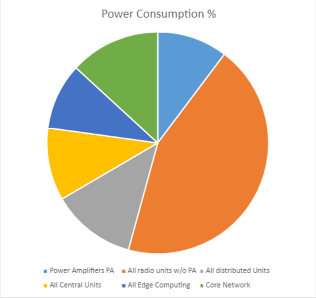
- **Input:**
  - RF Level Plans
  - Efficiency and energy consumption of components
  - System resource usage, scaling with system load
  - Forecast of worldwide spread of systems





- **Output:**
  - Portion of energy usage of each relevant component
  - Extrapolation to worldwide CO_2-footprint
  - Quantification of savings potential of optimization approaches

Note: KPIs (e.g. data throughput) from system simulation



	2018-2020	2025		2030	
		GreenICT [kWh/a]	Referenz [kWh/a]	GreenICT [kWh/a]	Referenz [kWh/a]
S1: Campusnetzwerk	0	180.868.596	737.295.912	361.737.192	1.474.591.824
S2: Urban Szenario	0	237.908.059	607.792.014	475.816.118	1.215.584.028
Hochrechnung der beiden Szenarien auf 10 Staaten in Europa (D, E, Fr, It, Dänemark, Benelux, Polen, Tschechien)	0	S1: 1.085.211.576 S2: 1.427.448.354	S1: 4.423.775.472 S2: 3.646.752.084	S1: 2.170.423.152 S2: 2.854.896.708	S1: 8.847.550.944 S2: 7.293.504.168
Maximale Gesamtersparnis	0	CO2 in kg 2.223.147.050		CO2 in kg 4.446.294.100	

EdgeLimit – How to Assess Energy Efficiency
Summary and Outlook

- Current Project Status
  - Edge-Limit-2 at half time
  - All partners busily working on their topics:
  - Overall analysis method, efficient solutions for transmission and compute, energy saving algorithms
- Upcoming Work
  - Integration and Validation
  - Joint Conclusions on CO_2-footprint of dense deployments (assuming different figures for worldwide rollout)
  - Demonstration and discussion of the optimization potential
- Relevance and Relations
  - 3GPP: "Network Energy Savings" as topic in Rel-18 and upcoming topic for Rel-19
  - Input to the natively energy efficient design of 6G

Vielen Dank für Ihre Aufmerksamkeit!

Team Green-ICT-EdgeLimit

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