technische universität
dortmund

EDeMa

Federal Ministry of Economics and Technology

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

5th International Workshop on OMNeT++

Desenzano, Italy, 23.03.2012

A Modularized and Distributed Simulation Environment for Scalability Analysis of Smart Grid ICT Infrastructures

Christian Müller, Hanno Georg and Christian Wietfeld

TU Dortmund University
Communication Networks Institute (CNI)
Dortmund, Germany

christian5.mueller@tu-dortmund.de

Faculty of Electrical and Computing Engineering
Communication Networks Institute
Prof. Dr.-Ing. Christian Wietfeld

Agenda

- **Motivation**
  - Project Outline
  - System Architecture
- **Distributed Simulation Framework**
  - Architecture and Messaging
  - GeNeSiS++ Framework
  - System Model Directory Register
  - Reference Scenarios
- **Exemplary Performance Analysis**
- **Conclusions and Outlook**

E-Energy Smart Grid Region

Development and Demonstration of decentralized integrated energy systems on the way towards the E-Energy marketplace of the future

- One of six Smart Grid regions in Germany funded by:

Federal Ministry of Economics and Technology

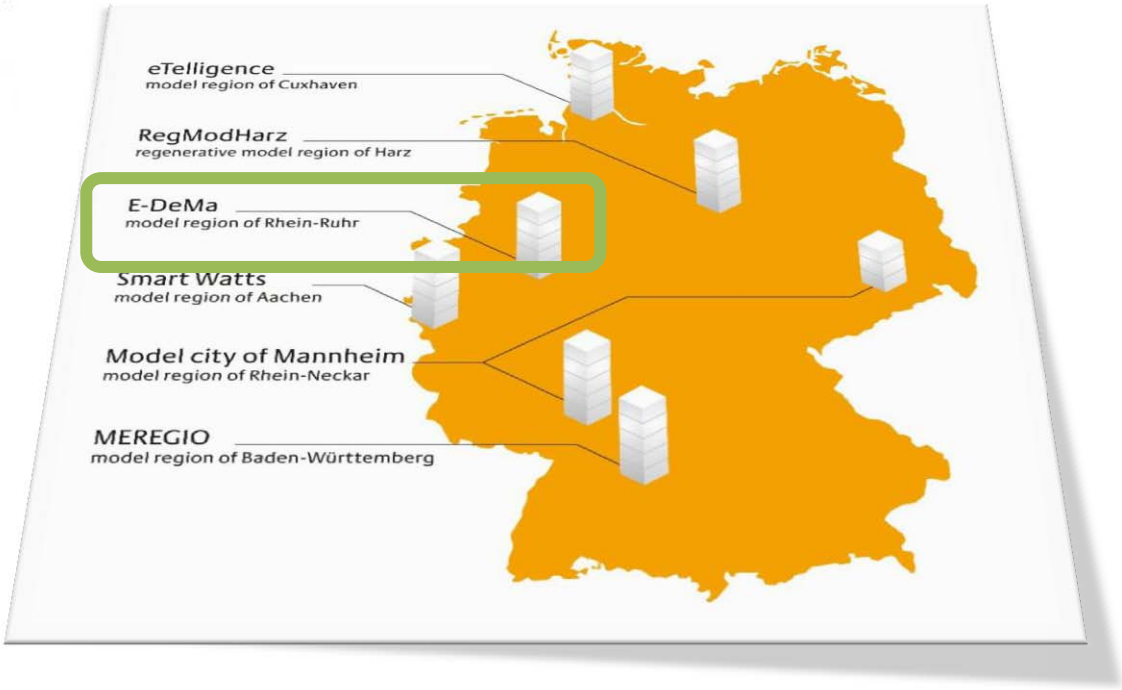
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

- Project consortium:

VORWEG GEHEN SIEMENS

Miele IMMER BESSER · ProSyst · SWK

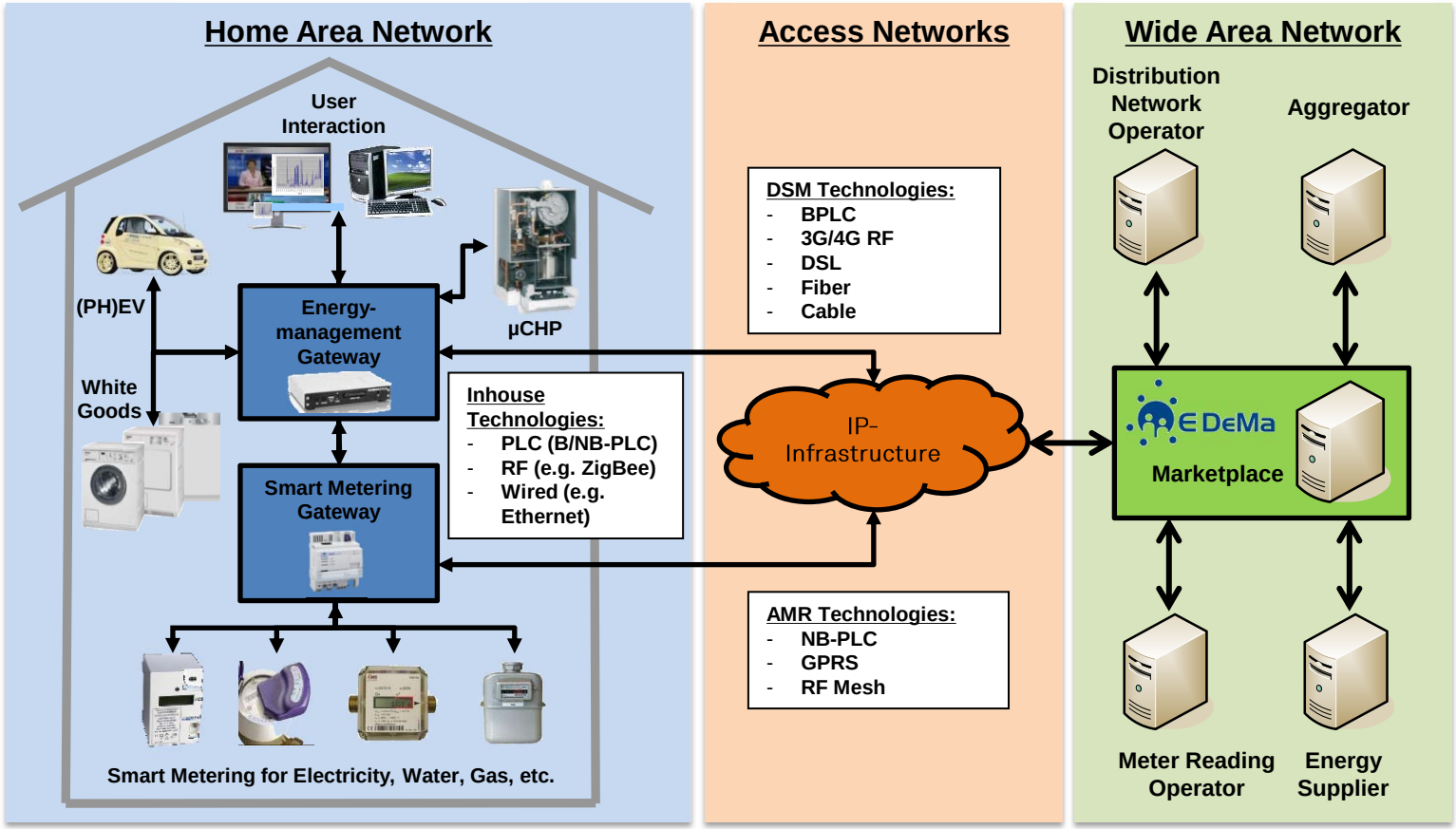
Fachhochschule Dortmund University of Applied Sciences and Arts · technische universität dortmund · Universität Duisburg Essen



- Cooperation project

IKT
INTEGRATION DER ELEKTROMOBILITÄT IN DIE NETZSYSTEME DER ZUKUNFT

System Architecture



Integration of customers into the Smart Grid using reliable and secure ICT infrastructures

- **Metering HAN Gateway** (Aggregation of (sub-) metering data, decoupling of energy and ICT components, data provisioning, user interface)
- **Management HAN Gateway** (Energy marketplace interaction, DSM, advanced user interface)

State-of-the-Art Technologies

Home Area Networks

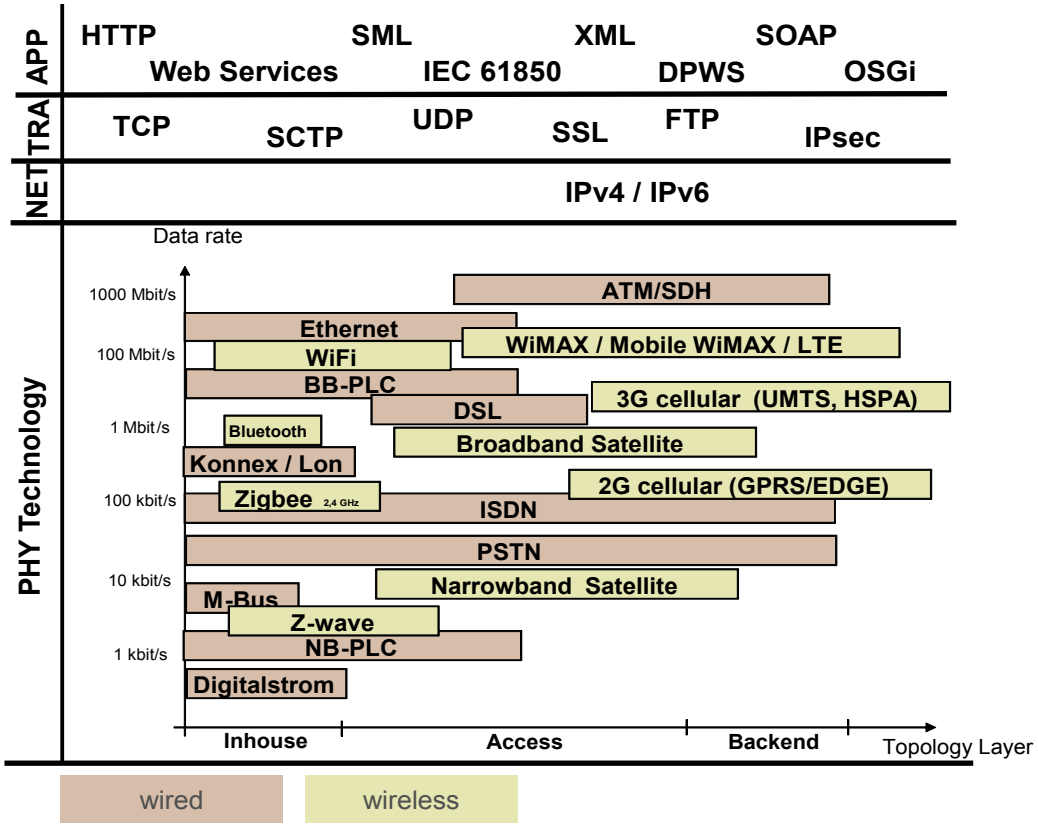
- Broadband Powerline Communications (HomePlug 1.0 / 1.0 turbo, AV, DS2, etc.)
- Wireless (ZigBee, Wireless M-Bus, Z-Wave, WLAN, etc.)
- Wired (Ethernet, Seriell, Bus, etc.)

Access Networks

- Powerline Communications (HomePlug 1.0 / 1.0 turbo, AV, DS2, NB-PLC) Wireless (GSM, UMTS, LTE, WiMAX, RF Mesh, etc.)
- Wired (DSL, Fiber, Cable, etc.)

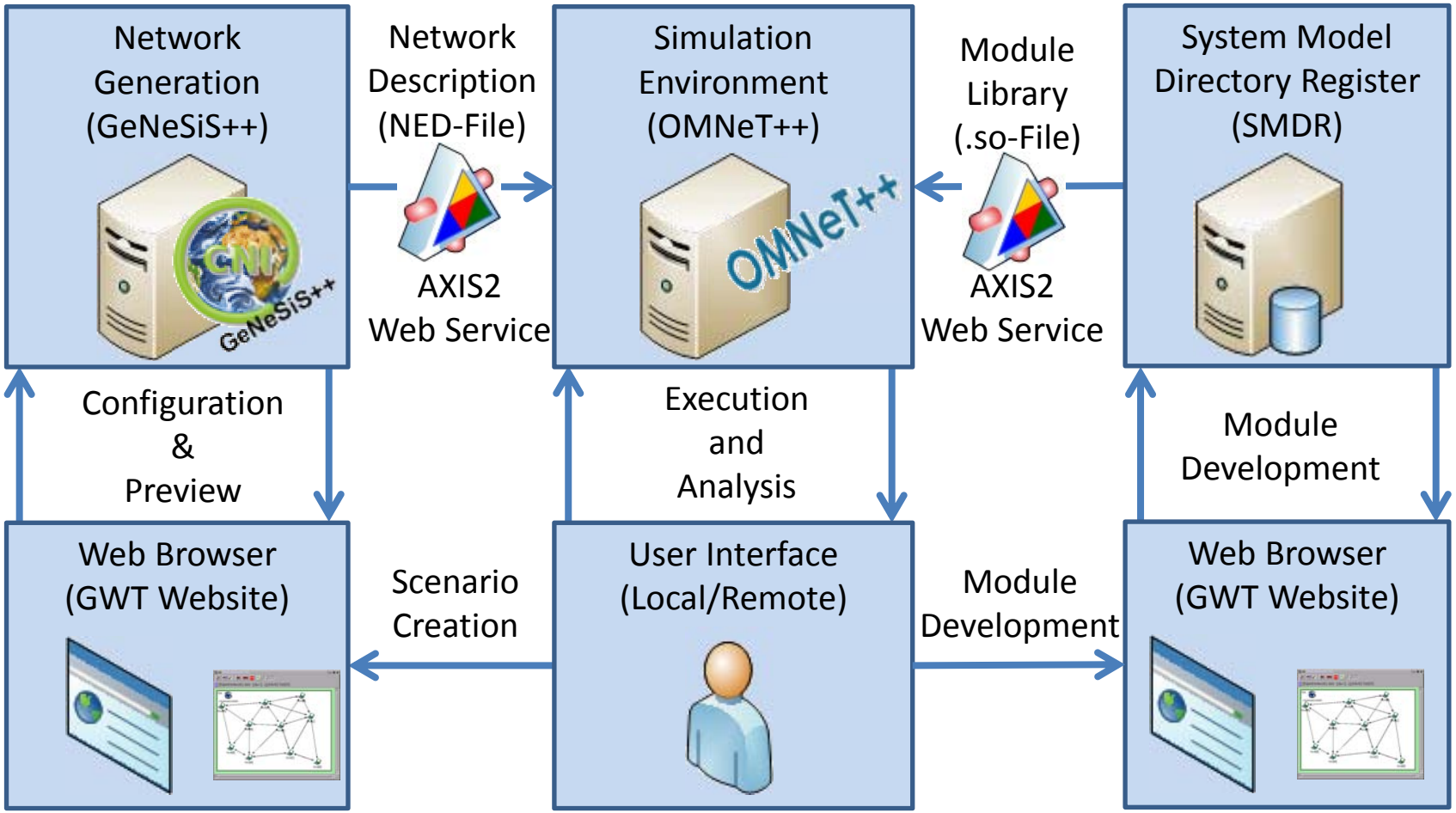
→**Modularized** approach for covering different application domains

→**Distributed** development approach for revision-based management of modules



State-of-the-Art Analysis „ICT Technologies for E-DeMa“

Simulation Framework Architecture based on AXIS2 Web Services



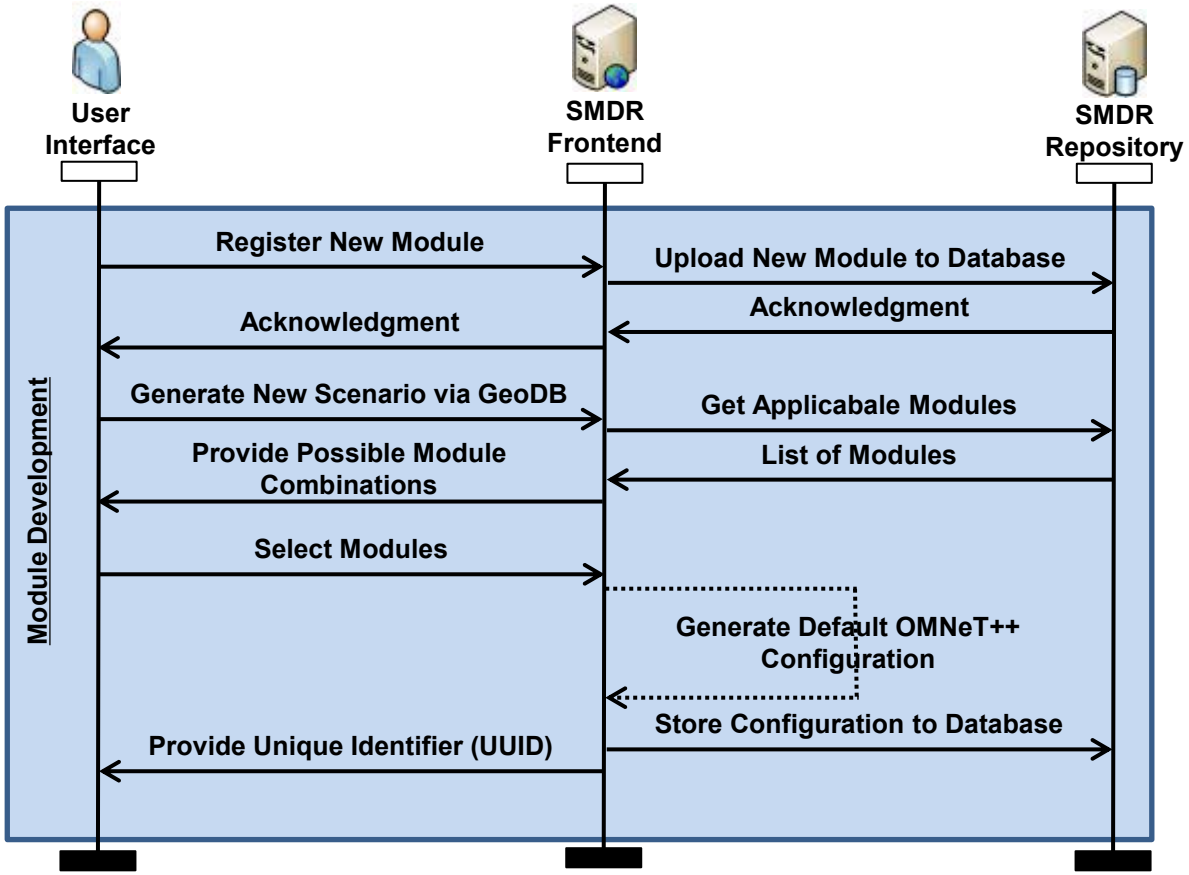
SMDR Sequence Chart – Modules and Scenario Development

Module Creation:

- Create new module
- Register Module to SMDR
- Upload module to SMDR

Scenario Creation:

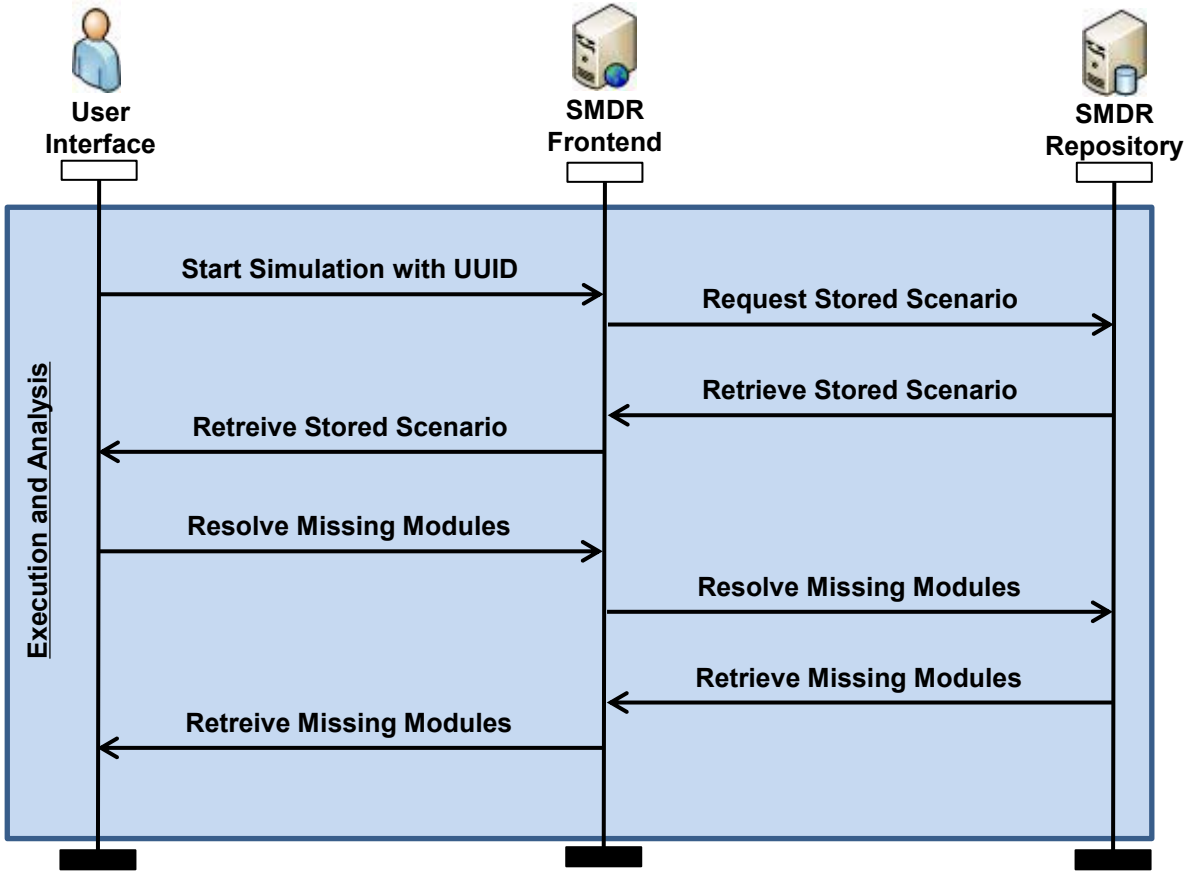
- Generate new geo-based scenario
- Select modules
- Retrieve UUID



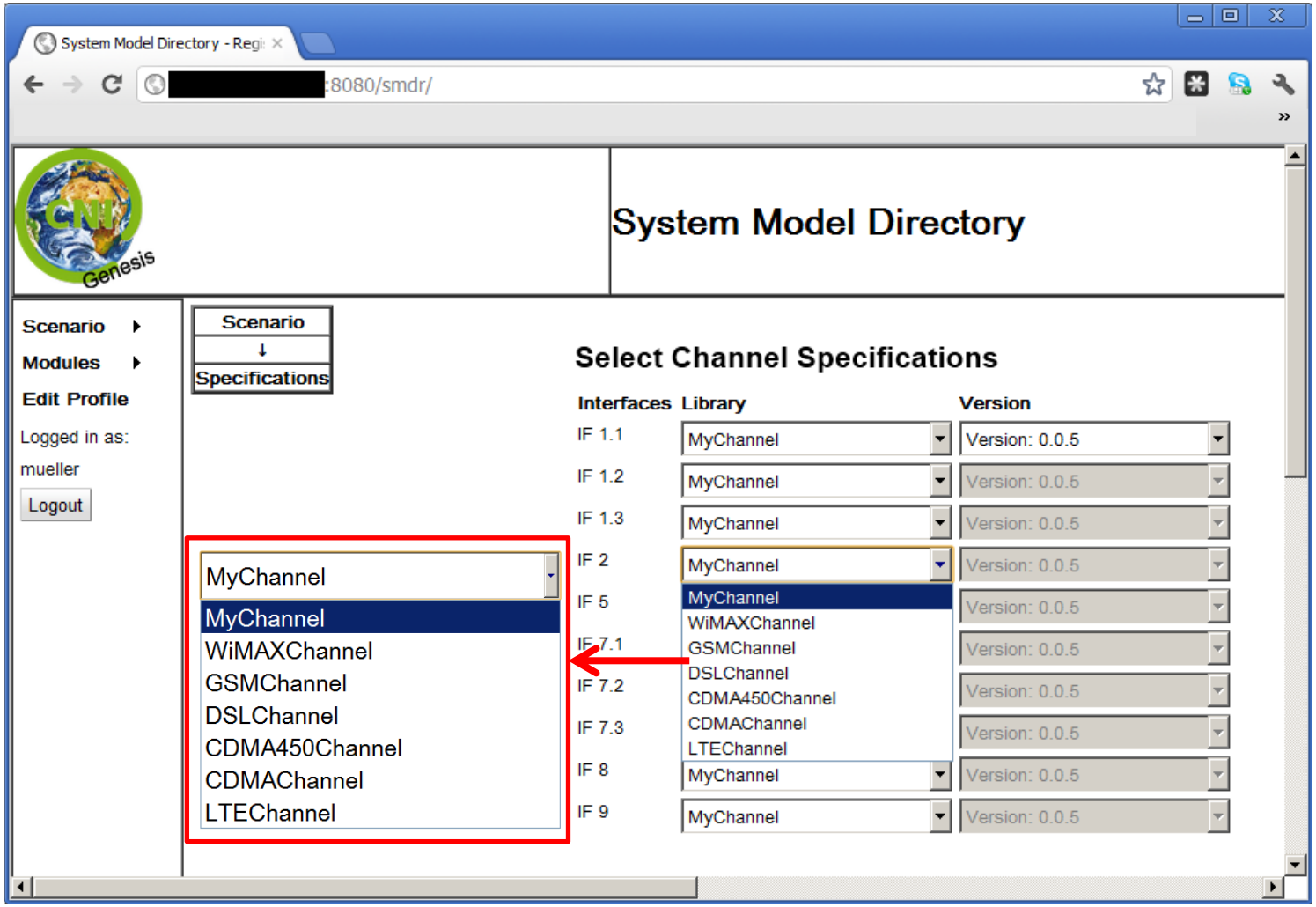
SMDR Sequence Chart – Simulation Execution and Analysis

Simulation Execution

- Provide UUID in omnetpp.ini-file
- Retrieve ned-file via Web Service
- Automatically check and resolve dependencies
- Update missing modules



SMDR Browser-based Frontend



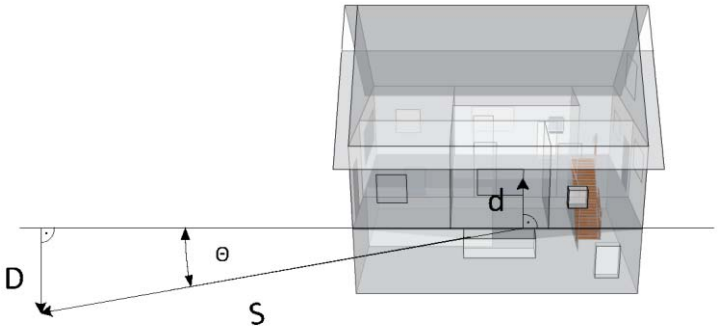
Channel Modeling based on Propagation Models

Cost 231 WI / Building Penetration

- LOS topologies
- Distance between 20m - 5km
- Different Building Types

$$L_{dB} = L_{fsp}(S+d)_{dB} + W_e + (1-\sin(\Theta))^2 \cdot W_{Ge} + \mathrm{Max}(\Gamma_1$$

$$\text{with } \Gamma_1 = W_i \cdot p \text{ and } \Gamma_2 = \alpha \cdot (d-2) \cdot (1-\sin(\Theta))^2$$



Parameters for Cost 231 Building Penetration

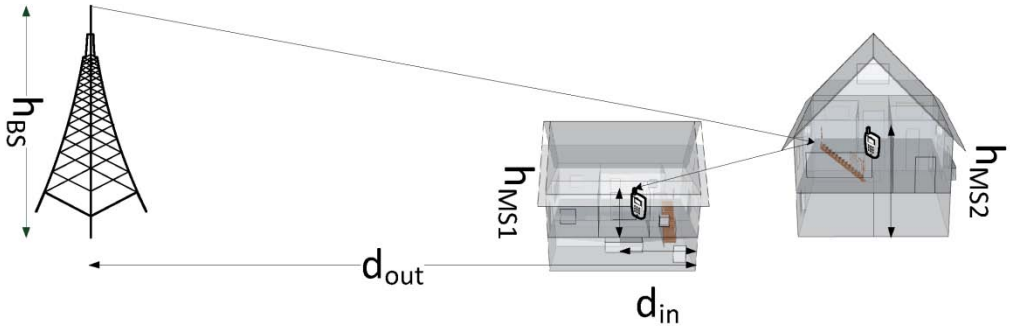
Winner II A2 / B4:

- Indoor-to-Outdoor / vice versa
- Urban Topologies
- Building Losses within Houses

Winner II C4:

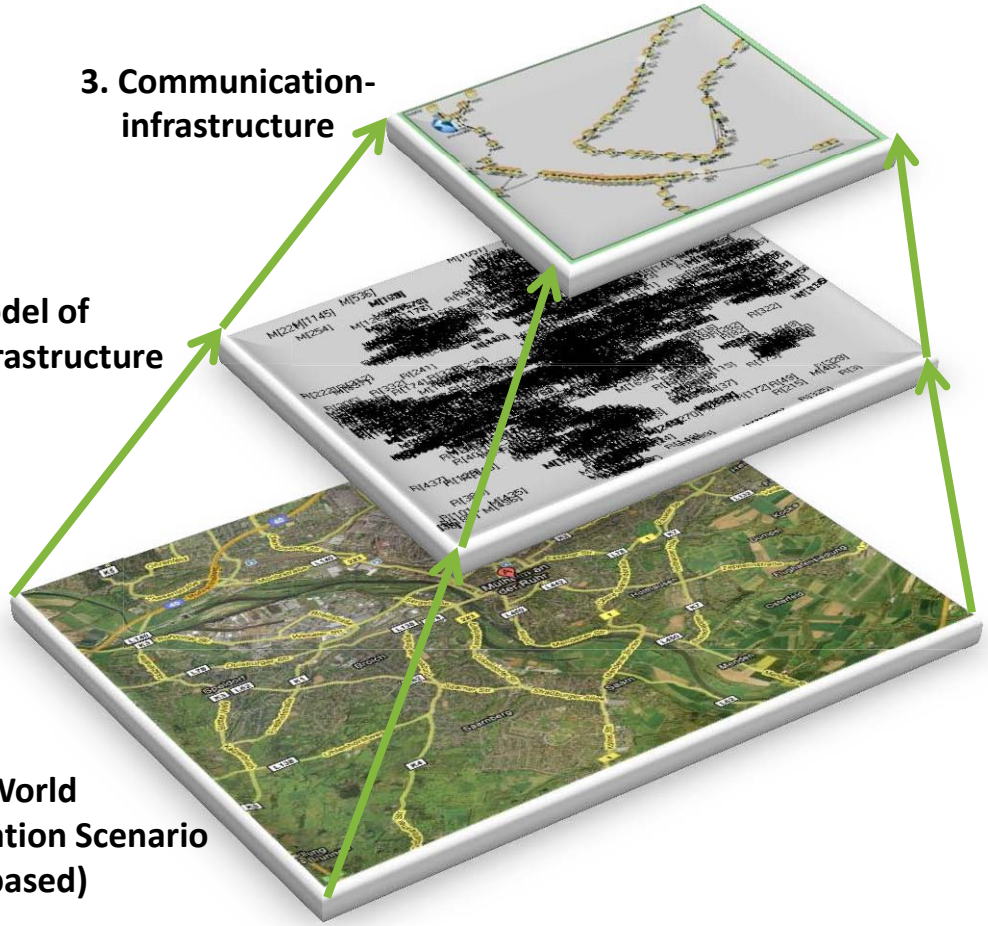
- Outdoor-to-Indoor
- Urban Topologies / NLOS
- Building Losses within Houses

$$PL_{tot} = PL_{B1}(d_{out} + d_{in}) + 15 + 15 \cdot (1-\cos(\Theta))^2 + 0.5 \cdot d_{in}$$



Parameters for Winner II C4

GEnerator for large-scale NEtwork SImulation Scenarios in OMNeT++ (GeNeSiS++)



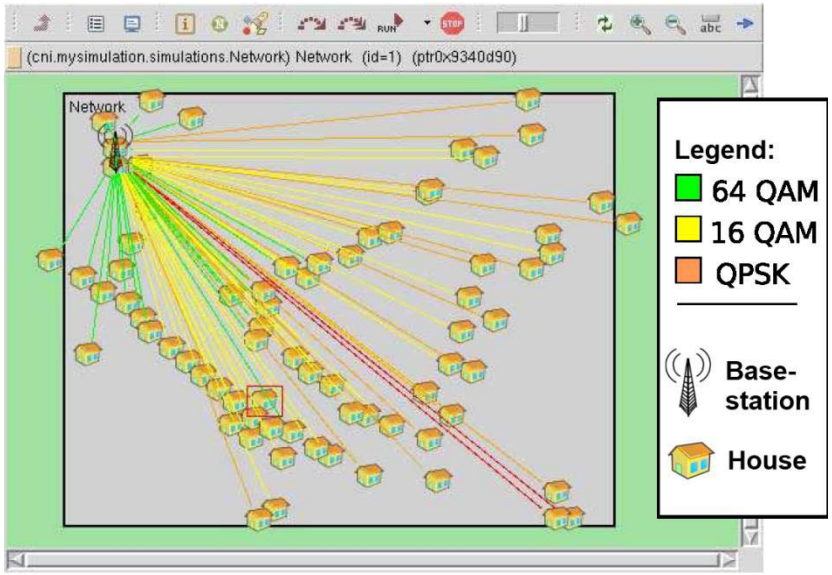
Real-world adaption:

- Topology generation based on geographic position (Latitude and Longitude)
- Connection to MySQL Database containing coordinates and node information
- Methods library for accessing data, coordinates transformation, distance calculation and neighbourlist generation.
- Flexible scenario generation

[1] C. Müller, S. Subik, A. Wolff, C. Wietfeld. "A System Design Framework for Scalability Analysis of Geographic Routing Algorithms in Large-Scale Mesh Networks", 3rd International Workshop on OMNeT++ co-located with International ICST Conference on Simulation Tools and Techniques (SIMUTools), Malaga, Spain, Mar 2010.

Exemplary Large-Scale Scenarios

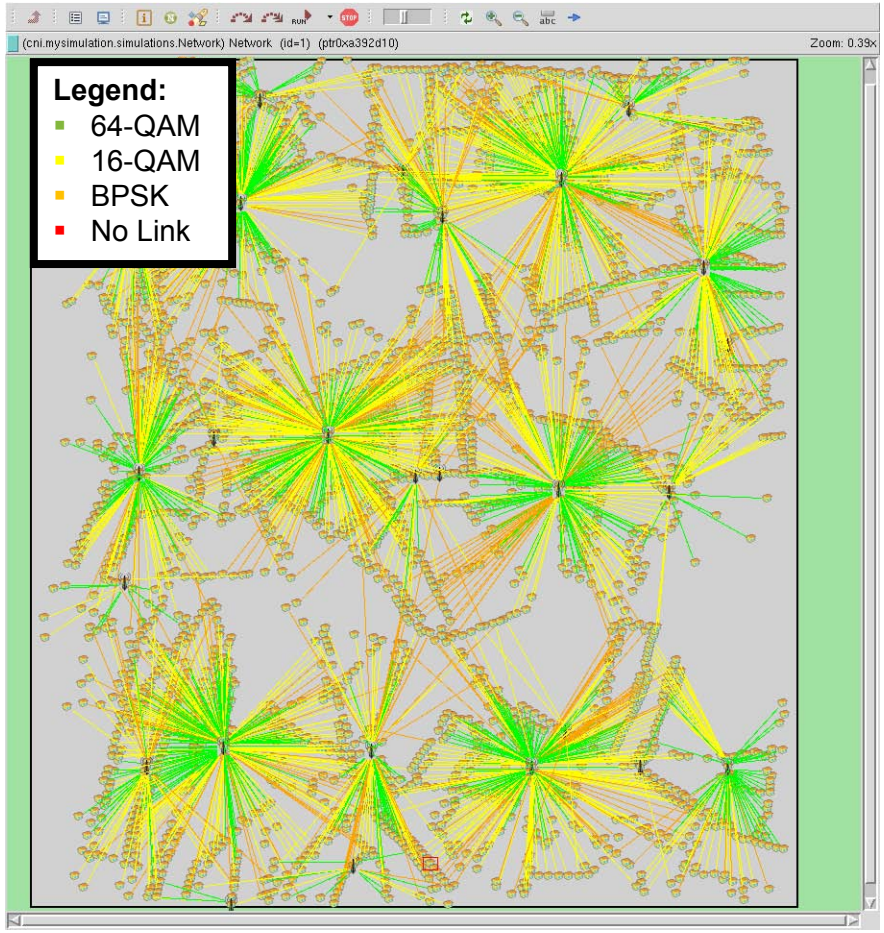
Large-Scale Scenario (Detail)



Large-Scale Scenario:

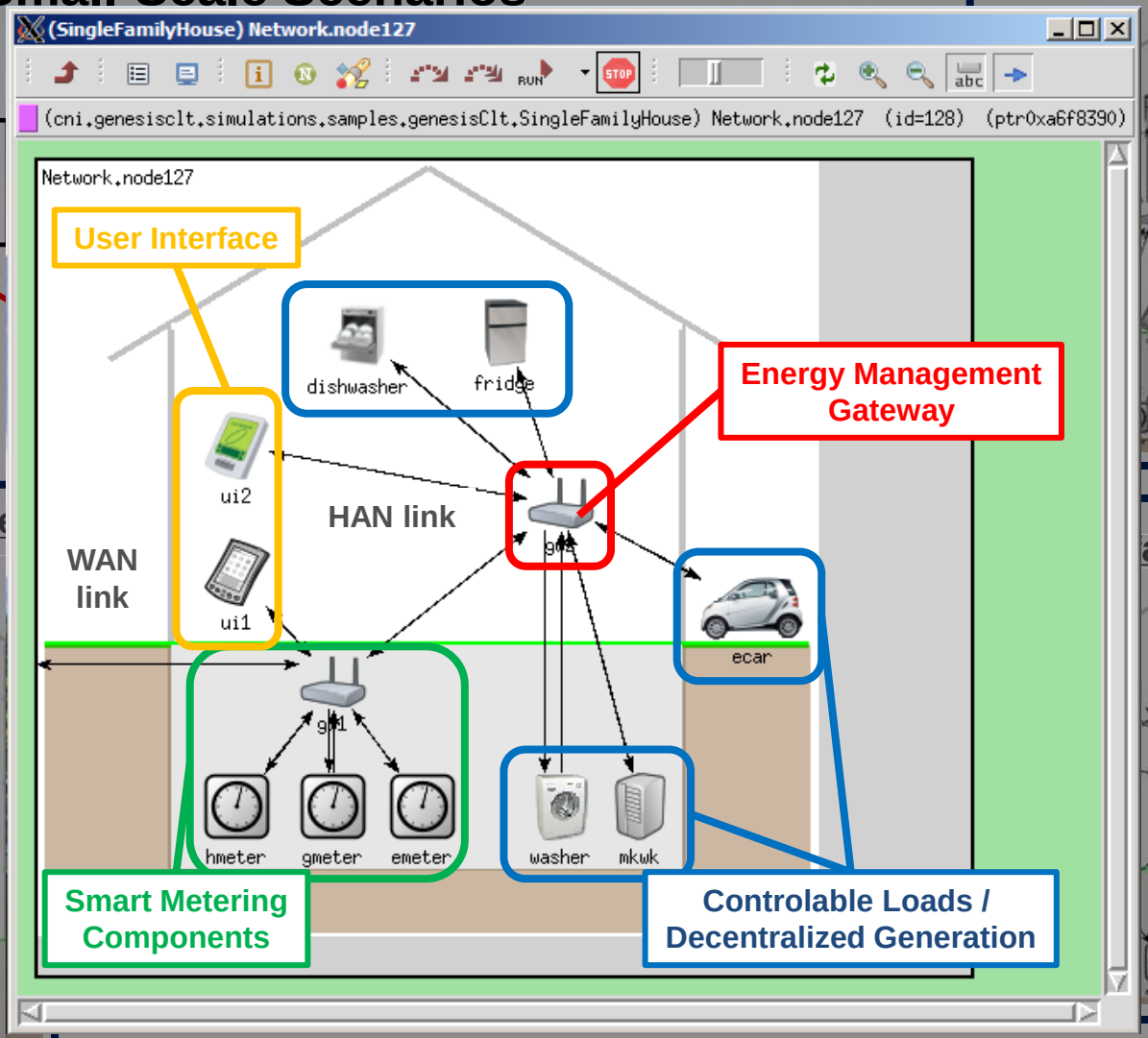
- Geo-based Scenario
- 802.16e (Mobile WiMAX) Infrastructure
- Suburban scenario
- ~10.000 different households

Large-Scale Scenario

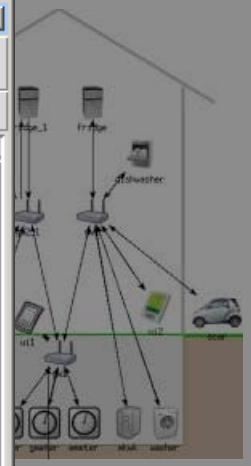


Exemplary Small-Scale Scenarios

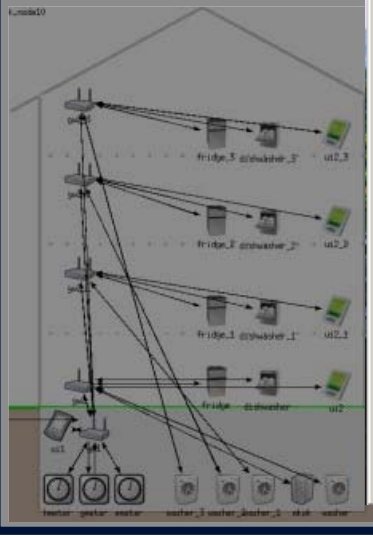
Infrastructure-komponents



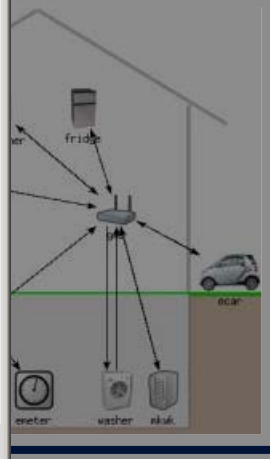
Double-family-house



Mulity-family-house

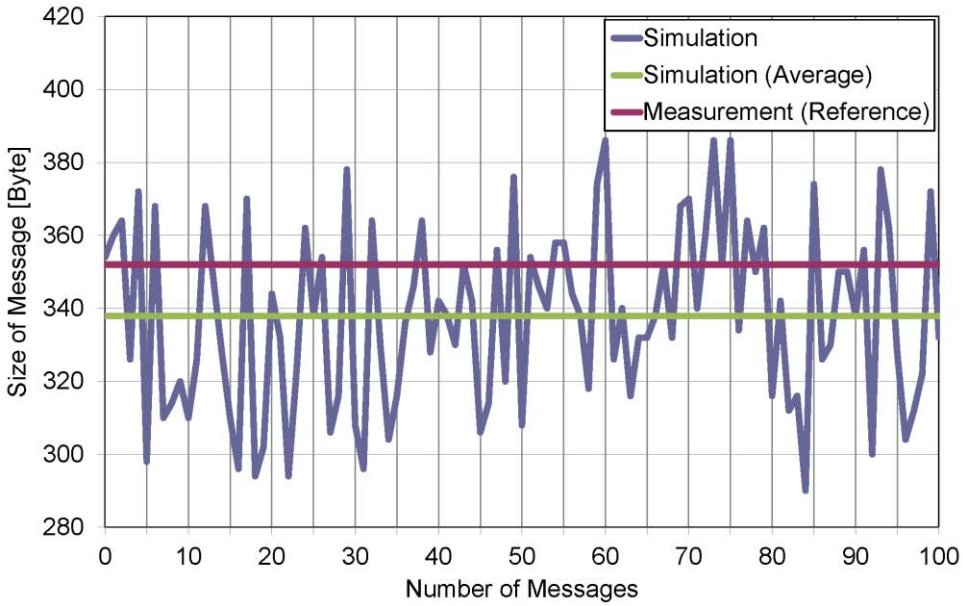


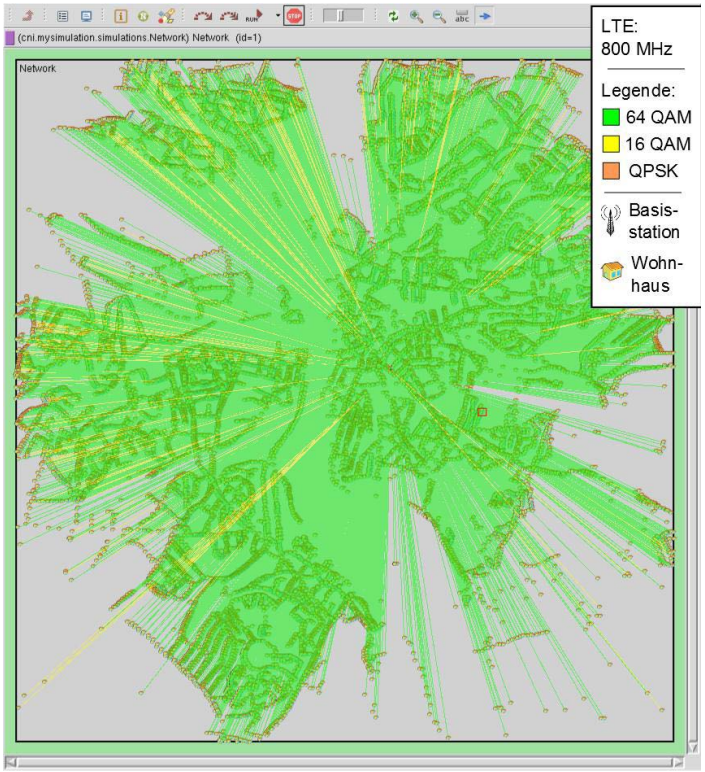
amily-house



Exemplary Performance Analysis

Analysis of Metering Data Format
(SML-getListResponse)





Network Planning for Wireless Technologies
with Building Penetration (Coverage Analysis for LTE at 800 MHz)

Conclusions and Outlook

- Proof-of-concept for a modularized OMNeT++ simulation environment based on Web Service on-demand module management.
- Analysis of topology specific influences on scalability for different technologies and various traffic patterns for Smart Grid applications.
- Exemplary analysis for suburban scenario with more than 10.000 different households combining detailed Home Area Networks has been presented.
- On-going work focuses on the evaluation of different technologies for the presented use cases in order to obtain network planning heuristics for Smart Grid ICT networks and optimization approaches for existing infrastructures.
- Proof-of-Concept for dynamic build automation (e.g. Ant, Maven)

Thank you for your Attention!