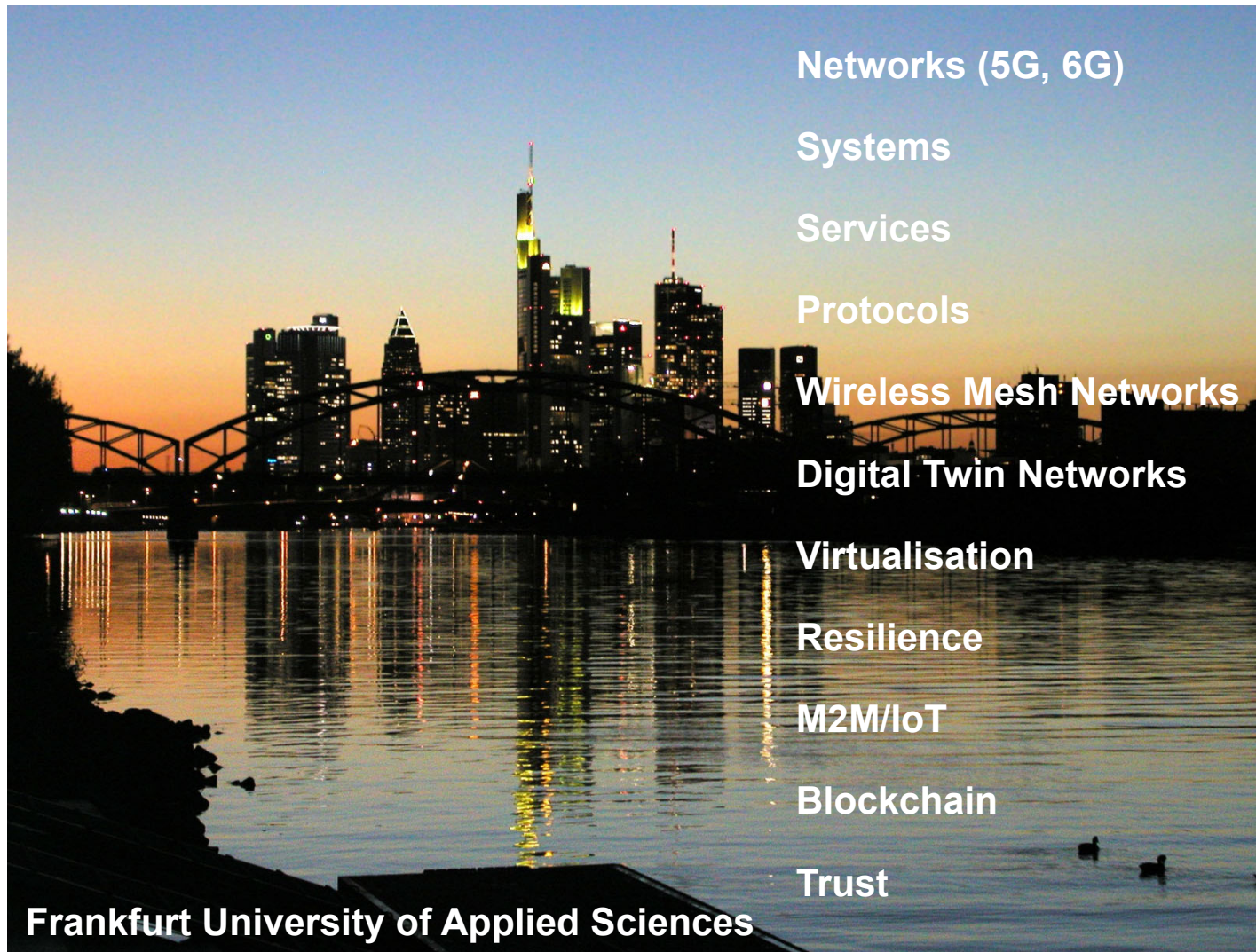# Research Group for Telecommunications Networks

Networks (5G, 6G)

Systems

Services

Protocols

Wireless Mesh Networks

Digital Twin Networks
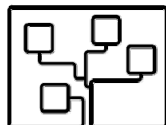
Virtualisation

Resilience

M2M/IoT

Blockchain

Trust

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Tele-
kommunikationsnetze

Prof. Dr.-Ing. U. Trick
Prof. Dr. A. Lehmann

Research Group for Telecommunications Networks

Prof. Dr. Ulrich Trick
Telecommunications Networks

Prof. Dr. Armin Lehmann
Programming in
Information Technology
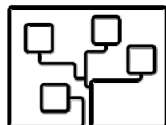
+ approx. 10 students

M.Eng. Gregor Frick

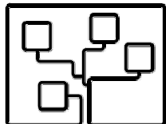**M.Sc. Alexander Seng**

M.Sc. Rami Khaldi

Dr. Besfort Shala

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kommunikationsnetze

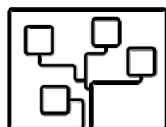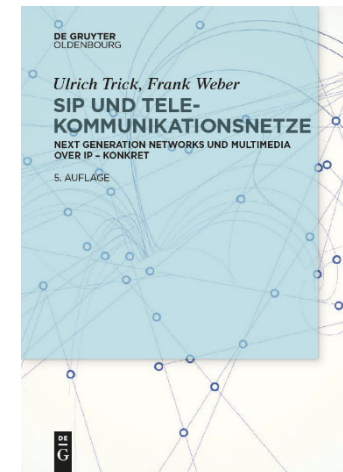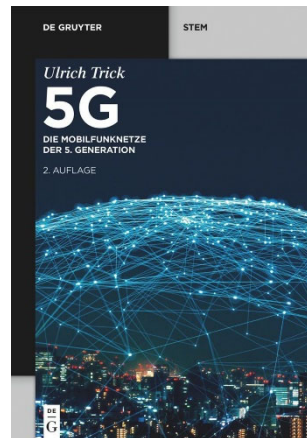Prof. Dr.-Ing. U. Trick
Prof. Dr. A. Lehmann

Subjects

- **Modelling, optimisation and migration of networks** (e.g. 5G, 6G)

- **Session Initiation Protocol** (SIP)**, WebRTC and SIP**

- **Future communication services and Application Servers incl. testing**

- **Peer-to-Peer** (P2P) **communication with Multimedia over IP**

- **NGN-systems and architectures, Wireless Mesh Networks** (WMN)**, resilience**

- **Network Functions Virtualisation** (NFV)**, network slicing, virtualisation technologies, Cloud Computing technologies**

- **Digital Twin Networks** (DTN)

- **Smart Home, Smart Grid and Smart Market**

- **Machine-to-Machine Communications** (M2M)**/Internet of Things** (IoT)

- **Trust, Blockchain, Distributed Ledger**

- **Software Engineering in Telecommunications**

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- **R&D activities cover the entire cycle from requirements to concepts and implementations to evaluation and testing**

- **Performed R&D projects: 7 BMBF, 11 companies, 5 internal**

- **Currently 3 PhD students, 1 postdoc, 2 professors**
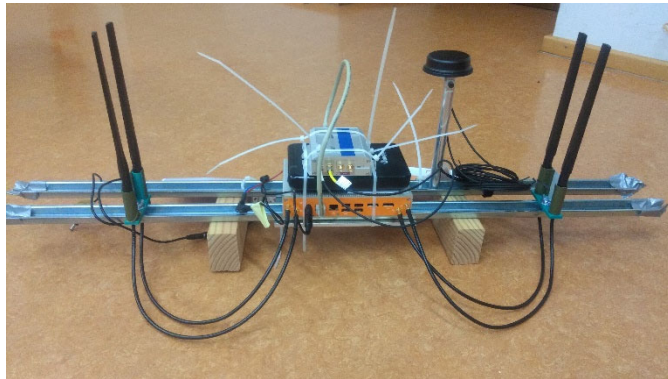- **Currently 1 company project, 3 internal R&D projects**

- **More than 100 publications**

- **Partners so far:**
  - **4 universities**
  - **17 companies**
  - **1 public authority**

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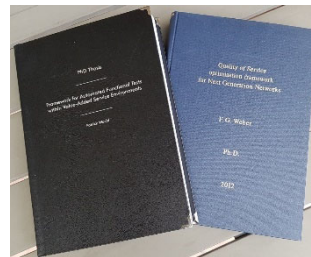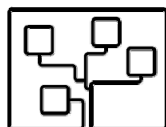Prof. Dr.-Ing. U. Trick
Prof. Dr. A. Lehmann

- **Laboratory for Telecommunications Networks**

- **Close collaboration with CSCAN at the University of Plymouth since 2006**

- **Since 2015 PhD Frankfurt Node of the University of Plymouth**
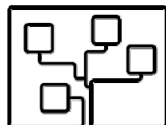
- **Since 2012 7 PhDs**

- **Member of the Hessian Promotionszentrum für Angewandte Informatik (PZAI) since its foundation in November 2017**
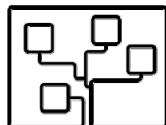
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Prof. Dr. A. Lehmann

- **Future telecommunication infrastructure**; 07/2002-03/2003 (Univ. of Applied Sciences)
- **Optimisation of heterogeneous, packet switched telecommunication networks**; 10/2003-04/2005 (BMBF)
- **Development of a concept for a new telecommunication network**; 01/2005-03/2005 (company project)
- **Emergency call with Voice over IP**; 05/2005-01/2006 (company project)
- **Requirements for Carrier Class VoIP networks**; 08/2005-01/2006 (company project)
- **Anti-spam and Click-to-Dial with Voice over IP**; 08/2005-02/2006 (company project)
- **Complete integration of IP networks for multi-media communication** (Next Generation Network); 09/2005-12/2005 (Univ. of Applied Sciences Frankfurt/M.)
- **High Quality Audio VoIP technology for broadcasting stations**; 10/2005-03/2006 (company project)
- **Conceptual Study for the monitoring of Quality of Service with VoIP** (Voice over IP) **in an NGN** (Next Generation Network); 03/2006-11/2006 (company project)
- **Services in NGN**; 10/2006-04/2007 (company project)
- **Services and architectures in future telecommunication networks** (DazTel); 11/2005-04/2008 (University of Applied Sciences Frankfurt/M.)
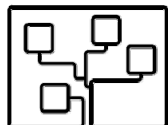
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Prof. Dr. A. Lehmann

Completed Research and Development Projects　　2

- **Improvement of Quality of Service across networks with SIP-based VoIP communication** (QoSSIP); 10/2005-04/2008 (BMBF)
- **Multimedia over IP and security**; 11/2007-05/2008 (company project)
- **Provisioning and Developing of Value-added Services in NGN**; 02/2009-03/2009 (company project)
- **NGN Core technology**; 10/2008-10/2009 (company project)
- **IMS- or P2P-based provisioning and development of services for customer-specific communication processes** (TeamCom); 05/2007-05/2010 (BMBF)
- **Unified Communications System**; 04/2008-08/2010 (company project)
- **Test-controlled evolution and automated provisioning of communication services** (ComGeneration); 07/2009-09/2012 (BMBF)
- **Easy-Service Creation for Home and Energy Management** (e-SCHEMA); 10/2011-09/2014 (BMBF)
- **Optimised P2P service architecture for high-available M2M applications** (P2P4M2M); 04/2015-03/2019 (BMBF)
- **Optimising Wireless Mesh Networks with Network Virtualisation for Disaster Operations** (VirtO4WMN); 10/2017-09/2021 (BMBF)

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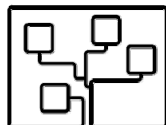kommunikationsnetze

Prof. Dr.-Ing. U. Trick
Prof. Dr. A. Lehmann

- **Virtualization and Energy Consumption Optimization in WMN** (VirtEnWMN); 10/2021 - 03/2022 (internal project)
- **Security and Test Optimisation of Decentralised M2M Application Services** (SecTOptM2M); 04/2019-04/2022 (internal project)
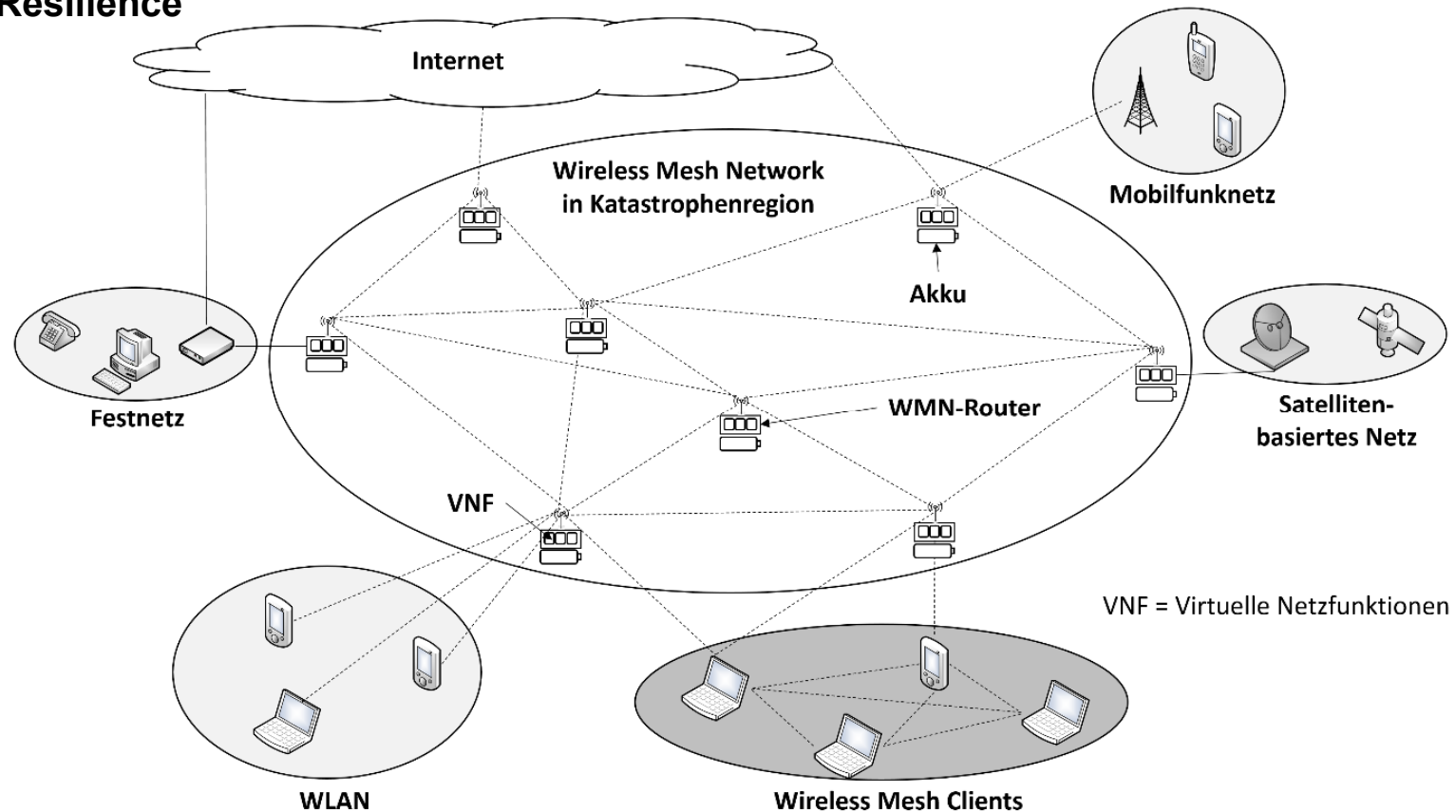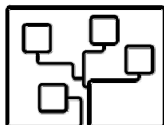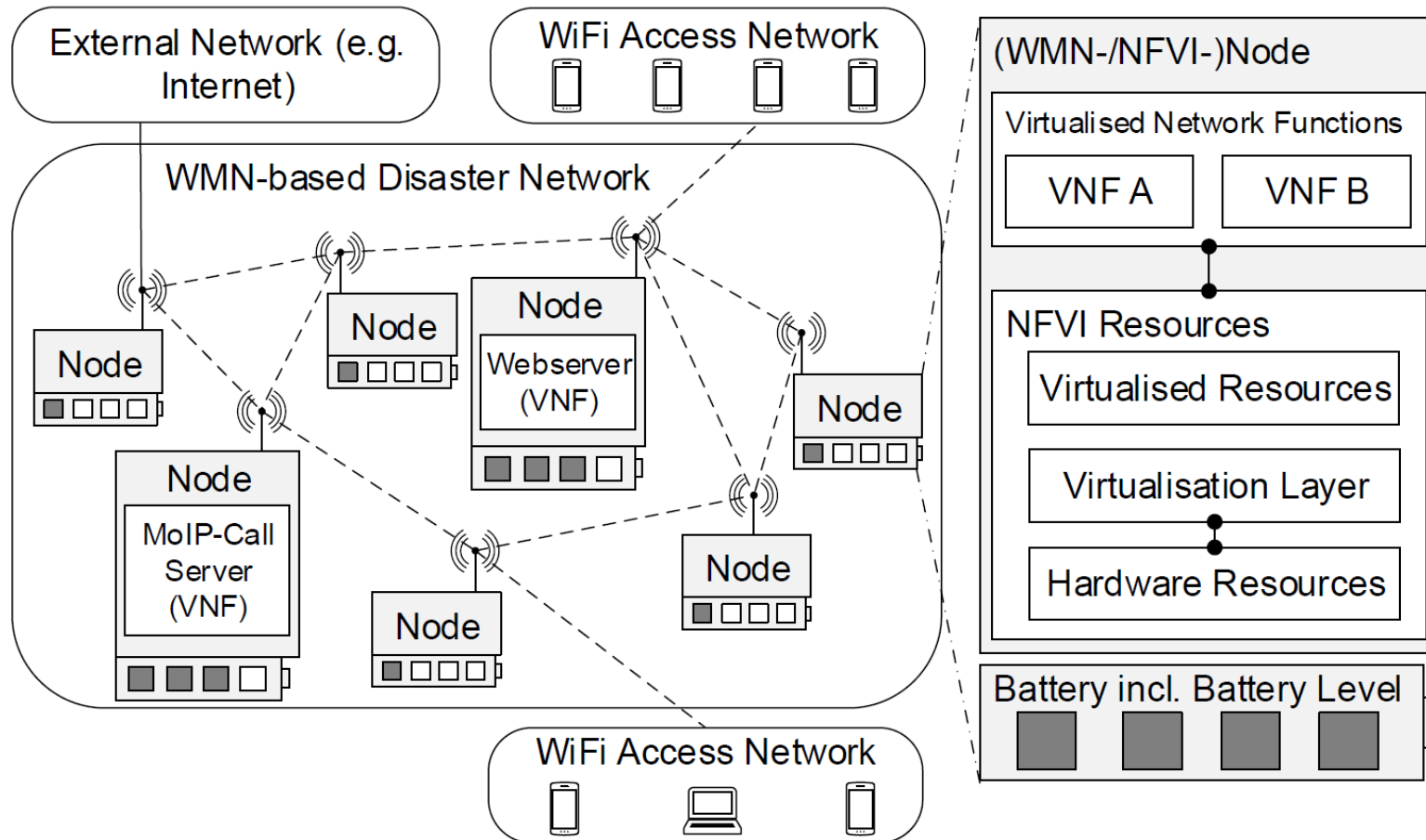
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Prof. Dr.-Ing. U. Trick
Prof. Dr. A. Lehmann

- **Network Slicing for WMN** (NS4WMN); 11/2020 - 10/2024 (internal project)

- **Distributed Orchestration and Resilience in WMN** (OrchResWMN); 10/2021 - 06/2024 (internal project)

- **Digital Twin for Heterogeneous 5G/6G Subnetworks**; 09/2023 – 08/2026 (internal project)

- **SIP-Routing Infrastructure for Audio over IP**; 04/2011-12/2023 (company project)

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- **OrchResWMN**
  - **WMN optimisation** (e.g. throughput)
  - **Optimisation of energy consumption** (e.g. energy model)
  - **NFV** (Network Functions Virtualisation)
  - **Distributed orchestration**
  - **Resilience**

Internet

Wireless Mesh Network
in Katastrophenregion

Mobilfunknetz

Akku

Festnetz

WMN-Router

Satelliten-
basiertes Netz

VNF

VNF = Virtuelle Netzfunktionen

WLAN

Wireless Mesh Clients

- **Virtualisation**

**Prof. Dr.-Ing. U. Trick
Prof. Dr. A. Lehmann**

- **Clustering in WMN, distributed orchestration, resilience**
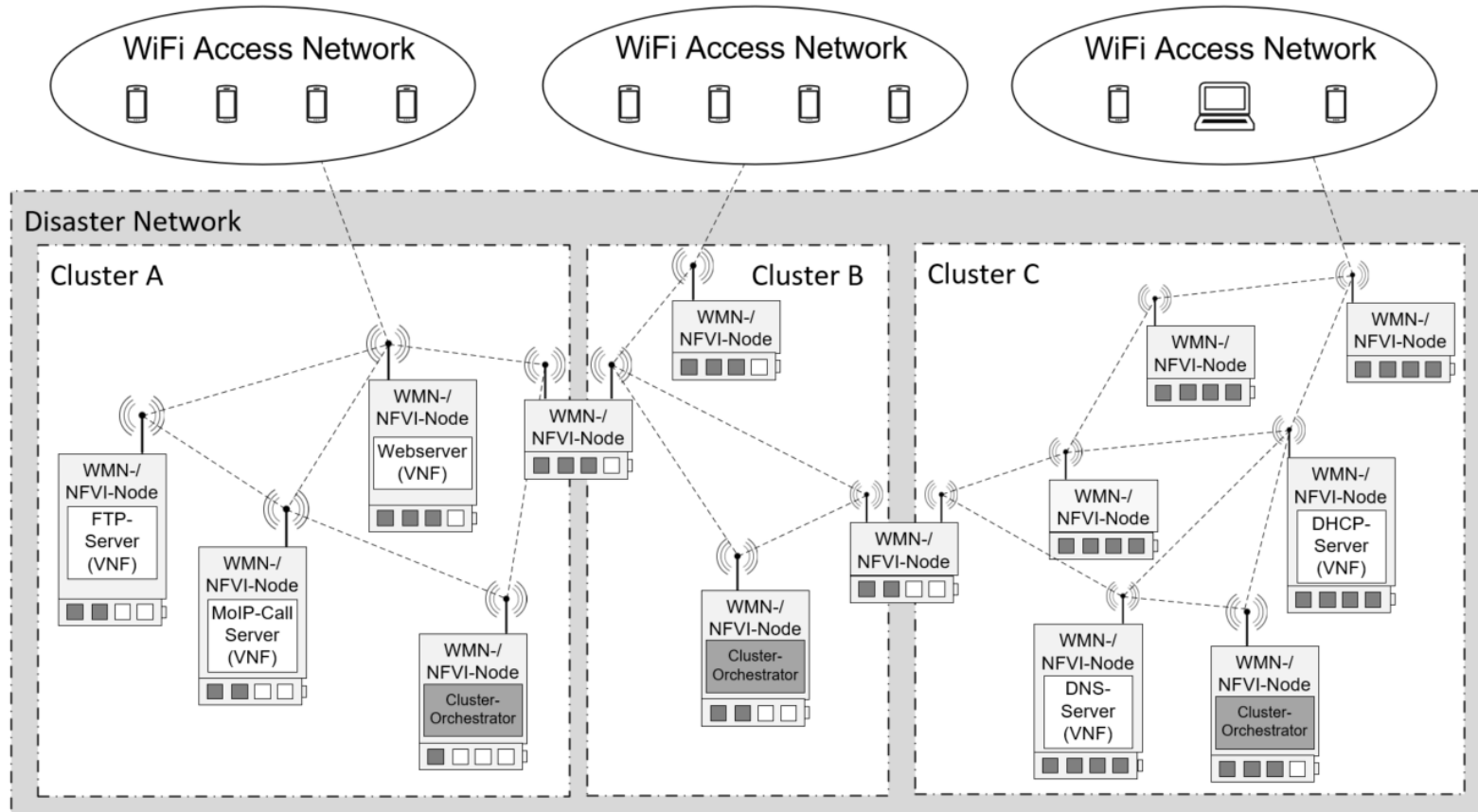
VNF = Virtual Network Function
NFVI = Network Functions Virtualisation Infrastructure

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Prof. Dr. A. Lehmann
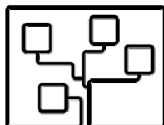
- **NS4WMN – Network slicing in WMN**

A wireless mesh network can extend the coverage with Wi-Fi on large areas. However, it is not possible to change the architecture dynamically to fit the requirements of specific services or support multitenancy.

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Application

Application

Wireless Mesh Network
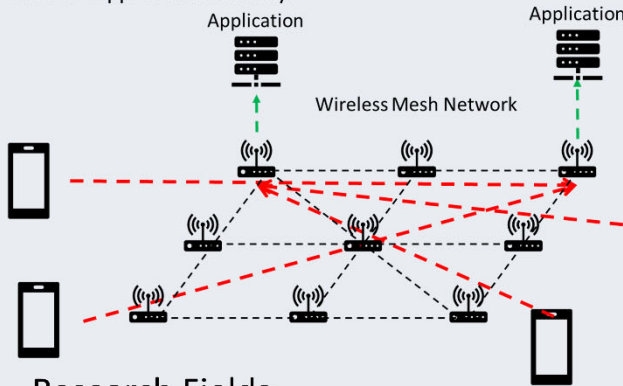
Network Slicing provides a solution for this problem through virtualisation of the network and the functionality.

Network Slice

Virtual Links

Virtual Network Functions
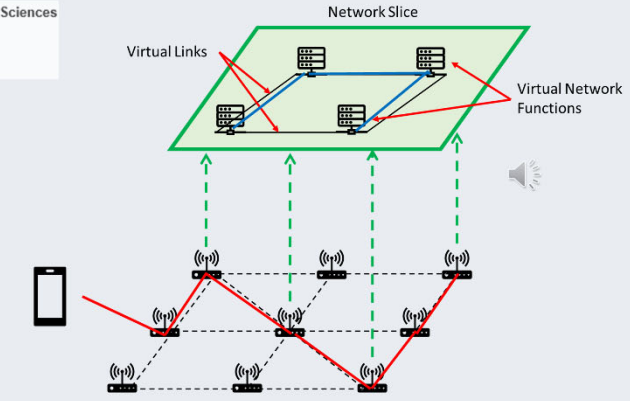
This allows the creation of multiple independent, autonomous and isolated networks on the same physical infrastructure. These networks can be adapted to the services provided.

Research Fields:

Core Network Slicing

orchestrator

orchestrator   orchestrator
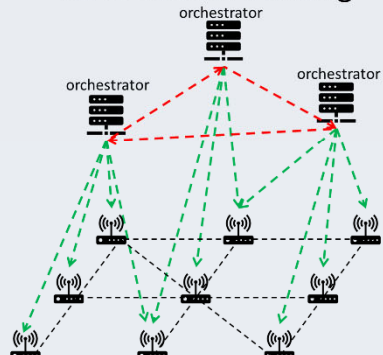
Core Network Slicing describes the management and orchestration of the slices and the logical connection between the virtual network functions

Access and Transport Network Slicing

Access Network

Transport Network
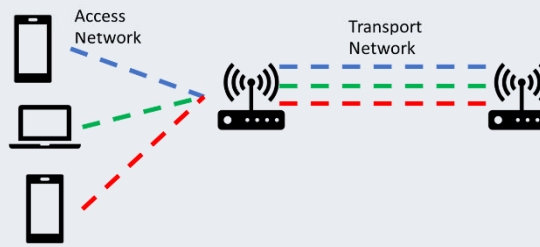
Access Network Slicing describes the mechanisms for association and multiplexing of the radio resources in the network

Terminal Association

Slice 1	Slice 2	Slice 3
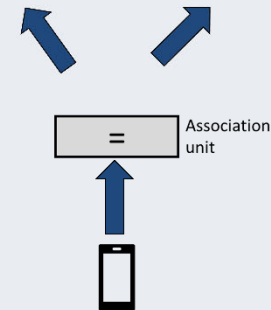
=   Association unit

Terminal association is the procedure of assigning a terminal device to a slice and corresponding services. This should be done without prior

- **Digital Twin for Heterogeneous 5G/6G Subnetworks**

Physikalisches Netzwerk
- Core Network
- (R)AN
- Umgebung
- Subnetwork

Steuerung

Datenerfassung

Digital Twin Network
- Management
- Modelle
  - Core
  - (R)AN
  - SubNet
  - ...
- Daten

Anwendungen
- Optimierte Resilienz
- Bestmögliche Netzabdeckung
- Optimale Platzierung
- Vorausplanung
- Prädiktion
- Netzmanagement
- ...
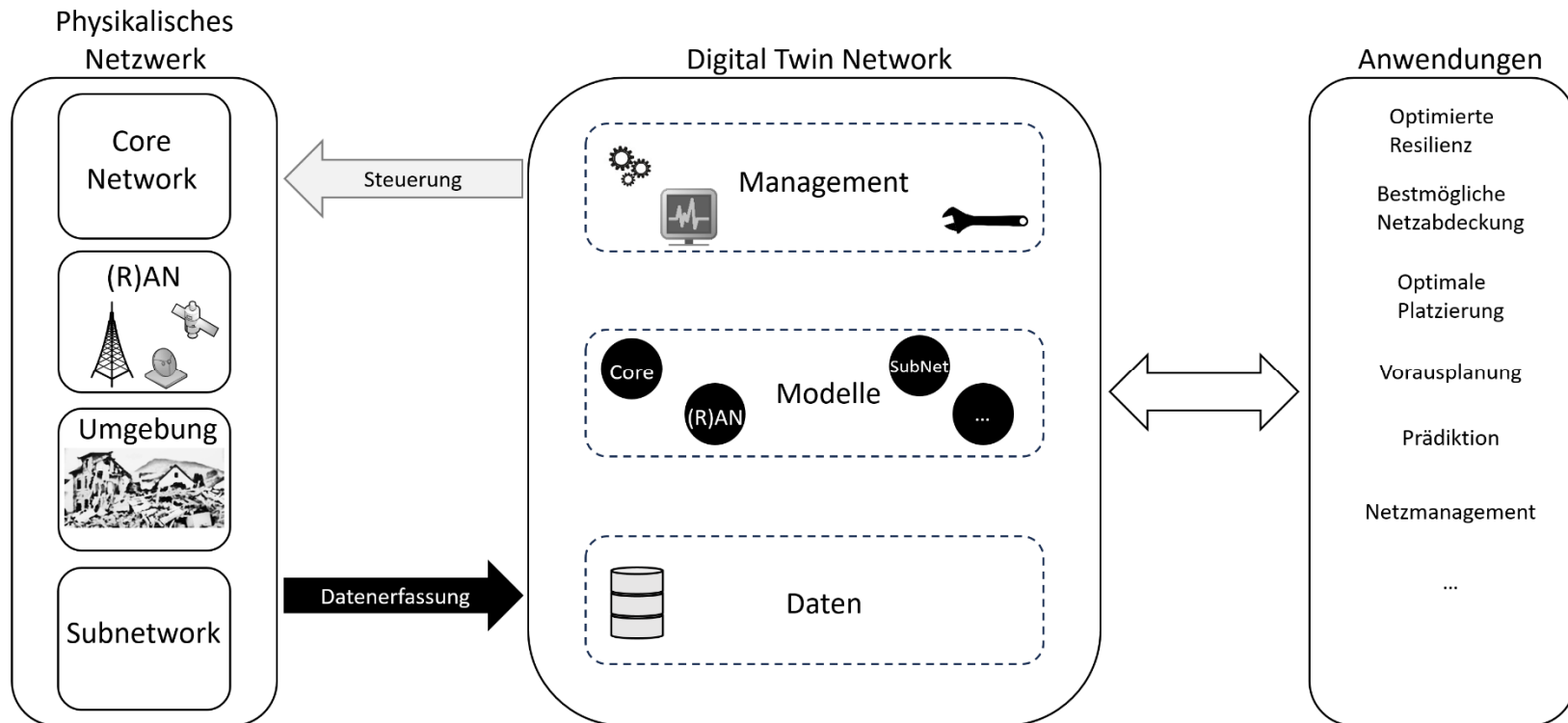
5G Solutions at Frankfurt UAS

- **5G with Open Source SW UERANSIM** (UE, gNB) **and OpenAirInterface** (5GC) **with Docker in CORE Network Emulator**

- **5G with Open Source SW Open5GS**
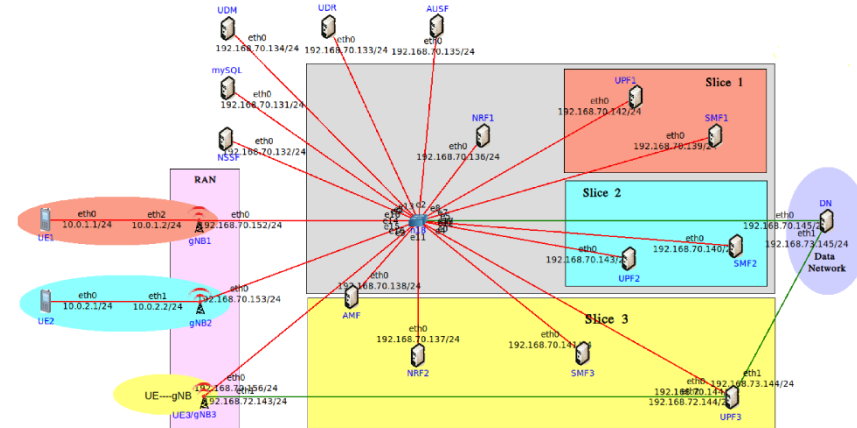
- **5G Testbed with Amari Callbox**
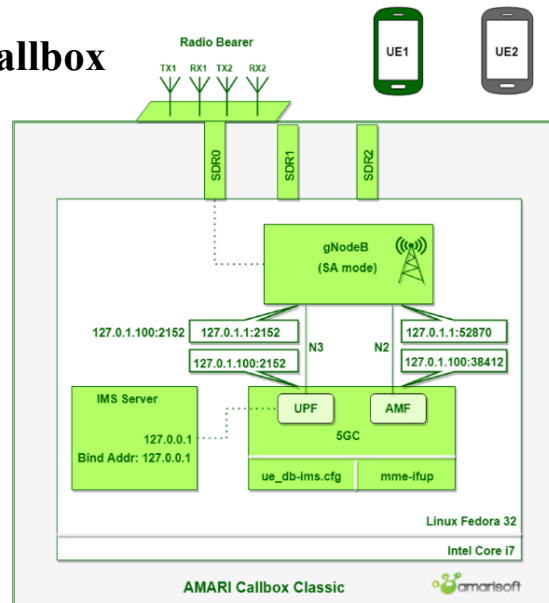
- **Own campus license for 3,7 – 3,8 GHz** (100 MHz)

Special Purpose Networks (SPN) for 6G

- **Autonomously operating SPN with internal subnets, incl. network slicing**
- **Concept for e.g. Body Area Networks** (BANs) **in 5G/6G, or Industry 4.0**
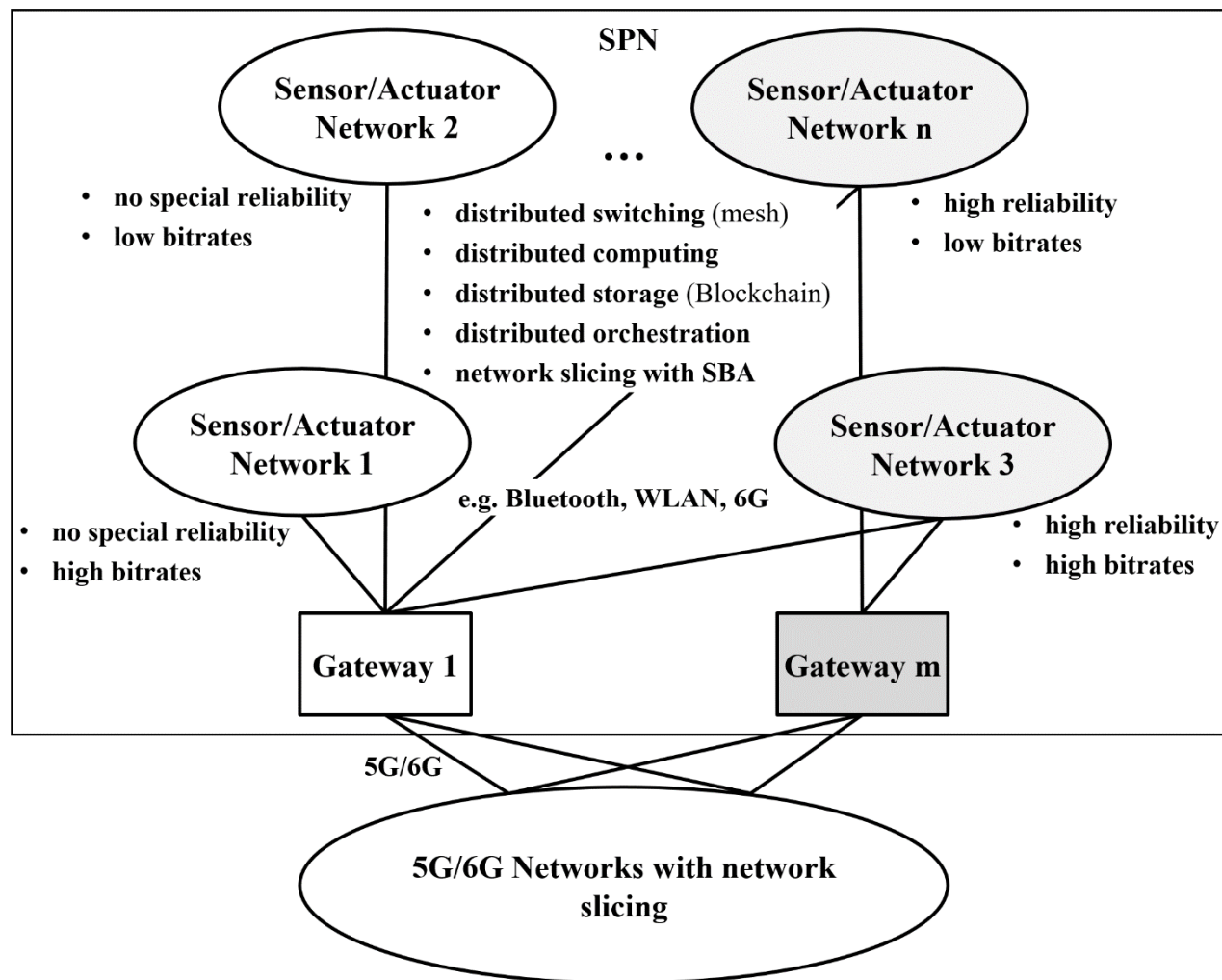
Research and development partners

AETA Audio Systems, Le Plessis Robinson/Frankreich	**ARD-Sternpunkt, Frankfurt**	**BT Germany, München und Frankfurt**
Centre for Security, Communications and Network Research (CSCAN) – Plymouth University	**Detecon International. Bonn**	**EVL Energieversorgung Limburg**
GIP, Mainz	**HEAG MediaNet, Darmstadt**	h_da HOCHSCHULE DARMSTADT UNIVERSITY OF APPLIED SCIENCES, aida INSTITUT FÜR ANGEWANDTE INFORMATIK DARMSTADT
Hochschule Osnabrück, Mobilkommunikation (Prof. Dr. Tönjes)	**JDSU, Eningen u.A.**	**NetModule, Eschborn**
NRM Netzdienste Rhein-Main, Frankfurt	**R-KOM, Regensburg**	**Robert Bosch, Stuttgart**
Tekelec, Morrisville/USA	**Teliko, Limburg**	**TH Köln, Institut für Nachrichtentechnik** (Prof. Dr. Grebe)
Technisches Hilfswerk, Bonn	**TransTel, Hamburg**	**T-Systems, Darmstadt**
Vodafone, Eschborn	**Vodafone, München**	

PhD topics

- PhD thesis, Frank Weber: **Quality of Service optimisation framework for Next Generation Networks**. Finished in September 2012

- PhD thesis, Armin Lehmann: **Service composition based on SIP peer-to-peer networks**. Finished in August 2014

- PhD thesis, Thomas Eichelmann: **Automated creation and provisioning of value-added telecommunication services**. Finished in April 2015

- PhD thesis, Patrick Wacht: **Framework for automated functional tests within value-added service environments**. Finished in August 2016

- PhD thesis, Michael Steinheimer: **Autonomous decentralised M2M application service provision**. Finished in July 2018

- PhD thesis, Besfort Shala: **On Trust Optimisation for Decentralised M2M Services**. Finished in November 2021

- PhD thesis, Auberlin Paguem Tchinda: **Optimisation of Wireless Disaster Telecommunication Network Based on Network Functions Virtualisation Under Special Consideration of Energy Consumption.** Finished in December 2022

- PhD working title, Gregor Frick: **Optimisation of the Resilience of a Wireless Mesh Network for Disaster Scenarios Through Network Function Virtualisation with Distributed Orchestration**

- PhD working title, Alexander Seng: **Network Slicing for Wireless Mesh Networks**

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