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Opportunities and Research Challenges of 5G Networks

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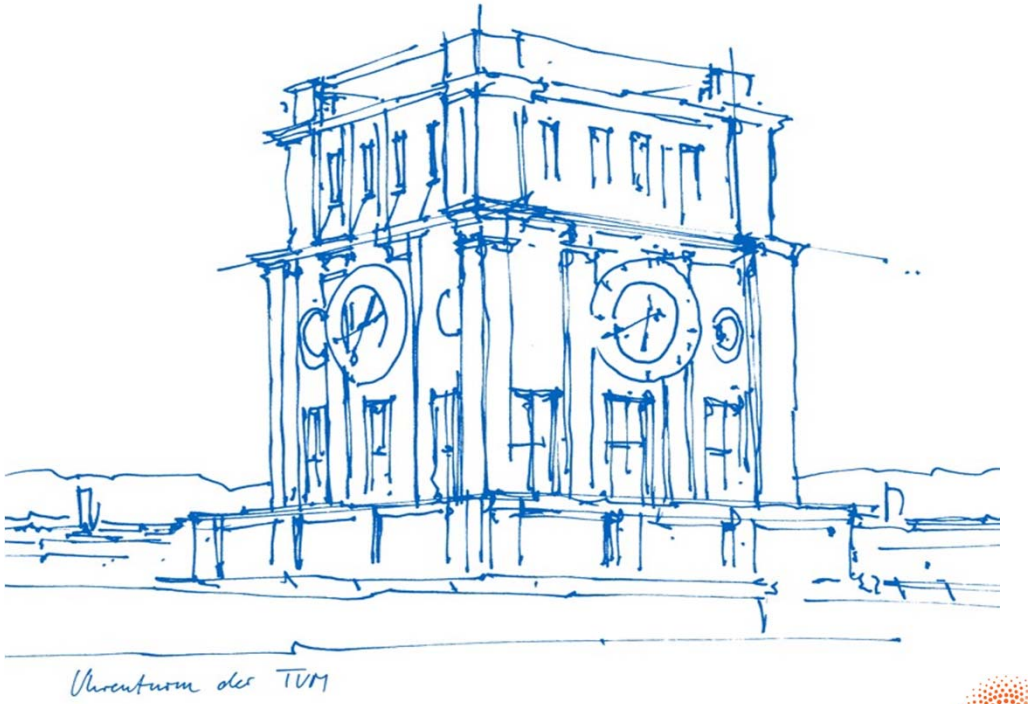
www.networkflexibility.org

Oct. 22, 2019

Wireless Congress Munich



This work is part of a project that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program grant agreement No 647158 – **FlexNets (2015 – 2020)**.

5G

→ *opens up fundamentally new opportunities*

→ *research challenges for network infrastructure*

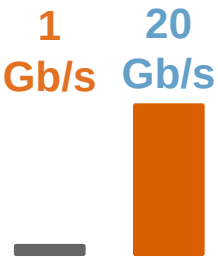
Important challenge: flexibility and dynamic adaptation

→ *we addess this with “5G Research Hub Munich” @ TUM*

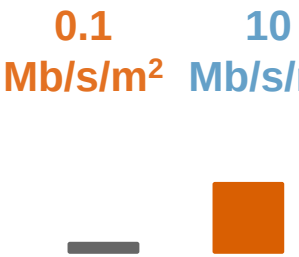
5G Opportunities

Comparison of 4G and 5G System Parameters

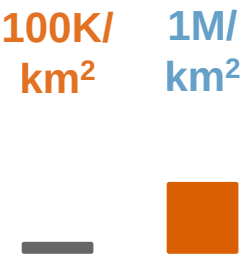
4G – 5G comparison



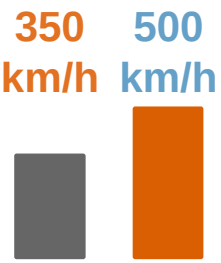
data rate



data processing

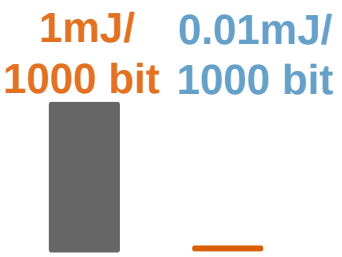


device density



mobility

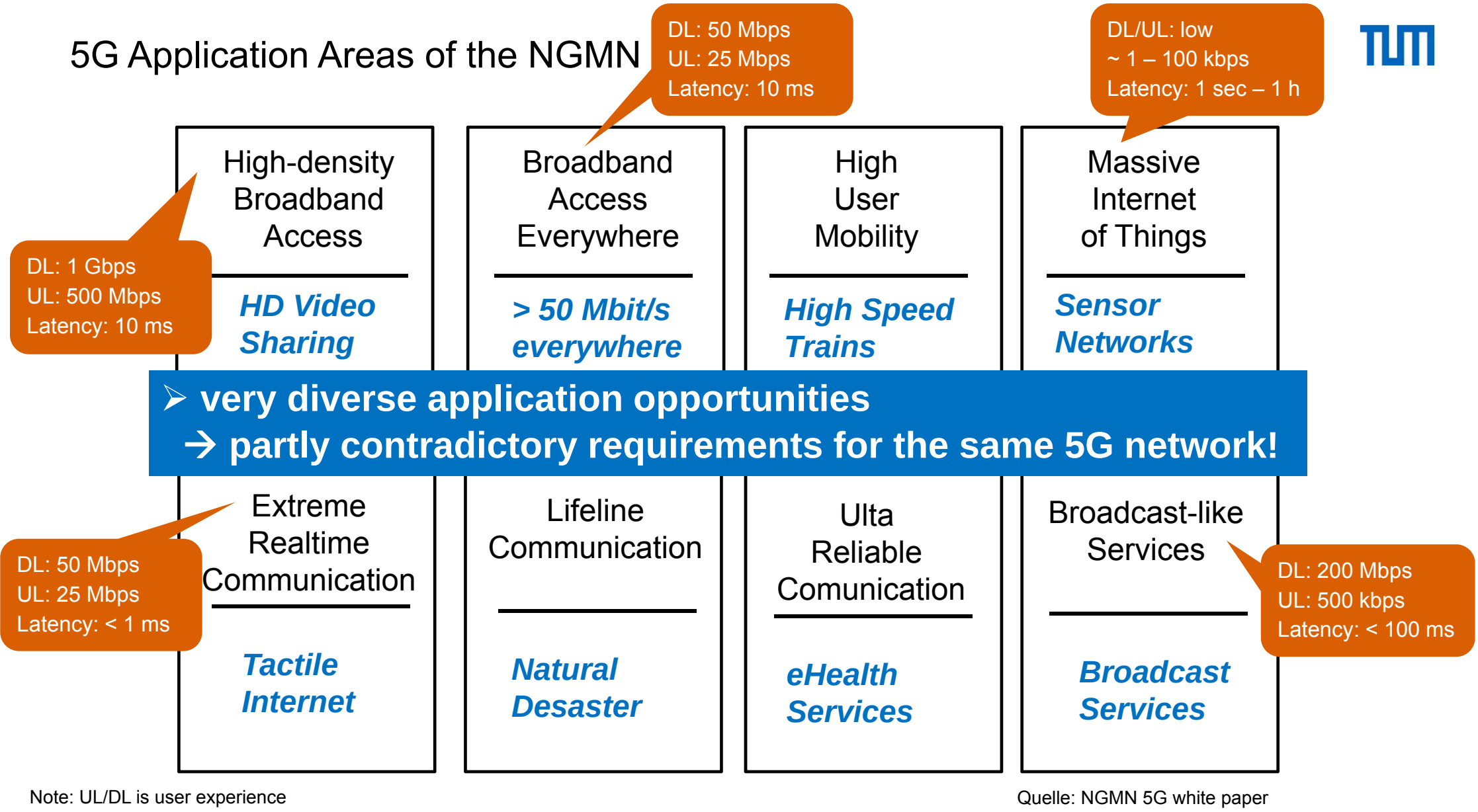
latency



energy consumption

Quelle: Young, L. J. (2015): *Telecom Experts Plot a Path to 5G*. IEEE Spectrum, Vol. 52, no 10 (INT), Oct. 2015

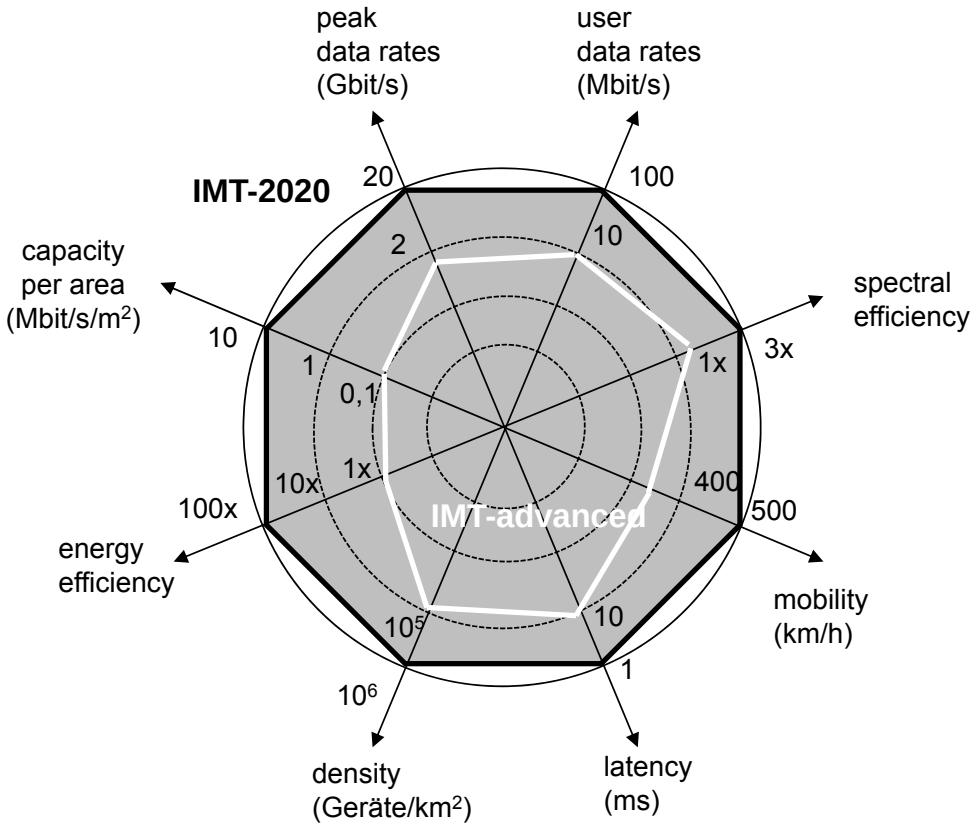
5G Application Areas of the NGMN



Note: UL/DL is user experience

Quelle: NGMN 5G white paper

5G from the viewpoint of the radio networks



- **5G promises a higher performance in many aspects**
- **Not all can be provided at the sam time!**

Quelle: ITU-R (2015): Recommendation ITU-R M.2083-0 IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond (09/2015)

Three Service Areas for 5G

eMBB

enhanced Mobile BroadBand

mMTC/ mIoT

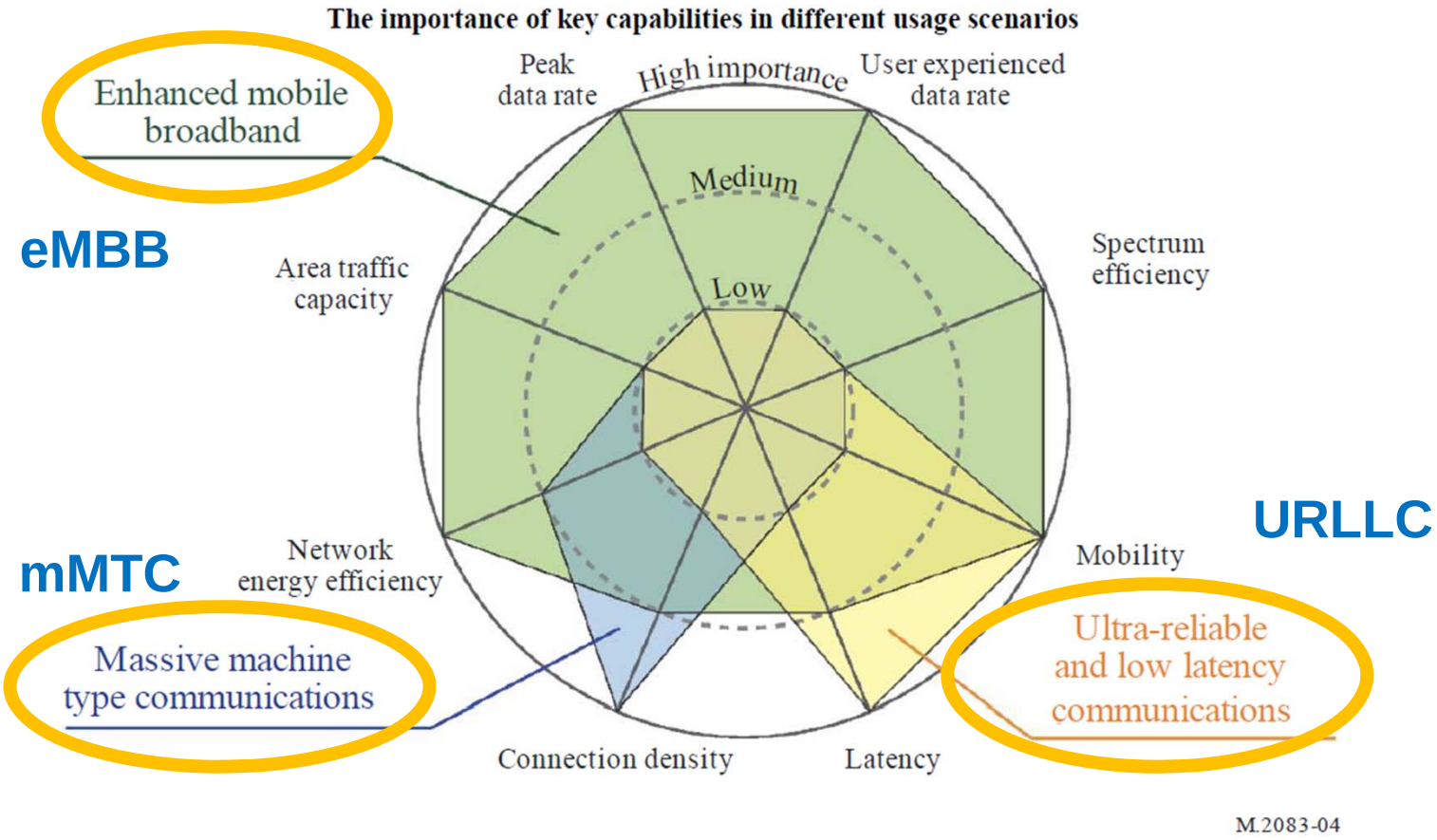
massive Machine-Type Communication / massive Internet of Things

URLLC

Ultra Reliable Low Latency Communication

Bildquelle: 3gpp.org

Matching applications to the 3 main 5G services



➢ **Not all aspects are needed for all services**

Quelle: ITU-R (2015): Recommendation ITU-R M.2083-0 IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond (09/2015)

Germany: Spectrum Auction AND (local) **Spectrum Assignment**

- After the auction:
  - Antragsverfahren für Spectrum allocation in 3,7 GHz – 3,8 GHz
  - for local usage
  - Goal: regional operators, production sites, small medium enterprises, start-ups, local communities and stakeholders for agriculture and forestry → use the opportunities of 5G

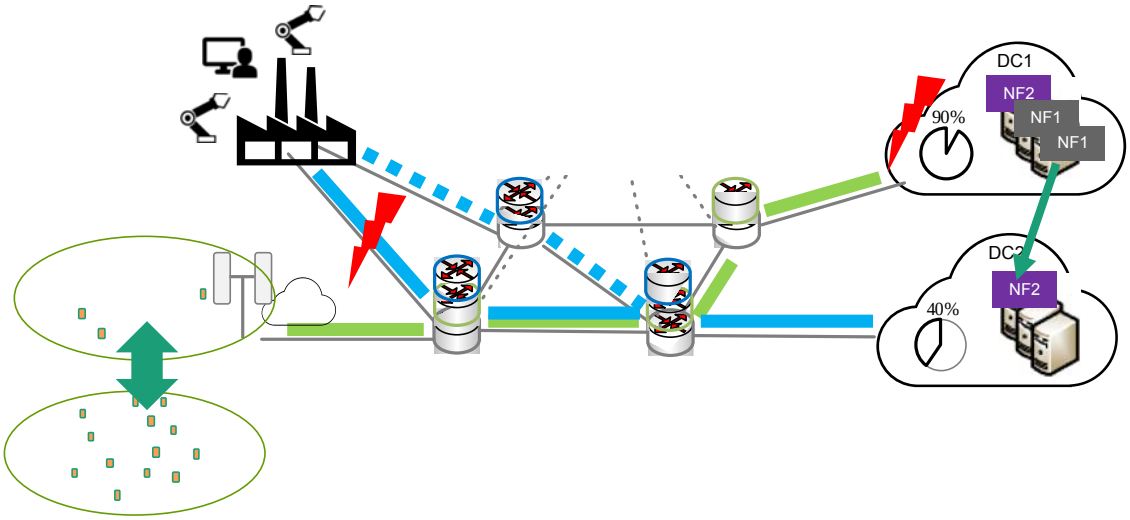
- Keywords „Private 5G“ – „5G Campus Networks“– „non public networks“

Diverse Requirements demand for Flexible 5G Systems

5G Challenges: *Dynamic Changes and Timely Adaptation*

Beyond eMBB, massive IoT and URLLC new stakeholders bring ...

- *Exploding user densities*
- *Sudden change in demands*
- *High rate vs. low latency requests*
- *Local events vs. wide area popularity*

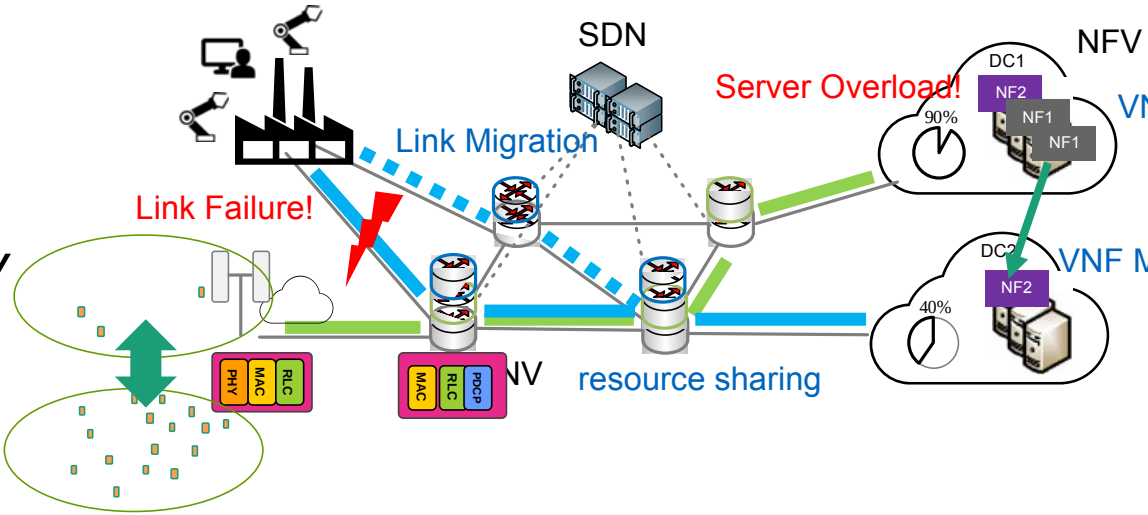


... to be addressed in a timely and cost efficient manner

5G Opportunities: *Programmability and Flexibility*

✓ Technology basis to support flexibility and adaptation

- *Network and RAN slicing*
- *Network Function Virtualization*
- *RAN Function Split*
- *SDN for control plane programmability*
- *Programmable hardware*
- *Data-driven adaptation*

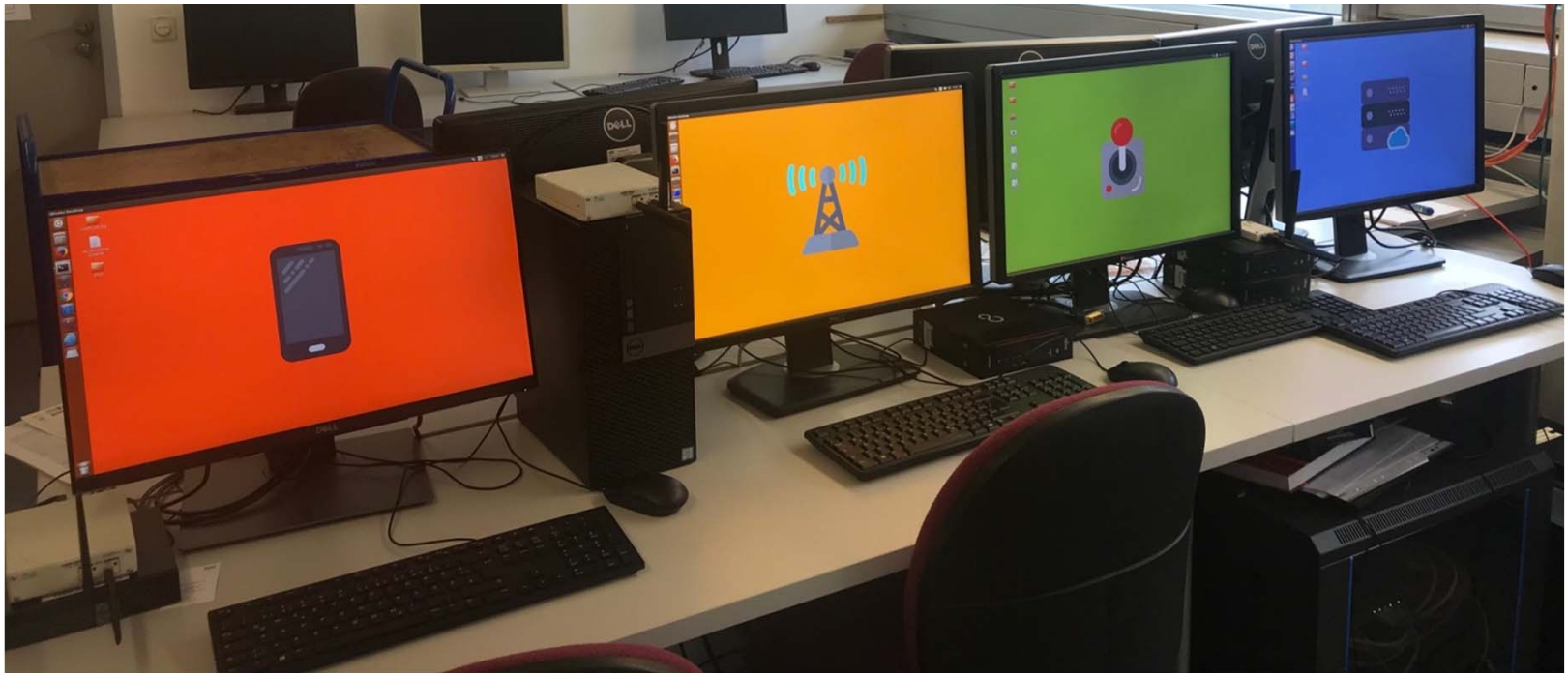


o Yet, we miss experience with adaptive 5G systems …

… from an end-to-end perspective

What is a flexible 5G system?

Example: Dynamic 5G RAN function split

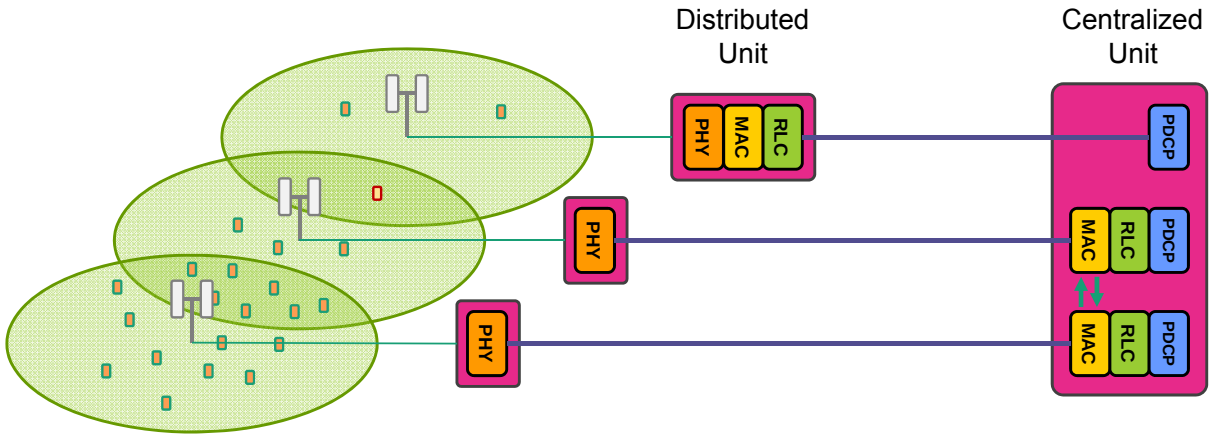


Based on a full Proof-of-Concept implementation at TUM

Foto: TUM LKN

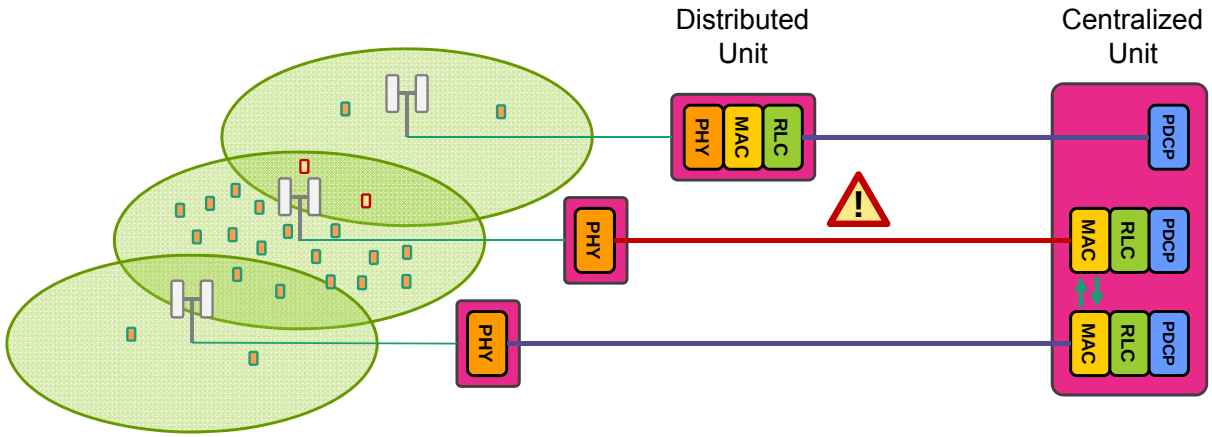
Fixed 5G Function Split

- Function split implemented on dedicated hardware
- Difficult to update
- User dynamics lead to



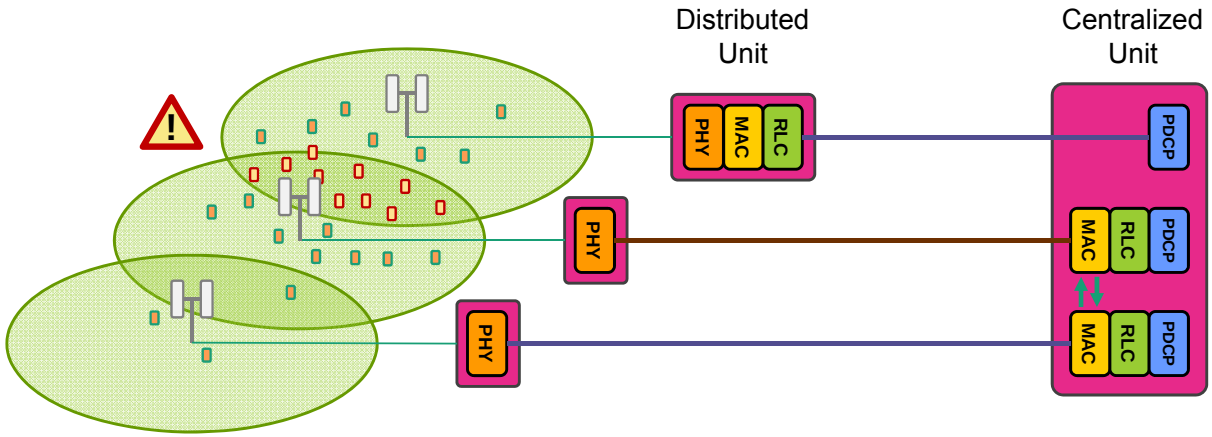
Fixed 5G Function Split

- Function split implemented on dedicated hardware
- Difficult to update
- User dynamics lead to
  - Network congestion



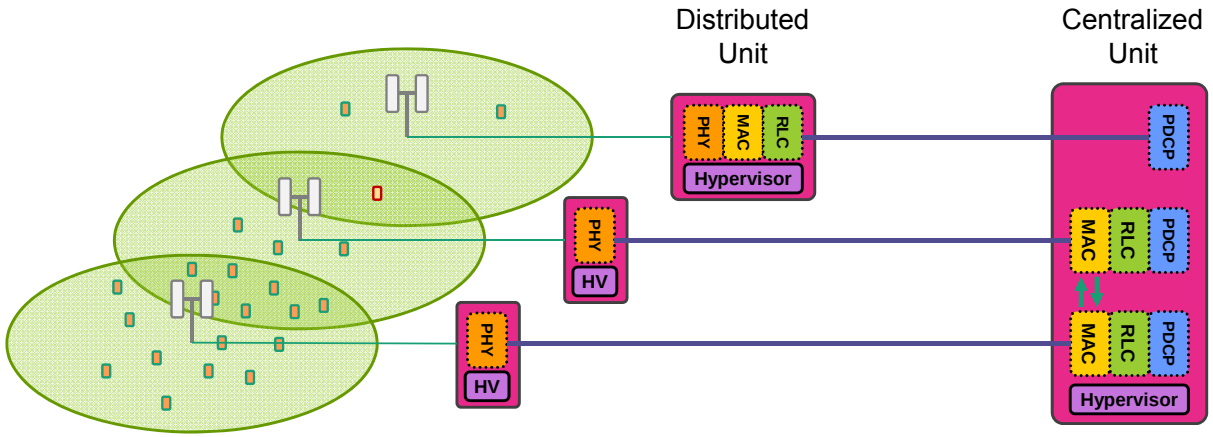
Fixed 5G Function Split

- Function split implemented on dedicated hardware
- Difficult to update
- User dynamics lead to
  - Network congestion
  - Unmanaged interference



NFV-based 5G+ Function Split

- Softwarized functions on off-the-shelf hardware
- Simple to deploy and update



NFV-based 5G+ Function Split

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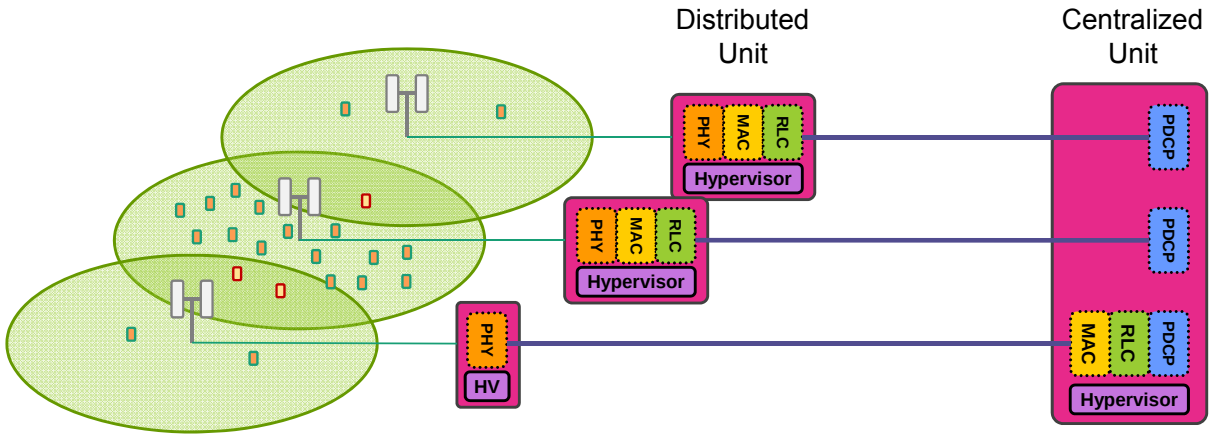
- Simple to deploy and update
- Functions can be migrated to adapt to dynamics



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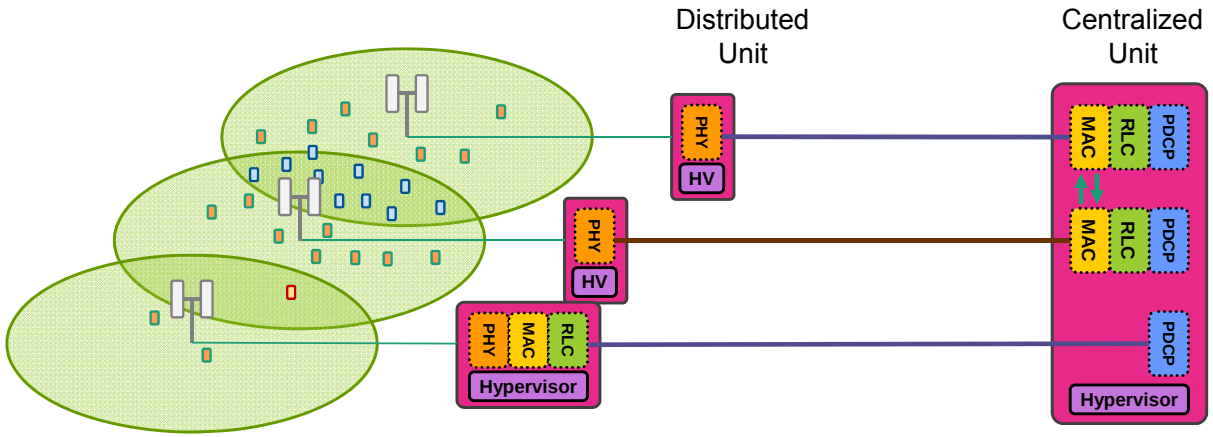
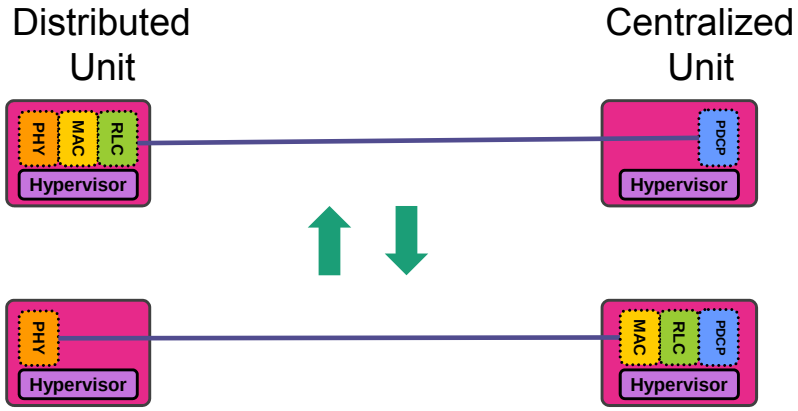


NFV-based 5G+ Function Split Use Case: **Focus on Adaptation**

- Use case: PHY-MAC split and RLC-PDCP split (*for this example*)
- Adaptation: dynamic migration between the two split options
- Constraints (for measuring flexibility *)
  - Time T to complete function migration
    - to avoid packet losses and latency
  - Cost C required to perform the adaptation
    - Packet losses
    - Computational cost
    - Power consumption

* W. Kellerer, et al. *et al.*,
How to measure network flexibility?
A proposal for evaluating softwarized networks,
IEEE Communications Magazine, 2018.

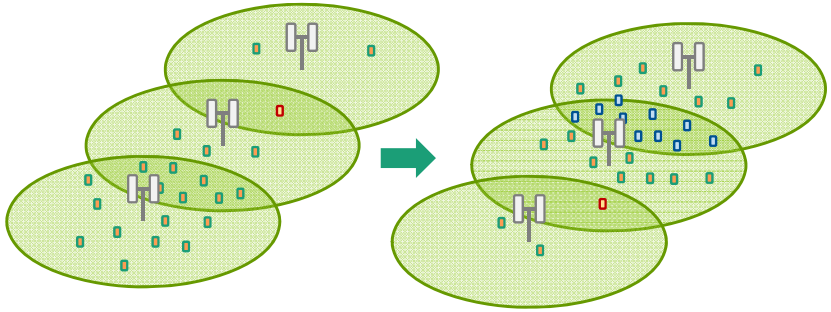


NFV-based 5G+ Function Split: **Flexibility Measure**

- **Objective:** maximize data rate for all UEs
- **Topology:** 18 DUs and 1 CU
  - The CU can implement up to 4 MAC-PHY DUs
- **Challenges:** change in the UEs distribution
- **Successful adaptation:** reach 80% of the data rate of the optimal configuration within T ms with cost C packet losses

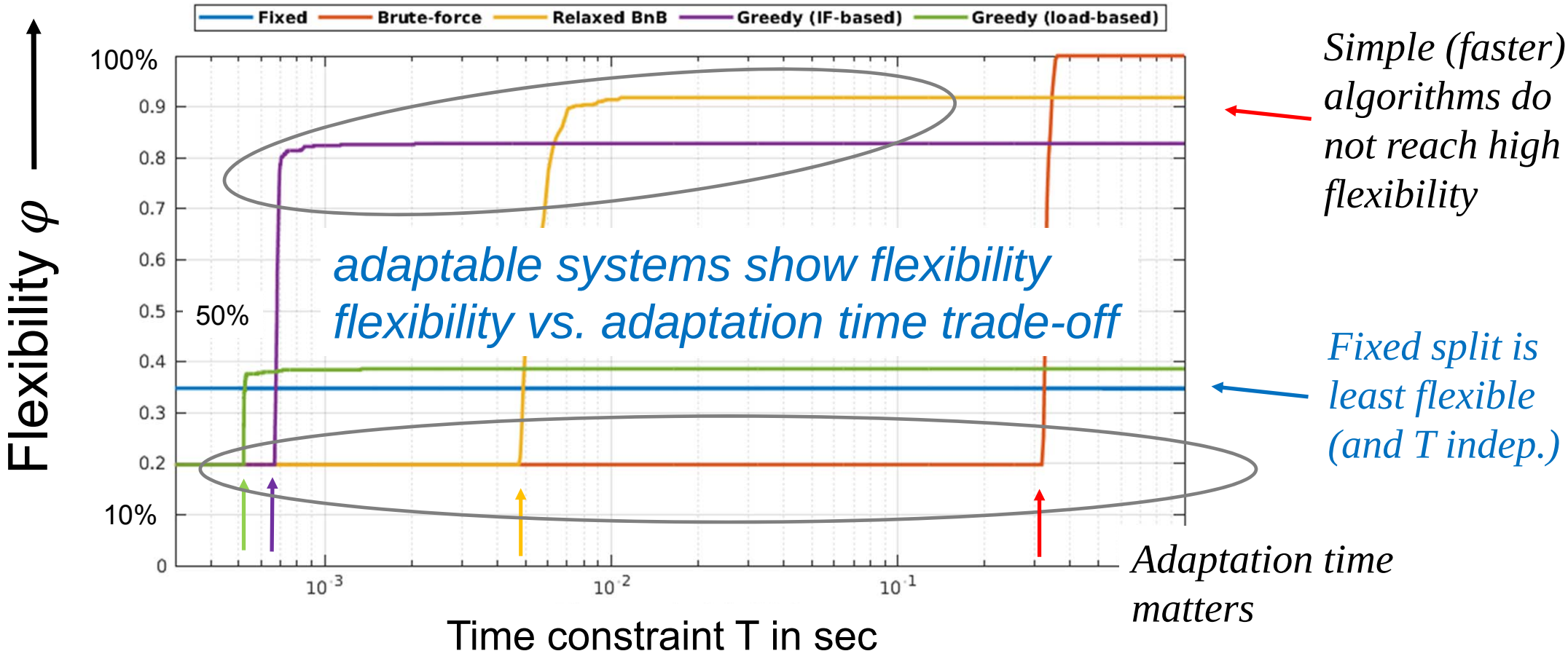
- **Systems under comparison:**
  - Fixed functional split

  NFV-based functional split:
  - Greedy algorithms (load-based)
  - Greedy algorithm (IF-based)
  - Lagrangian-relaxed BnB (branch-and-bound)
  - Brute-force search



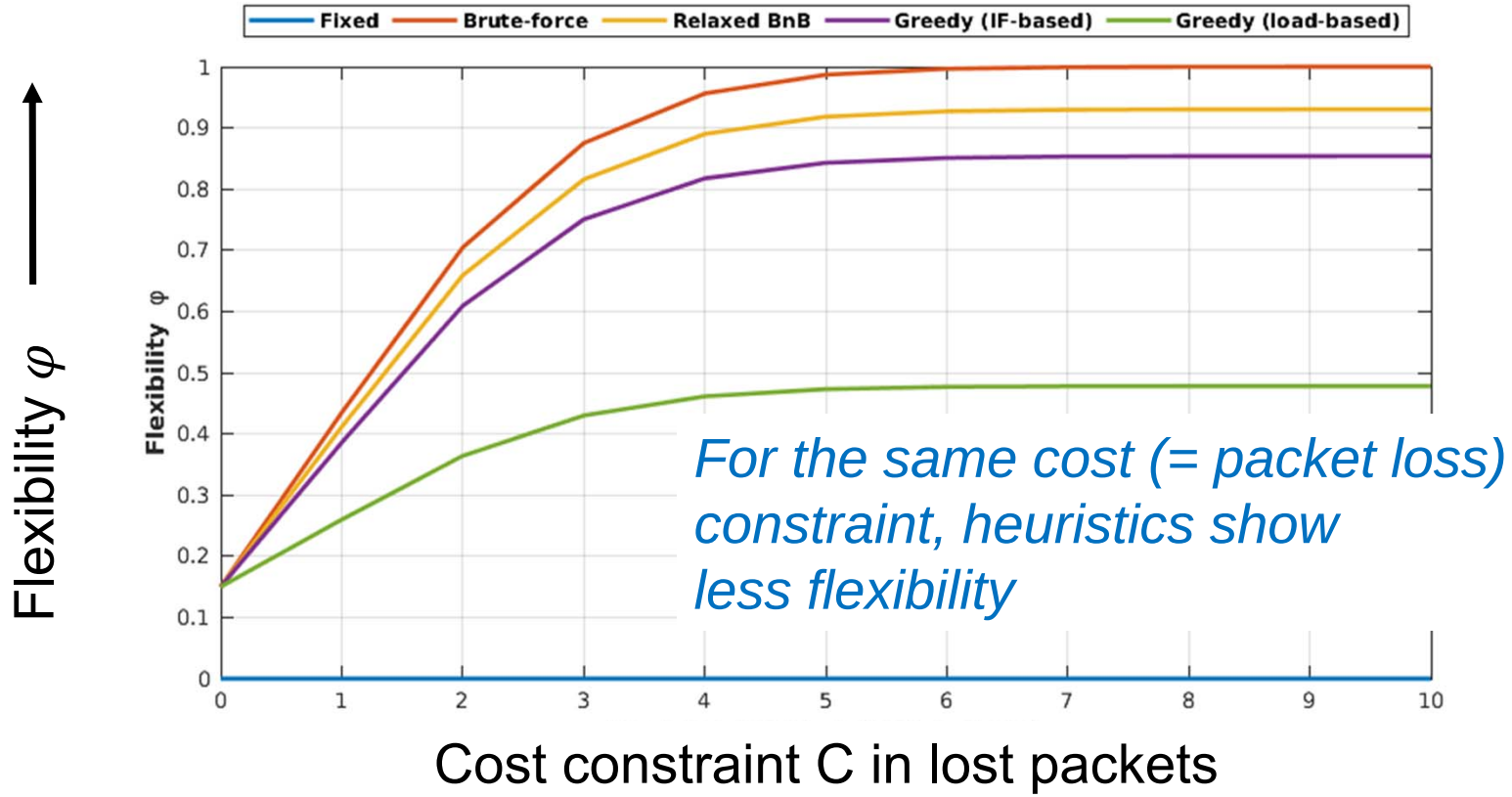
NFV-based 5G+ Function Split: **Flexibility Measure Results**

- Flexibility measure $\varphi = \frac{\text{successful adaptations given } T \text{ and } c}{\text{all challenges}}$ for $C \to \infty$



NFV-based 5G+ Function Split: **Flexibility Measure → Cost**

- Here: Cost C = number of packets lost during adaptation (= addtl. cost for adapt.)
- for $T \rightarrow \infty$

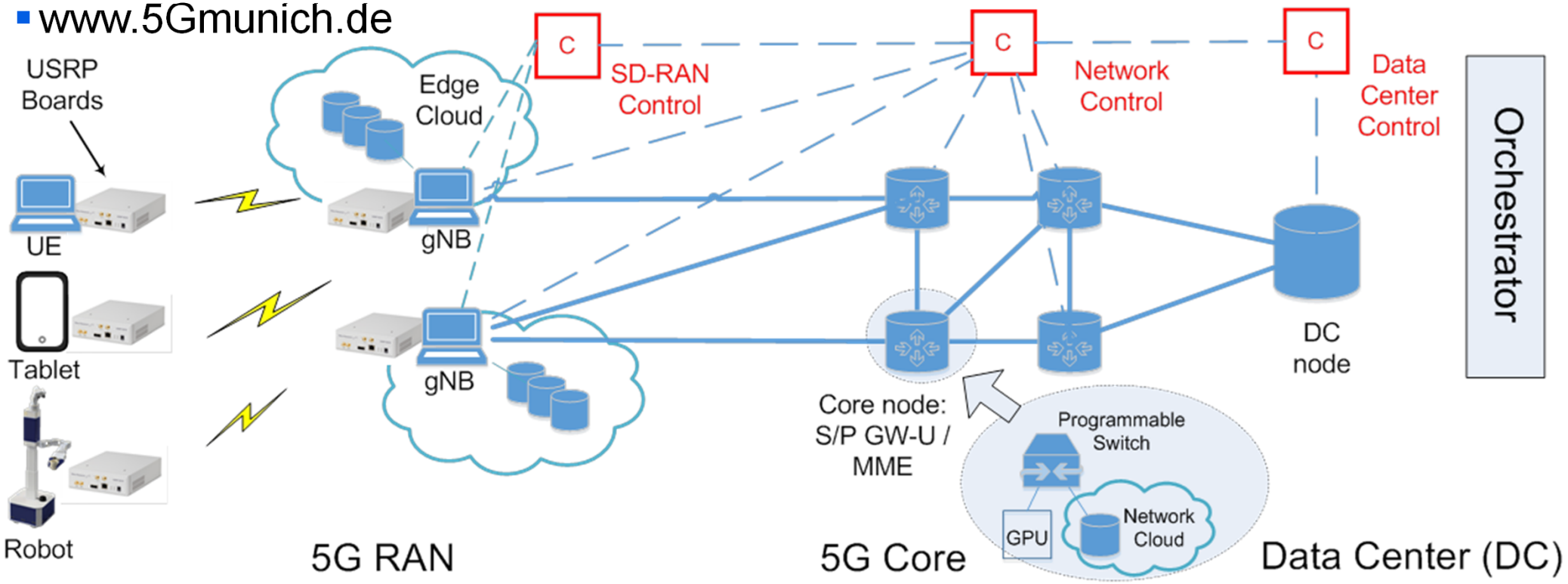


Our Experimental Platform:
5G Research Hub Munich

What's next: *End-to-End Flexible 5G Networking*

- 5G Research Hub Munich: 5G Experimental Platform
- www.5Gmunich.de

joint work with
Prof. Eckehard Steinbach, TUM



Sponsored by

Bavarian Ministry of Economic Affairs, Regional Development and Energy

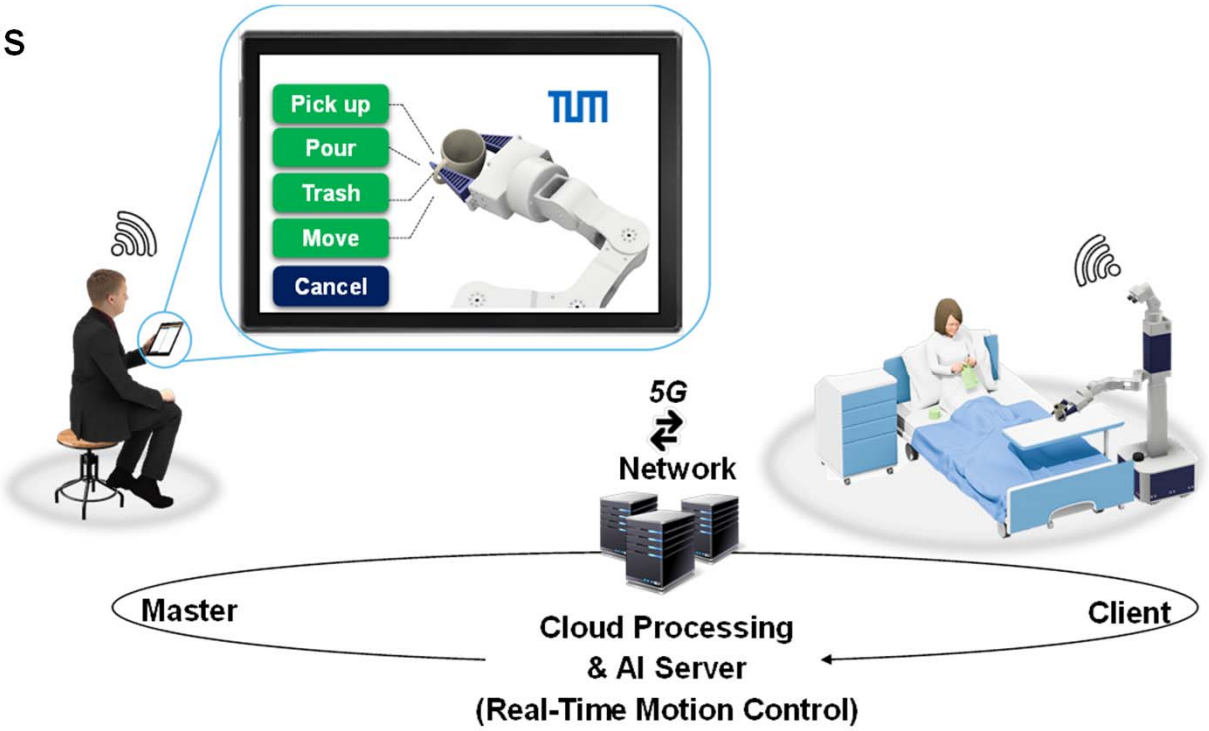
Focus application area: eHealth

Scenario: Telepresence and Teleservice

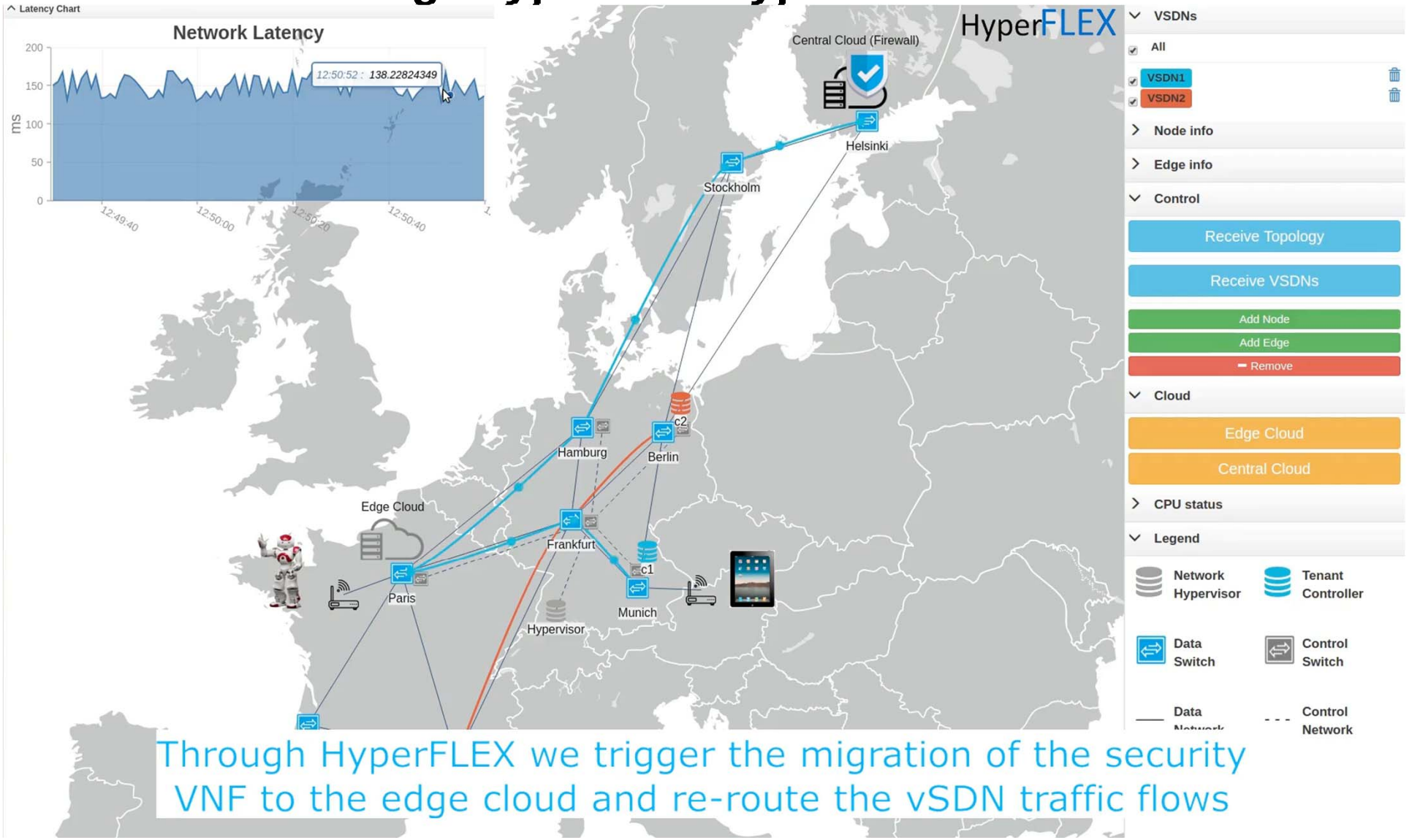
- Teleoperation and semi-autonomous task execution
- Visual immersion: 3D 360° video
- Object recognition
- Localization and mapping

5G requirements

- Ultra low delay
- Network-based processing
- High reliability
- High data rates (video)
- QoS differentiation → Slicing

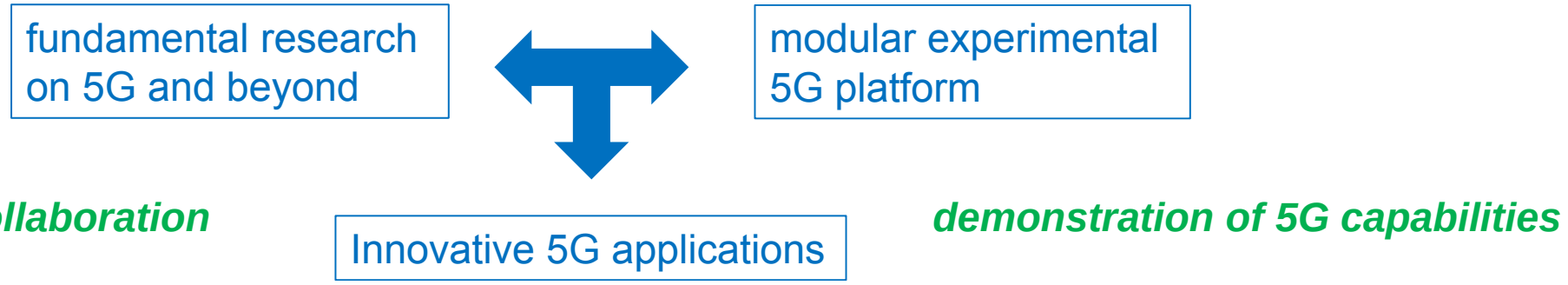


Core network slicing: HyperFlex Hypervisor



Objectives of the 5G Research Hub Munich

- **Realization of a 5G experimental lab platform** and its continuous advancement according to latest 5G standard releases and related research
- **Fundamental research** to significantly shape the state of the art for selected areas in 5G technologies and applications
- **Realization of a methods and technologies platform** as a modular framework being open for emerging applications



Research directions

Radio Access Network

- *Low latency high reliability* to support critical application functions
- Radio network *slicing* for reliable co-existence of different applications
- RAN *functions split* and its impact on latency and reliability
- Dynamic base station coordination and radio resource management
- *Reliability* in 5G New Radio

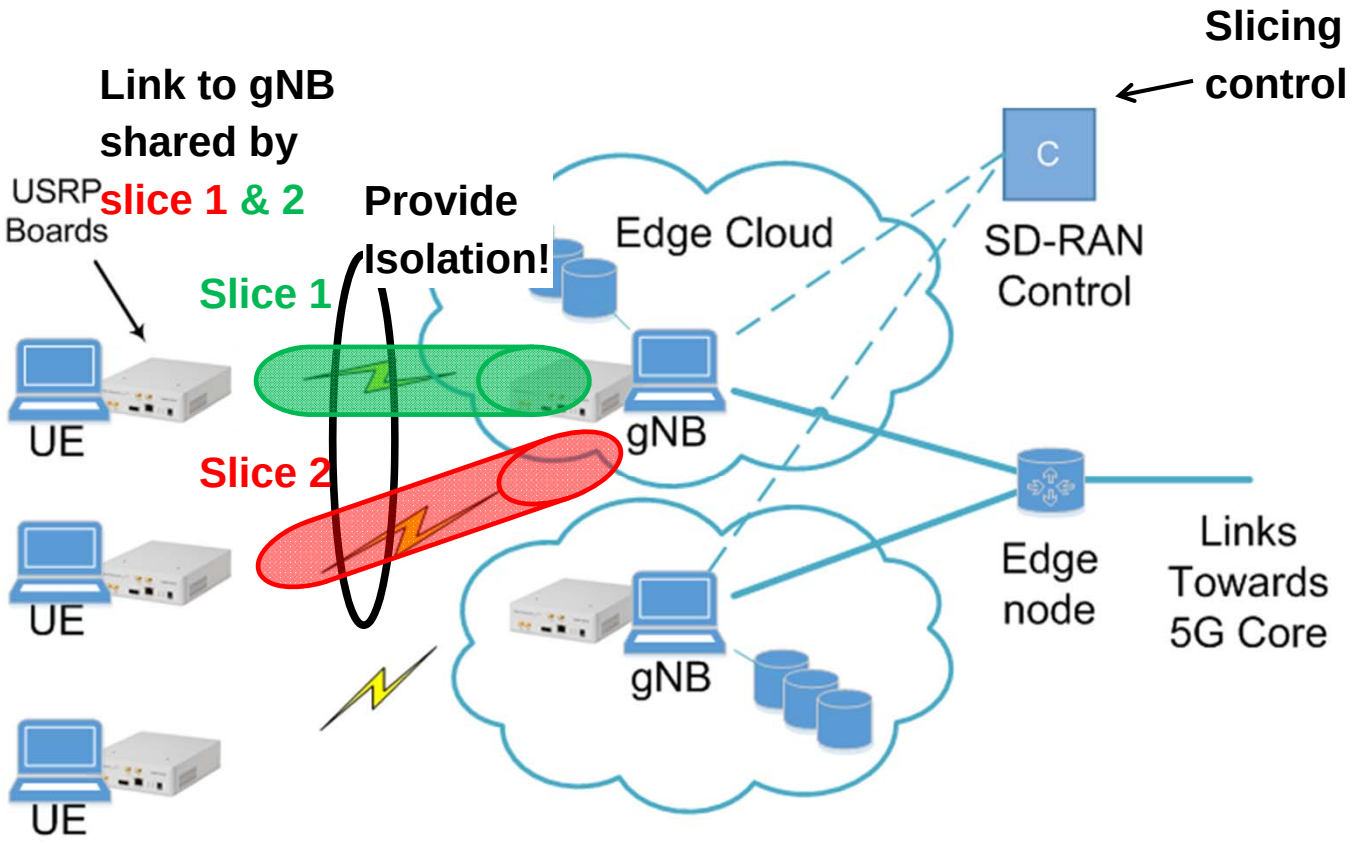
Core Network

- Resource provisioning and *isolation of data and control plane* incl. network hypervisors
- Function *placement* and operation in distributed *edge cloud* environments
- *In-network processing* to support emerging 5G applications
- Hardware acceleration and *offloading* of virtualization functions

Telepresence Robot

- *3D 360° immersive experience* of the remote scene (with delay compensation)
- HMD and tablet interface for natural remote control
- *Semi-autonomous* edge-based manipulation and object recognition
- Edge-based *navigation and SLAM*
- Edge-based *real-time motion* control and monitoring
- User-in-the-loop *real-time haptic & kinesthetic feedback*

Example: 5G Radio Access Network



Summary

- 5G opens up fundamentally new opportunities → machine-type communication
- 5G features → challenges to network infrastructure

- Core and access network: dynamically adapt to specific application demands
- *Flexibility and adaptation are important!*
- “5G Research Hub Munich” @ TUM: modular application-oriented experimental 5G platform

join us on

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and

www.networkflexibility.org

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