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# **Towards Flexible and Dynamic 5G Networks**

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Uhrenturm der TVM

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## 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



• 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

#### **Fixed 5G Function Split**



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



#### **Fixed 5G Function Split**

ТШ

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



#### **Fixed 5G Function Split**

ТUП

- 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



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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

ТШ

- **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 (<u>IF-based</u>)
  - Lagrangian-<u>relaxed BnB</u> (branch-and-bound)
  - Brute-force search



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



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



ΠП

## Focus application area: eHealth

## ТШП

#### **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  $\rightarrow$  Slicing



## **Core network slicing: HyperFlex Hypervisor**



ПΠ

## **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



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