

# Smart 6G Edge Node Interfaces

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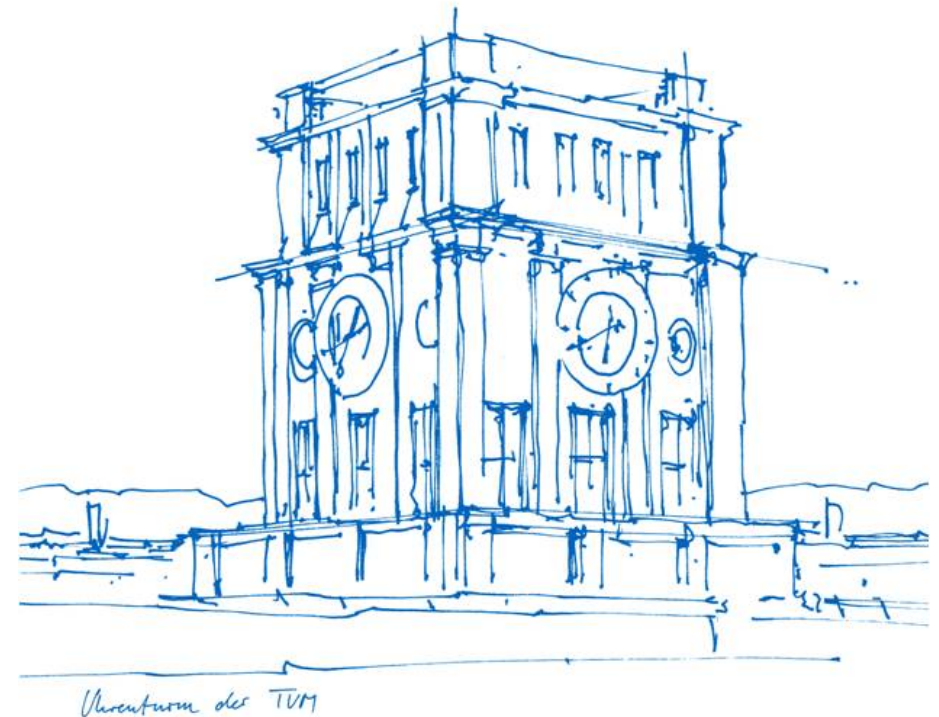
Technical University of Munich

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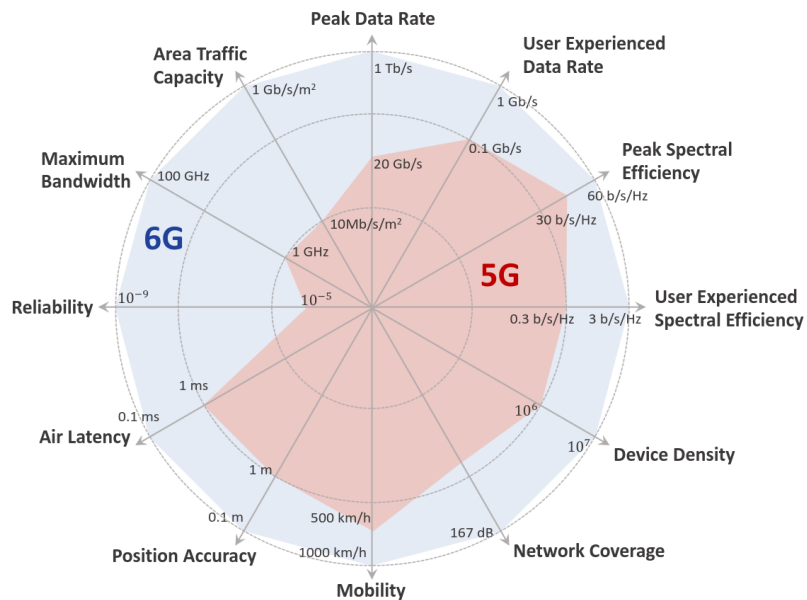
Chair of Integrated Systems



Kanazawa, July 9th 2024



# Objectives & Challenges for 6G Evolution



Source: Semiconductor Engineering – Multiple Hurdles in the Race to 6G (08/2023)

## Targets [1]:

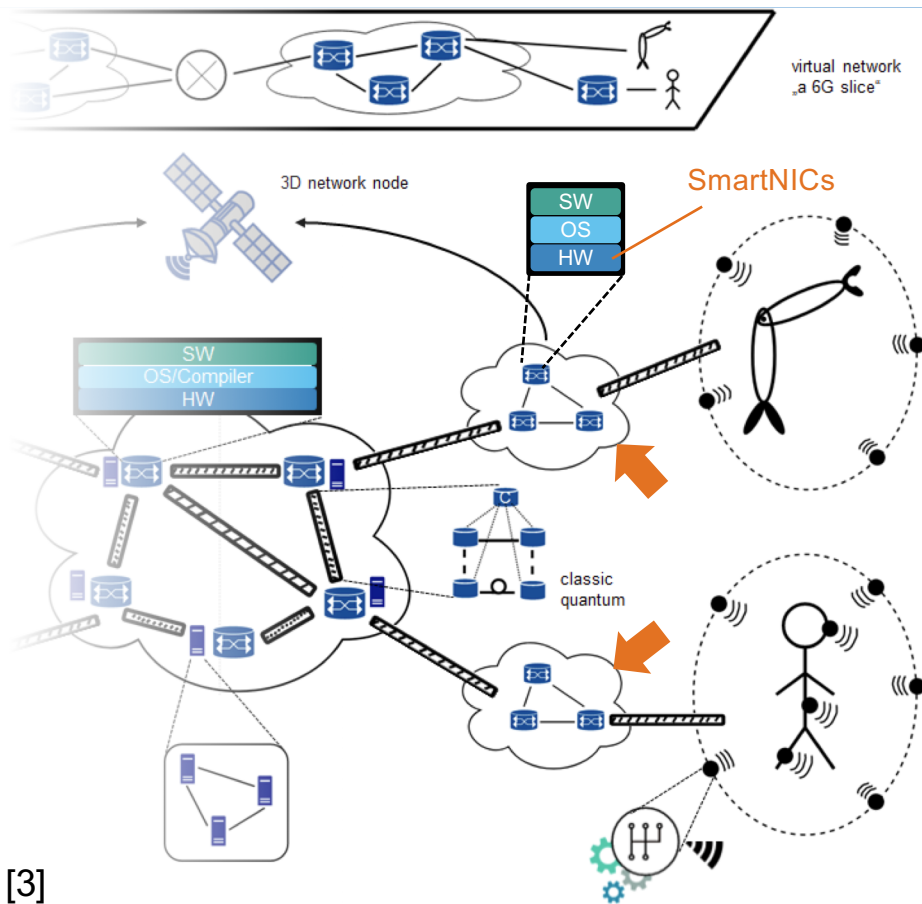
- < 1 ms round trip latency
- > 1 Gb/s average user experienced data rate
- < two orders of magnitude better energy efficiency

## Challenges [2,4]:

- User mobility
- Large number of devices
- Variety of services

→ Large, short-term fluctuations in traffic and compute loads

# Objectives & Challenges for 6G Evolution



## Targets [1]:

- < 1 ms round trip latency
- > 10 Gb/s user experienced data rate
- < two orders of magnitude better energy efficiency

## Challenges [2,4]:

- User mobility
- Large number of devices
- Variety of services

→ Large, short-term fluctuations in traffic and compute loads

→ Energy-efficient, adaptive SmartNICs

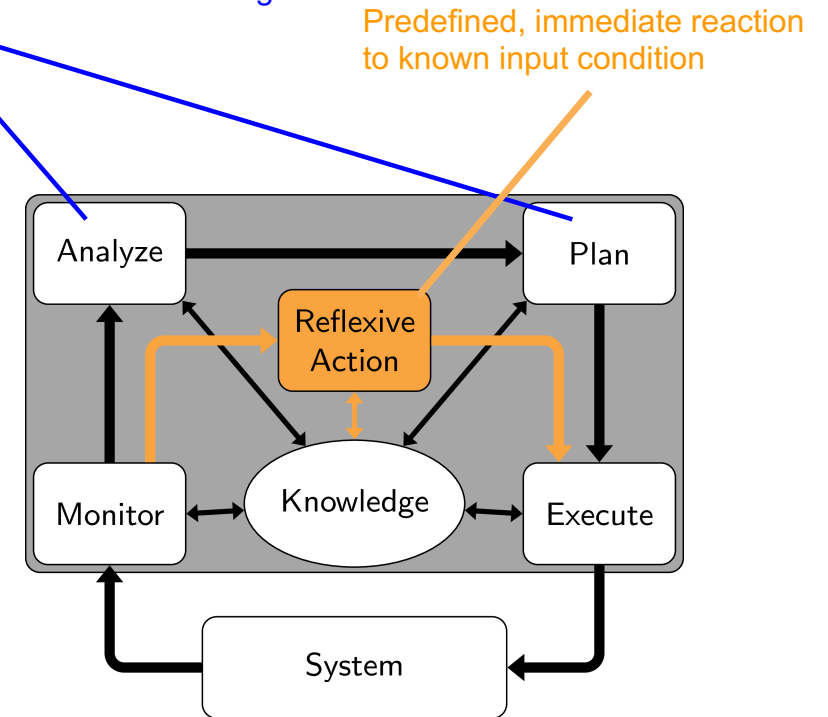
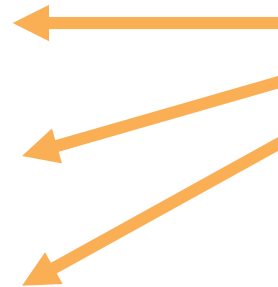
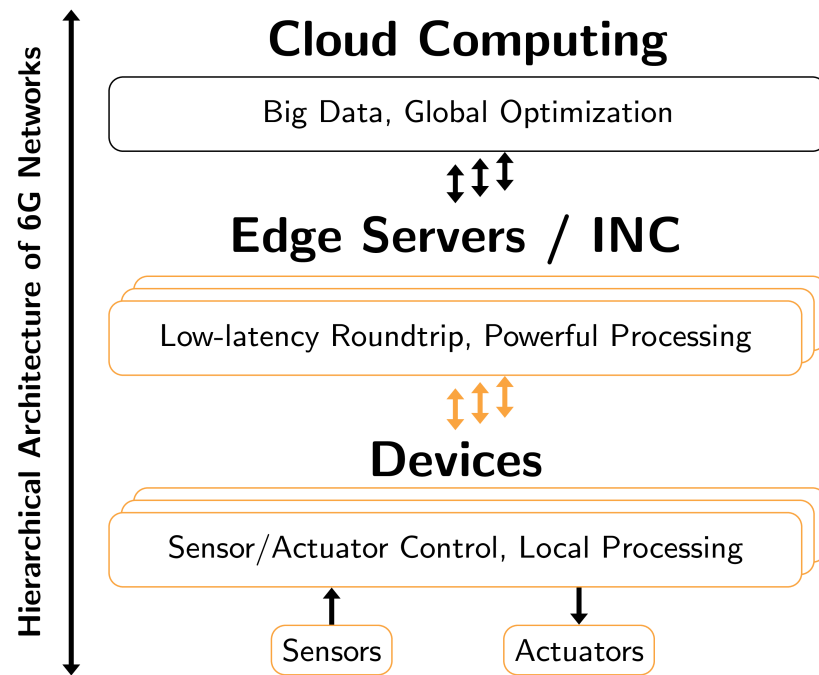


6G-life



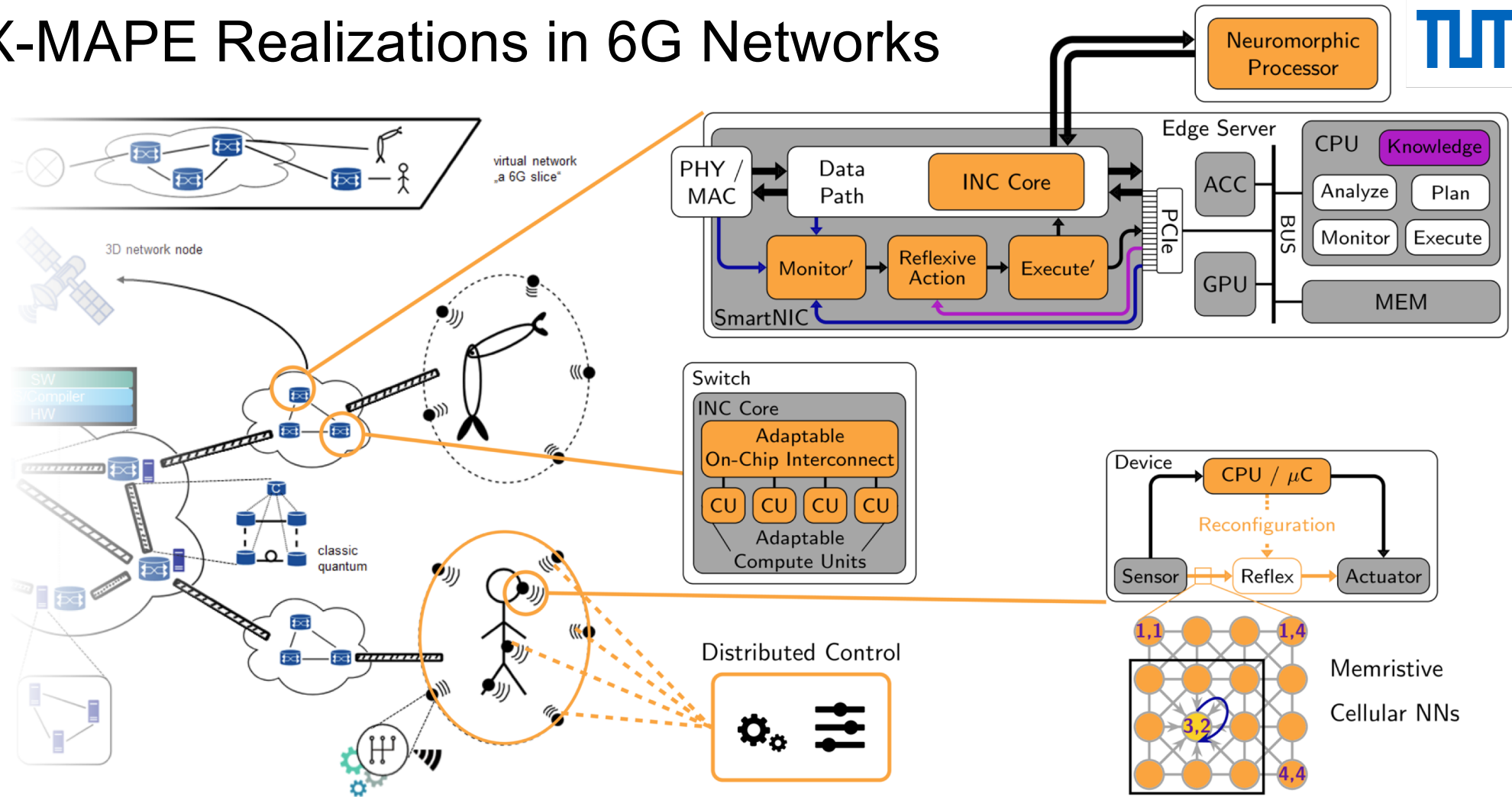
# X-MAPE: Reflex-enhanced Computing

Can become computationally expensive for complex systems  
 → Still executed for optimization and continuous learning

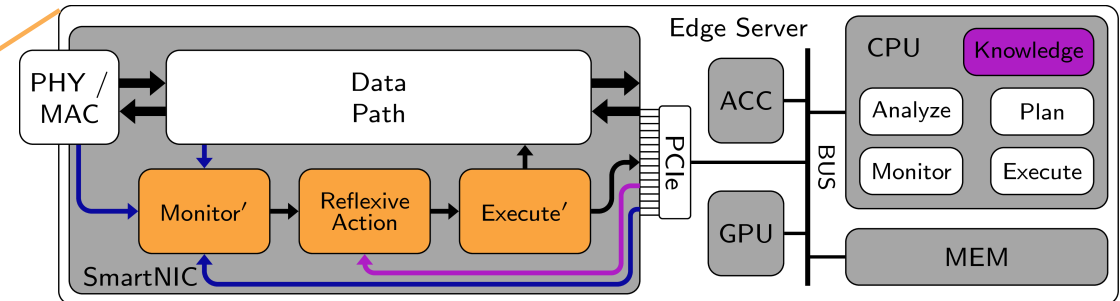
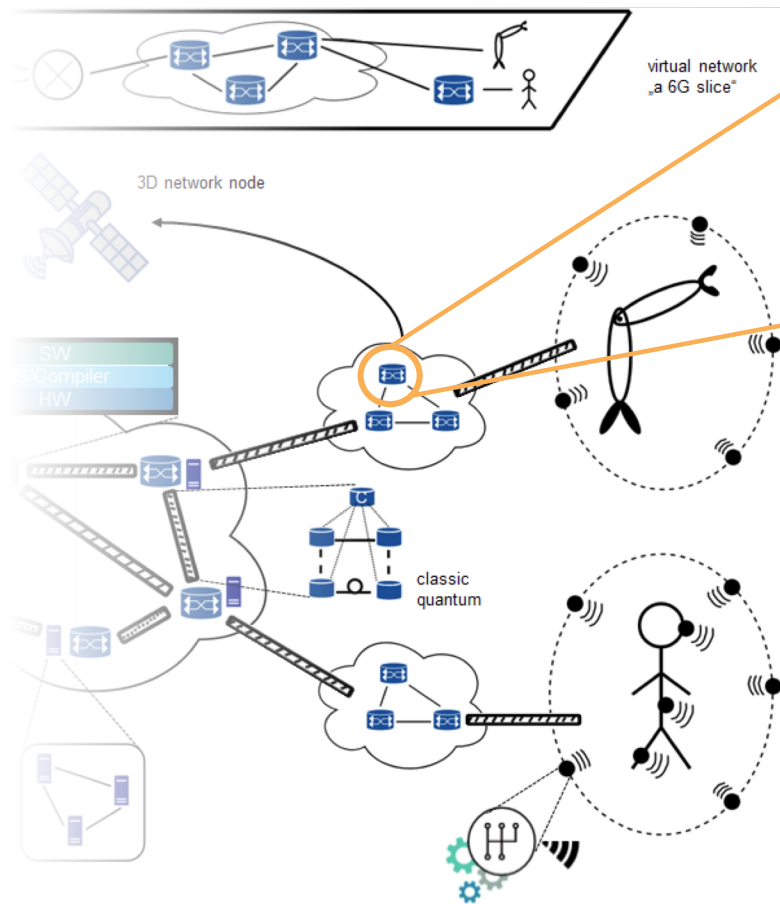


[5] Liess, M., Demicoli, et al. (2023, November). **X-MAPE: Extending 6G-Connected Self-Adaptive Systems with Reflexive Actions**. In *2023 IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN)* (pp. 163-167).

# X-MAPE Realizations in 6G Networks



# Reflex-enhanced SmartNIC



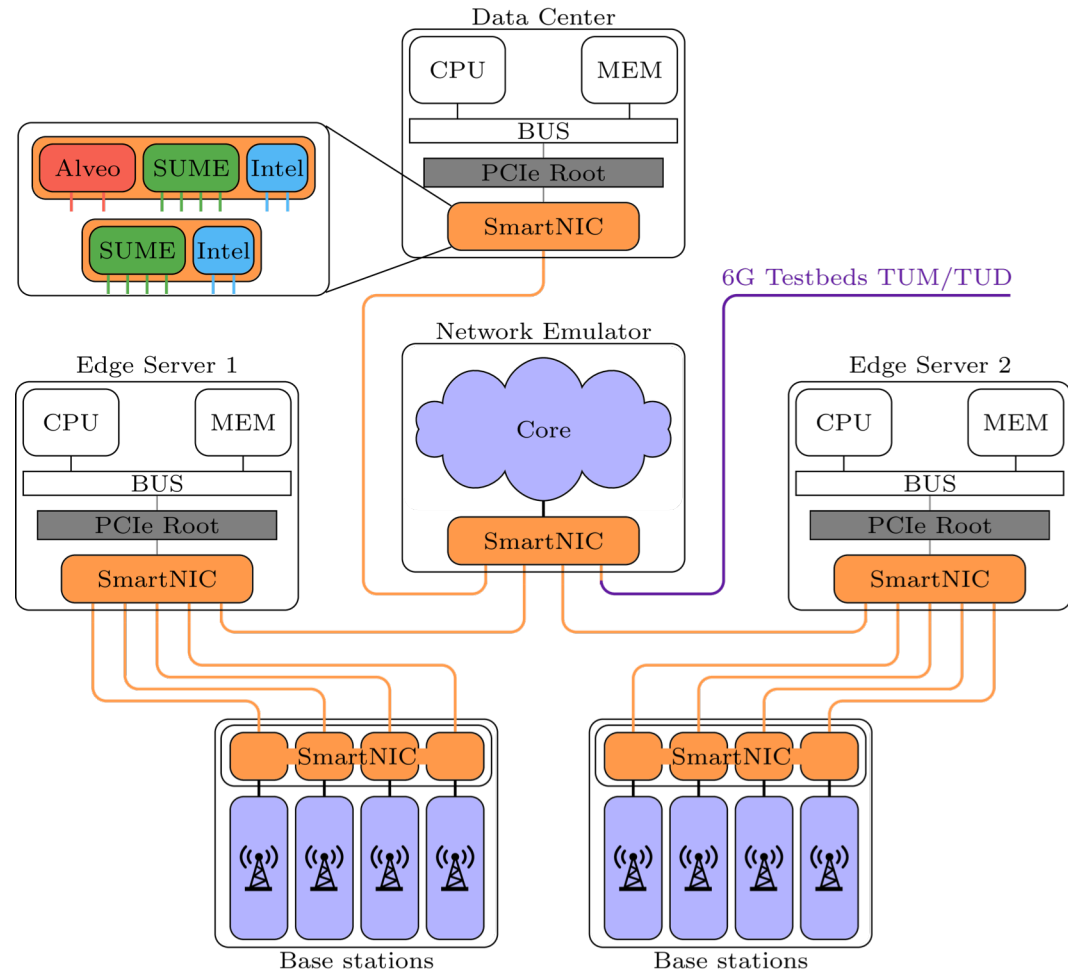
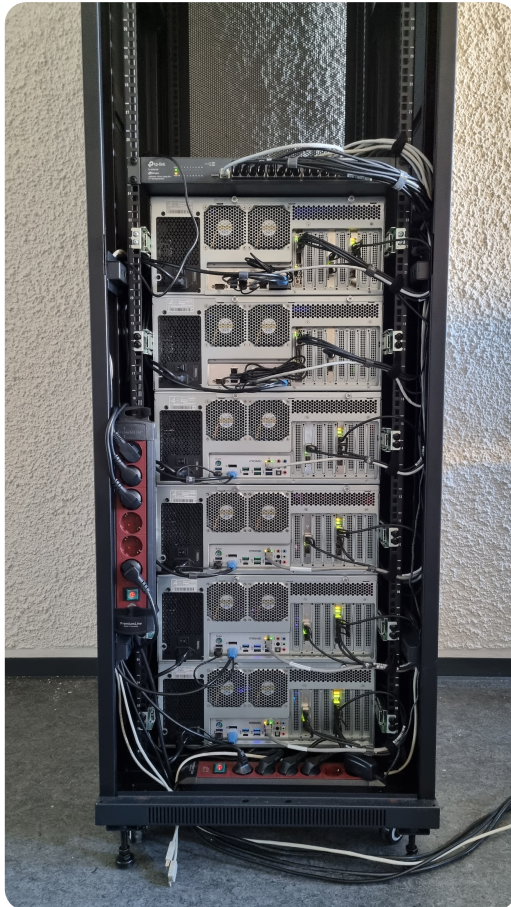
## Reflexes:

- Power management (e.g. DVFS of CPU cores)
- Offloading / Forwarding to other nodes in case of overload

## Enabled by:

- Configurable LUTs/MATs for system-level reflexive decisions
- Threshold-based triggering of reflexes
- Federated Learning-based Control Layer to configure trigger conditions and actions in MATs

# Network Testbed @ LIS



# Demo: AI-assisted Load-aware Service Migration

**Platform for AI-aware End-to-End 6G Networks**

**Demo: AI-assisted Load-aware Service Migration**

**Scenario 1:**

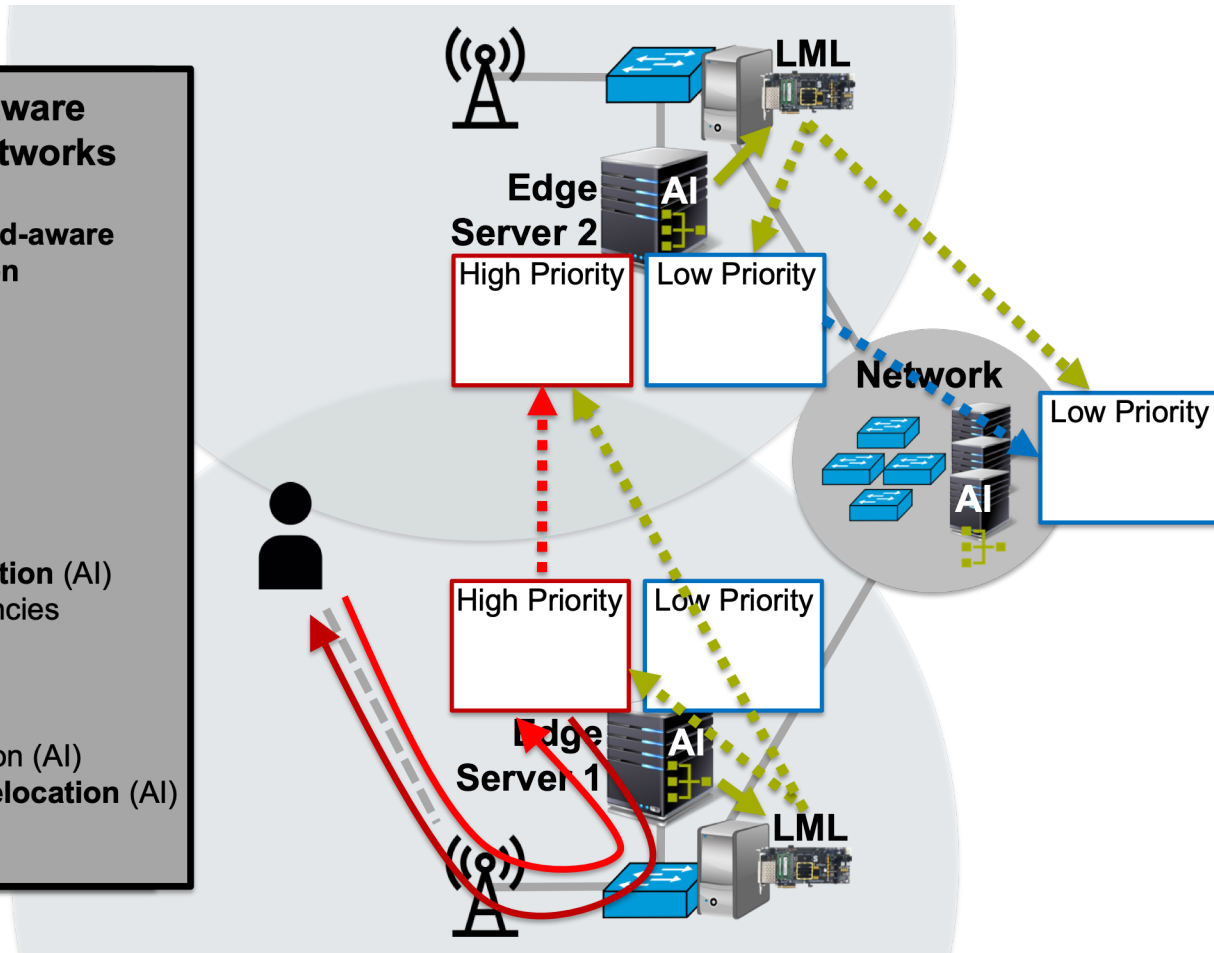
- Static Processing  
→ High Latencies

**Scenario 2:**

- Processing follows User
- **Predictive Service Migration (AI)**  
→ Prevents Network Latencies

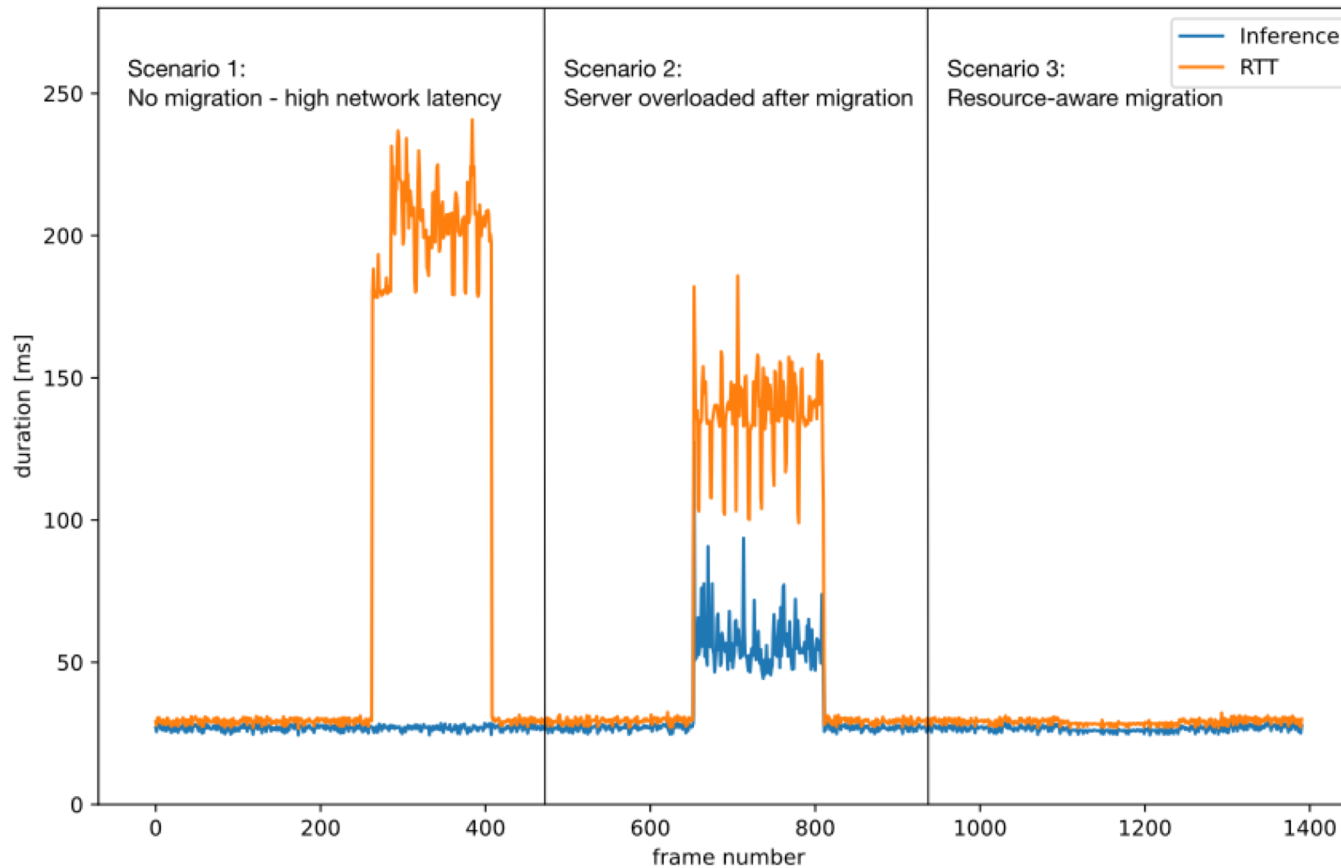
**Scenario 3:**

- Processing follows User
- Predictive Service Migration (AI)
- **Predictive Ressource Relocation (AI)**  
→ Prevents Overloads





# Demo: AI-assisted Load-aware Service Migration



# Take Aways ...

- 6G isn't just „*next generation wireless communications*“
- Requires innovations across the entire „chain of stakeholders“ towards a holistic 6G end-to-end system architecture:
  - ... from smart sensor/actuator technologies,
  - to new forms of decision-making with adaptive and even functional transforming hardware concepts
  - and holistic consideration of sensing, networking & computing in the network edge and core

# References



- [1] Mizmizi, M., Brambilla, M., Tagliaferri, D., Mazzucco, C., Debbah, M., Mach, T., ... & Spagnolini, U. (2021). **6G V2X technologies and orchestrated sensing for autonomous driving**. arXiv preprint arXiv:2106.16146.
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- [4] Fettweis, G.P., Boche, H. (2022). **On 6G and trustworthiness**. Communications of the ACM **65** (4), 2022, 48-49.
- [5] Liess, M., Demicoli, J., Tiedje, T., Lohrmann, M., Nickel, M., Luniak, M., ... & Herkersdorf, A. (2023, November). **X-MAPE: Extending 6G-Connected Self-Adaptive Systems with Reflexive Actions**. In 2023 IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN) (pp. 163-167). IEEE.

We are grateful for the financial support by the *Bavarian Ministry of Economic Affairs, Regional Development and Energy* in the *6G Future Lab Bavaria* project and the *Federal Ministry of Education and Research* of Germany in the *6G-life* project with project identification number: 16KISK002



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