GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung


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# Science and 6G – Bridges between Science & Entrepreneurship

NextGen Ventures Event
26.03.2024
*Munich, Germany*

# *What is <u>new</u> with 6G?*

- 4G: Video and Internet (Smartphone)
- 5G: Machine-to-Machine Communication
- **6G: put the human in the center – *Extension of the human intelligence and the human capabilities***





Image sources: TUM MRI, TUM LTI, TUM, TUD, 5G Campus, CeTI

# What are the 6G drivers?

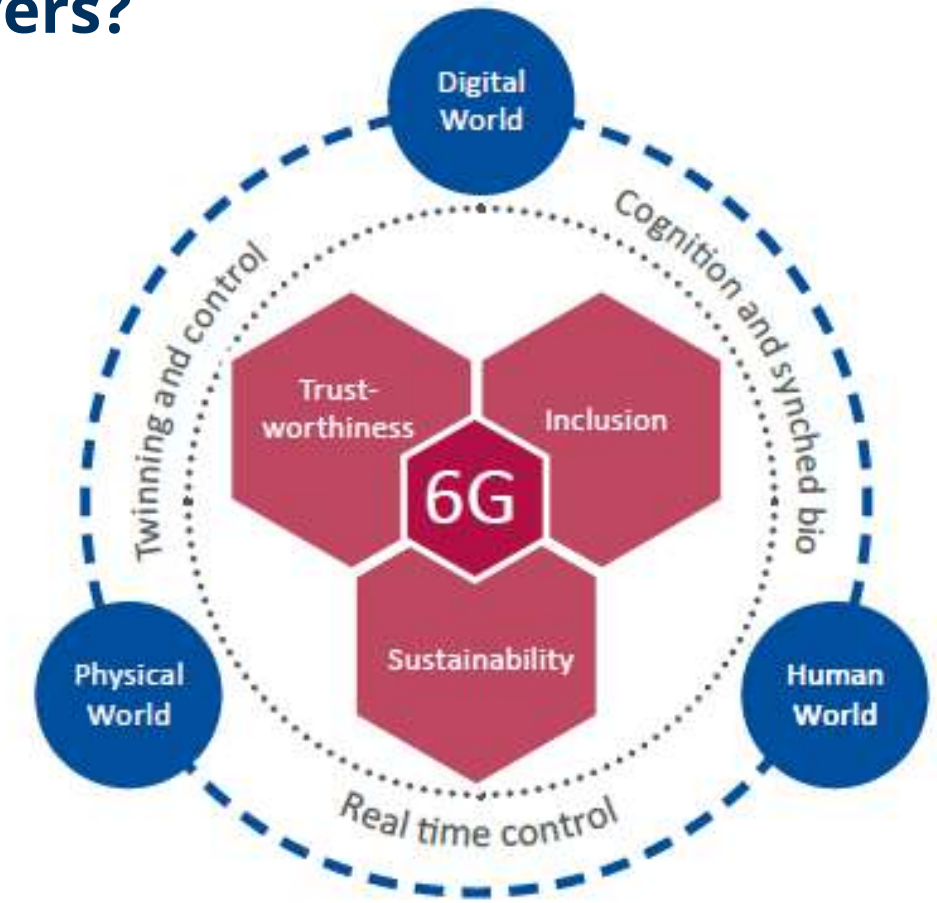



Figure 1 A vision of 6G
(Source: Hexa-X project)

K. Trommler, M. Hafner, W. Kellerer, et al.: ***Six Questions about 6G*** – White Paper. Bayern Innovativ / Münchner Kreis, 2022.
K. Trommler, M. Hafner, W. Kellerer, et al.: ***Six Insights into 6G***. Bayern Innovativ / Münchner Kreis, 2022.

# Science meets Entrepreneurship

- Results from fundamental scientific projects → consider early how to
  - Sustain the created knowledge
  - Boost impact towards industry

- Impact through
  - Publications
  - Patents
  - Educated engineers

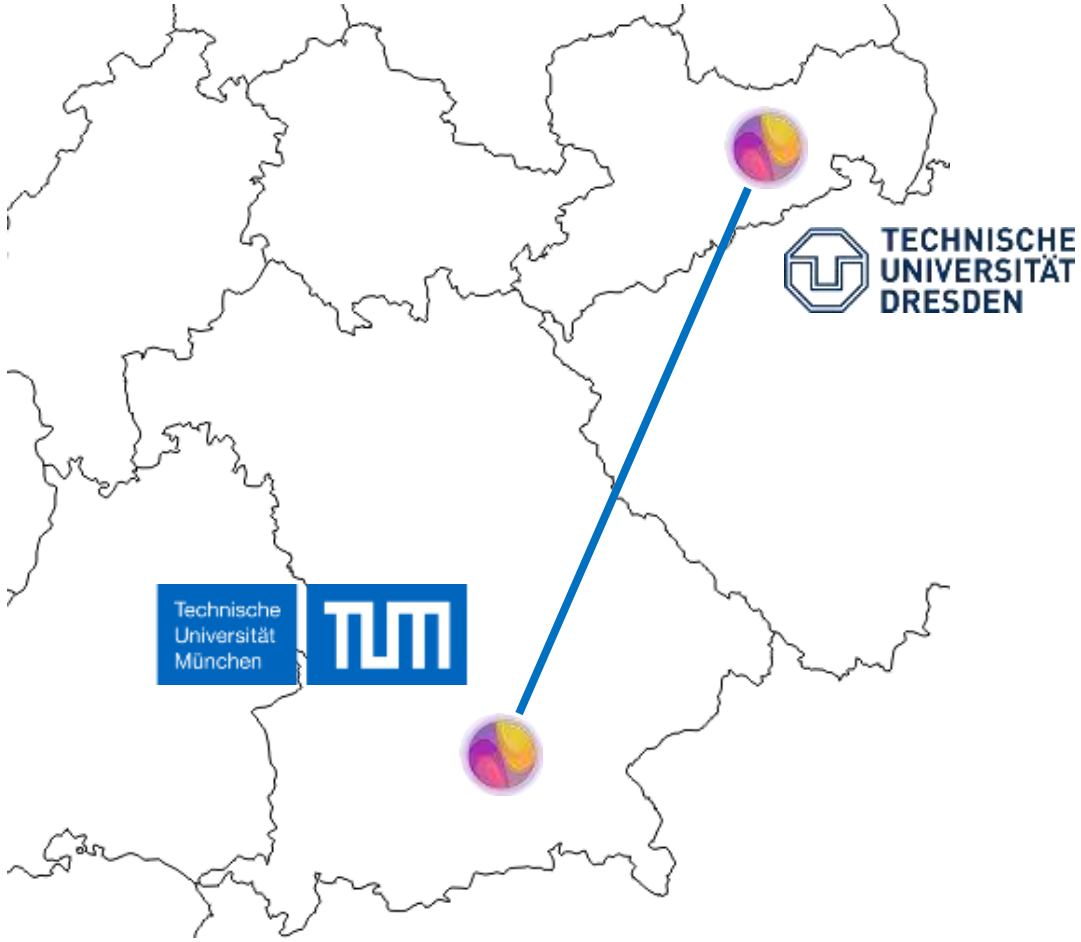
  - Startups = golden way
    - Business-ready technologies
    - Know-how and value creation in Germany/Europe
    - Technology sovereignty

# BMBF 6G Research Hub 6G-life

- Started August 15, 2021
- 70 Million € for 4 years
- 58 Principal Investigators + 156 researchers

- 6G: focus is on humans and their communication and interaction with machines and the virtual world → holistic research on innovative concepts for scalable communication, novel methods, flexible software concepts and adaptive hardware
- Four key performance indicators: Latency, Resilience, Security and Sustainability

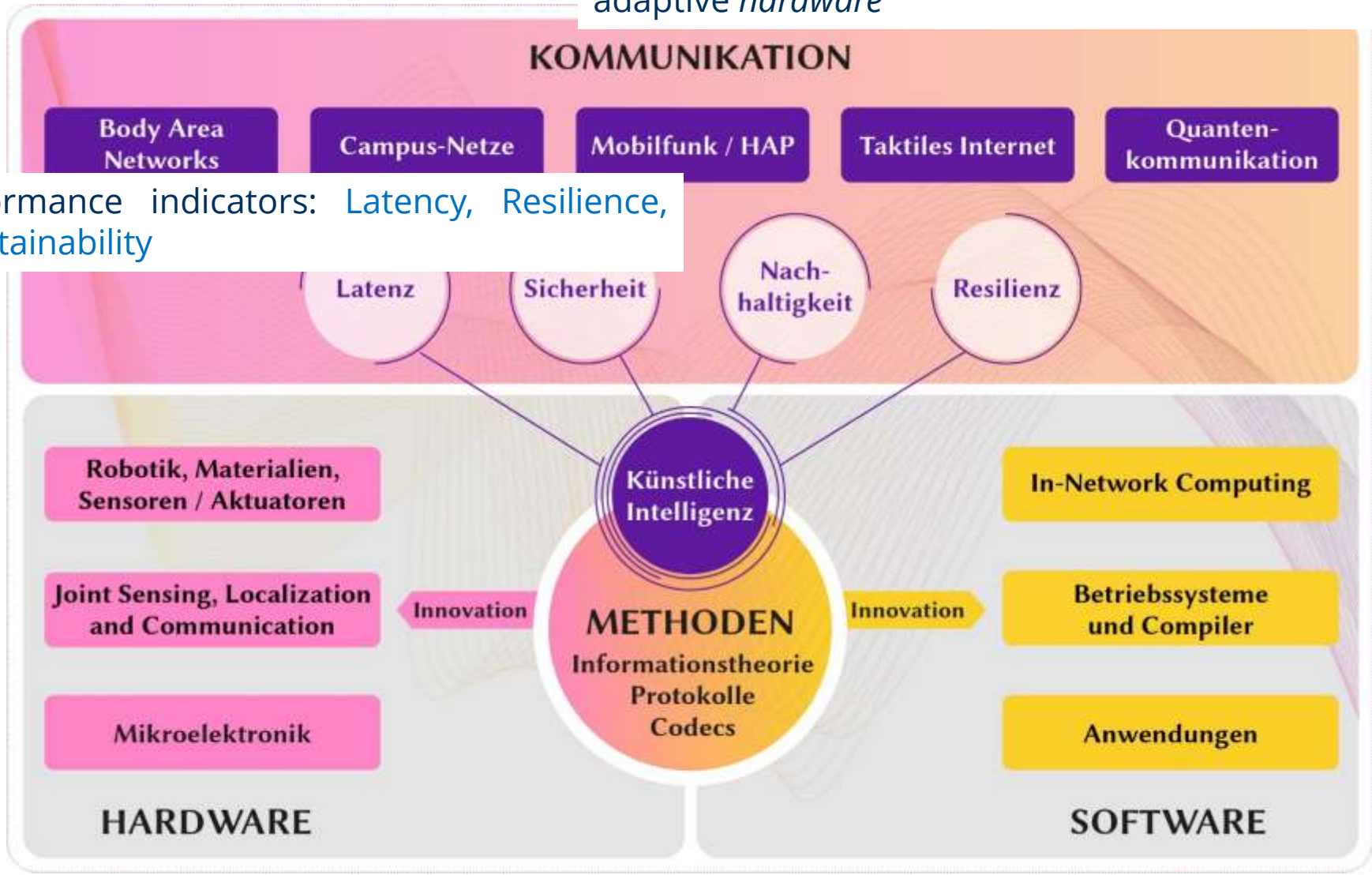
- Digital Sovereignty and Digital Transfer
- 10 Million € for Start-ups



# 6G-life Overview

holistic research on innovative concepts for scalable *communication*, *novel methods*, flexible *software* concepts and adaptive *hardware*

- Four key performance indicators: Latency, Resilience, Security and Sustainability



# 6G-life Innovation Areas

## *Scalable Communication*

communication network architectures including

- Cellular networks with Campus and HAP extensions
- Tactile Internet
- ***Quantum Communication***
- Body Area Networks
- **Molecular Communication**

## *Innovative Methods*

novel methods for communication networks based on

- **Post Shannon Communication**
- AI for network control and new services
- **AI & Digital Twins**
- Protocol and codec design for Human-Machine Collaboration

## *Flexible Software*

networks are dominated by SW

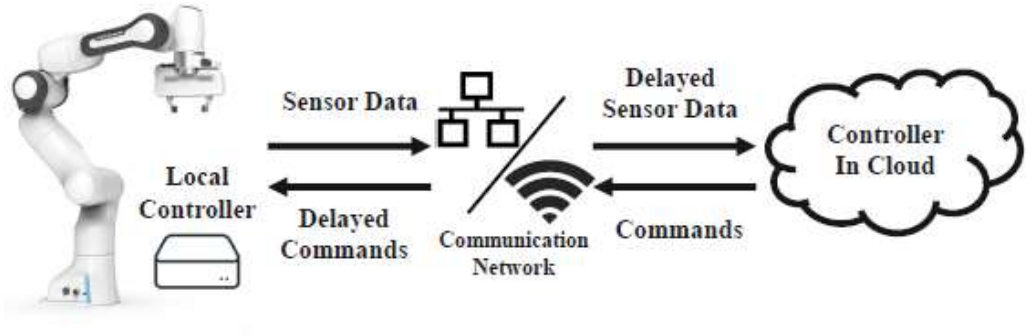
- **In-network computing and ORAN**
- 6G application in virtual worlds (digital twins and holograms)
- Low latency and energy efficient compiler/OS design

## *Adaptive Hardware*

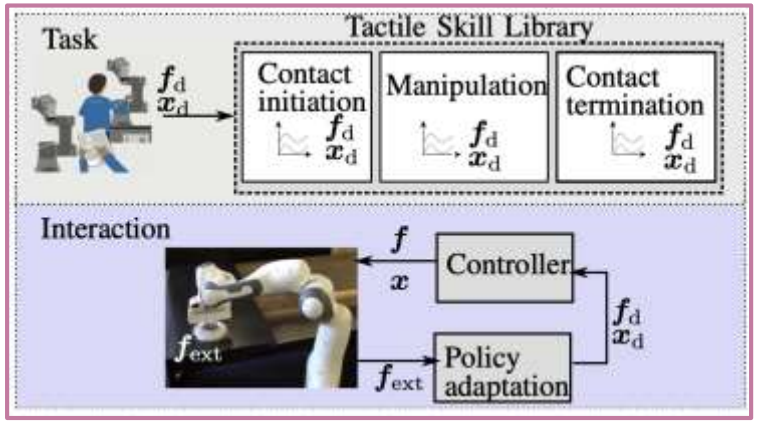
Novel hardware concepts for future needs and applications

- New materials for robotics and humans in virtual worlds
- **Joint sensing and communication**
- Flexible energy saving

# 6G-life use case examples: Industry

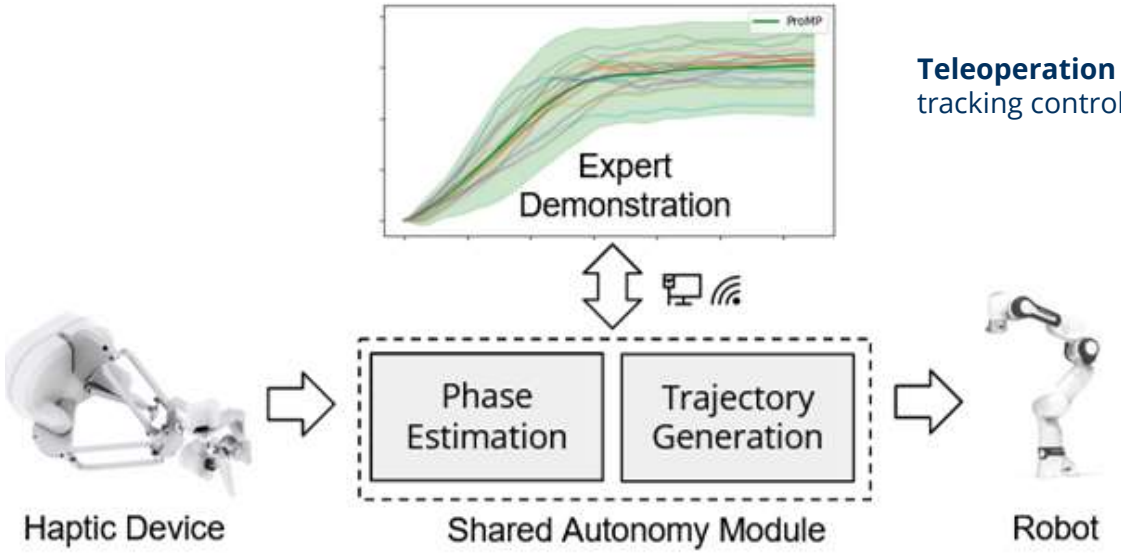



Framework of relocating the robot controller in the cloud




Passivity-Based Skill Motion Learning for robotic (dis)assembly

**Teleoperation cell:** GUI + moveme tracking controller /haptic controlle

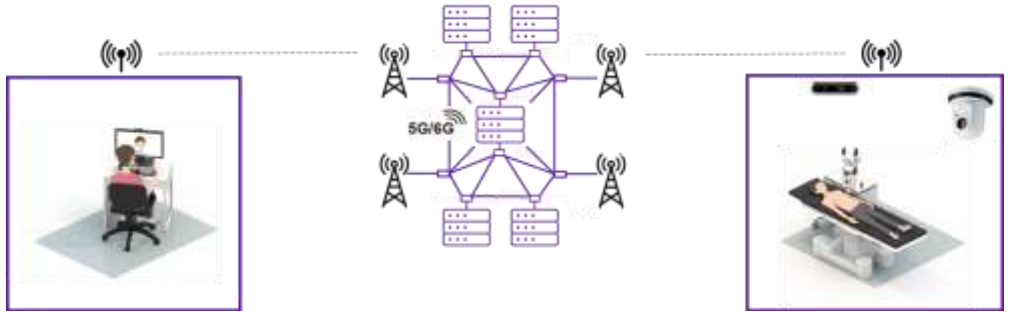



Shared autonomy in teleoperation

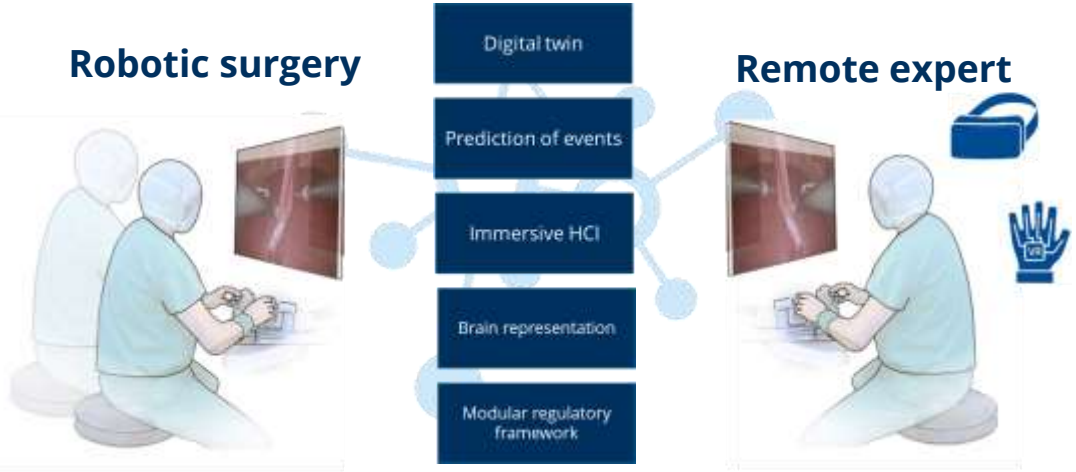
# 6G-life use case example: Healthcare

*Testbed remote-surgery*

*Testbed semiautonomous telerobotic examination suite*

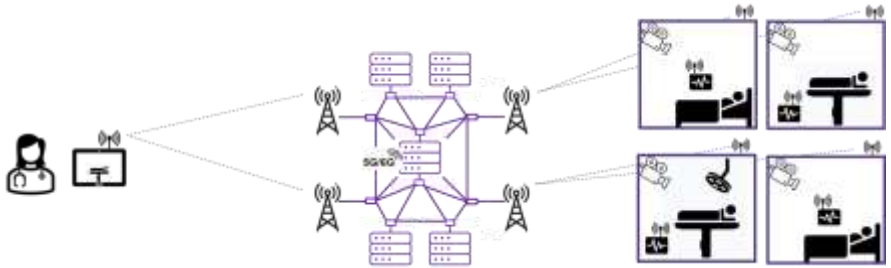



**Robotic surgery**

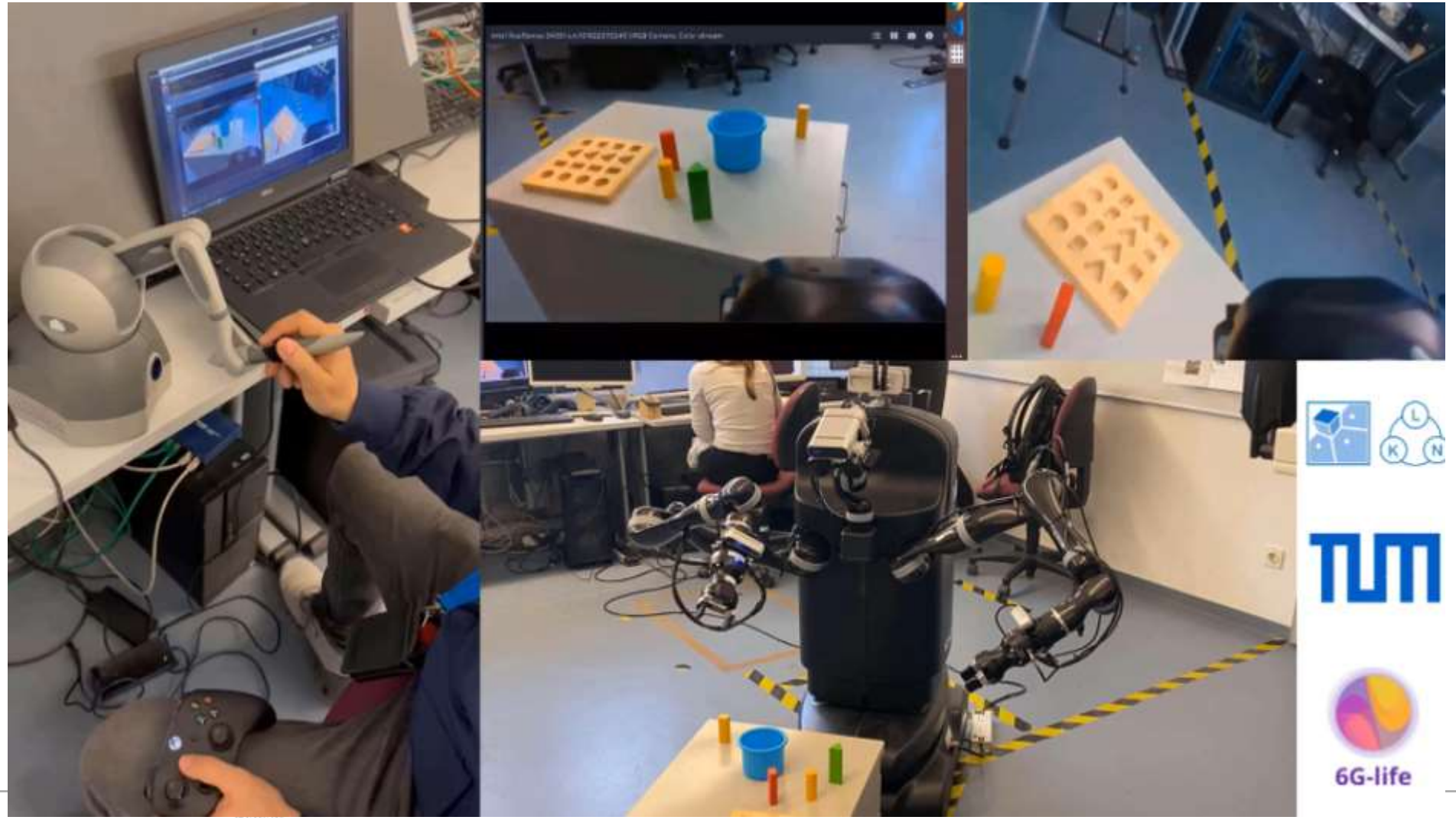



**Remote expert**

*Testbed context-sensitive patient monitoring*



# Demonstration of haptic-based teleoperation between Dresden and Munich



# 6G Perspective of Mobile Network Operators, Manufacturers, and Verticals

6G Perspective of Mobile Network Operators, Manufacturers, and Verticals

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***Abstract*—The first release of 5G technology is being rolled out worldwide. In parallel, 3GPP is constantly adding new features to upcoming releases covering well-known use cases. This raises the questions i.) when will 6G be introduced?, ii.) how can 6G be motivated for the stakeholders, and iii.) what are the 6G use cases? In this work, we present the perspective of these stakeholders, namely the network operators, manufacturers, and verticals, identifying potential 5G shortcomings and the remaining 6G solution space. We will highlight the Metaverse as the enabler for 6G addressing omnipresent daily challenges and the upcoming energy problem.**

***Index Terms*—6G Use cases, Metaverse, AI, Quantum Communication, Molecular Communication, Pandemic, Aging Society, Climate Change, Skill Shortage**

I. Introduction

Public 5G mobile communication systems are currently being rolled out. Most of the 5G communication systems in operation are based on Release 15 non-standalone (NSA) and are nowadays converted into standalone (SA) systems. While NSA is still based on a 4G core system, the SA embeds a 5G core and can therefore be considered the first natural 5G system. While 4G and its predecessors still had the consumer market in mind, 5G aims to open up entirely new markets. Even though 5G is advertised with high data rates to attract the old consumer customer front, the absolute novelty in 5G is the support of low latency communication for the Industrial Internet, health care, mobility, etc., mainly machine-to-machine communication. This led to a new customer base, namely the verticals. In addition to latency, 5G has brought two other groundbreaking changes.

Firstly, new communication architectures such as non-public or 3D networks are supported parallel to the public cellular networks. Secondly, in-network concepts from the Internet Engineering Task Force (IETF), mainly for the Internet, have been intensively incorporated into mobile communication systems. The latter increased the importance of software in communication systems. First, only the backbone's communication components have been realized by software rather than proprietary hardware boxes. Nowadays, even Radio Access Networks (RAN) technologies are candidates for softwarization. Even though most people or industry sectors have yet to experience the full 5G technology, researchers are starting to think about 6G technologies [1]. Unfortunately, a clear definition of 6G communication networks has not been defined yet. European flagship research projects such as HEXA-X [2] or the 6G Platform Germany [3] have gathered leading industry players and research institutions to develop such as definition.

Often, researchers advertise 6G technologies without considering the upcoming releases of the 3rd Generation Partnership Project (3GPP). This often leads to a misunderstanding in the community about what 6G is. Release 16 and 17 will complete Release 15, initializing the first wave of *lifelike* 5G technology enabling most of the envisioned use cases, especially those addressing low latency requirements such as machine-to-machine communication, e.g., with mobile robotics. The second wave starts with Release 18 (5G advanced starting standardizations in 2022). Currently, Release 19 is looking for new topics to be discussed in standardization.

Therefore, in this paper, we will first briefly list in Section II the features that will be available in the upcoming 5G releases. Then, in Section III, we will look at the current needs of the verticals and whether the current releases meet these. From the shortcomings of the current releases and the new needs of the verticals and consumers due to the recent results, we present possible use cases of 6G in Section IV. 6G can only succeed if we build a communications system that serves the needs of people or people-owned machines. Along the way, we will examine what new opportunities are available to the manufacturers and what role the network operators play in this.

II. What Will 5G Give Us?

To understand what 6G should focus on, a short description of the feature and study list in 3GPP for ongoing 5G activities is given. It is assumed that 6G will be introduced with Release 21 or higher. However, an earlier version can also be called 6G if the marketing departments of the companies want to outbid each other.

- **3GPP Feature and Study Item list: Rel-15-17**: Study on Communication for Automation in Vertical Domains; New radio, Non-Orthogonal Multiple Access; Satellite; TLS; Edge computing; network slicing;
- **3GPP Feature and Study Item list: Rel-18**: Satellite; IoT; UAV; Sidelink; Proximity; Location and Positioning;

- **3GPP Feature and Study Item list: Rel-15-17**: Study on Communication for Automation in Vertical Domains; New radio, Non-Orthogonal Multiple Access; Satellite; TLS; Edge computing; network slicing;
- **3GPP Feature and Study Item list: Rel-18**: Satellite; IoT; UAV; Sidelink; Proximity; Location and Positioning; Smart Energy; Ad hoc Group communication; Enhanced Network Slicing; eXtended, augmented, and virtual reality; Railways; Tactile and multi modality communication services; Self-organising Networks;
- **3GPP Feature and Study Item list: Rel-19**: Integrated Sensing and Communication; Metaverse; Network Sharing; AI/ML Model Transfer; Robots; Energy considerations

TABLE I: Overview of different technologies for 6G with respect to costs, energy consumption, latency, and security. ↑↑ / ↓↓ - tremendous impact, ↑ / ↓ - great impact, ↗ / ↘ - small impact, → - no impact

| Technology | Costs | Energy | Latency | Security | 5G/6G |
|---|---|---|---|---|---|
| In-Network Computing and OpenRAN | ↘ | → | ↓↓ | ↑ | Not 3GPP, started now |
| Joint Communication and Sensing | ↓ | ↓ | → | → | Release 18 |
| Post-Shannon Theorie | → | ↓↓ | ↘ | ↑ | 6G |
| Quantum Communication | ↑↑ | ↑ | ↓ | ↑↑ | 6G |
| Molecular Communication | ↓ | ↓↓ | ↑↑ | → | 6G |

Paul Schwenteck; Giang T. Nguyen; Holger Boche; Wolfgang Kellerer; Frank H. P. Fitzek **6G Perspective of Mobile Network Operators, Manufacturers, and Verticals** In: IEEE Networking Letters, pp. 1-1, 2023.

# Entrepreneurial Education and Startup Support




TUM with **CDTM** and **TUM Venture Labs**

- Trend Seminar
  „**The Future of Communication Technologies**“
  in Feb-April 2023
- Course
  „**Business Modeling & Prototyping**“ –
  Master students work on ideas of doctoral students/postdocs
- MOOC **Entrepreneurship in the era of 6G**
  open to all 6G-life researchers
- New **lecture series** (Ringvorlesung) on
  „**6G and entrepreneurship**“ in summer semester 2024



# Startups - currently 20+ interactions

## Sensors

blies tech

Haptic labs.io

PowerON Smart Elastic

## HMI

Enari.

Mimetik

veiio

## Robotics

HYDRABYTE

Olive Robotics

SMARTBIX

wandelbots

## Communication

aeroLiFi

CADAMI

CAMPUS GENIUS

EINHALB

MESHMERIZE
YOU MOVE. WE CONNECT.

QcomBIT

## Cloud Computing

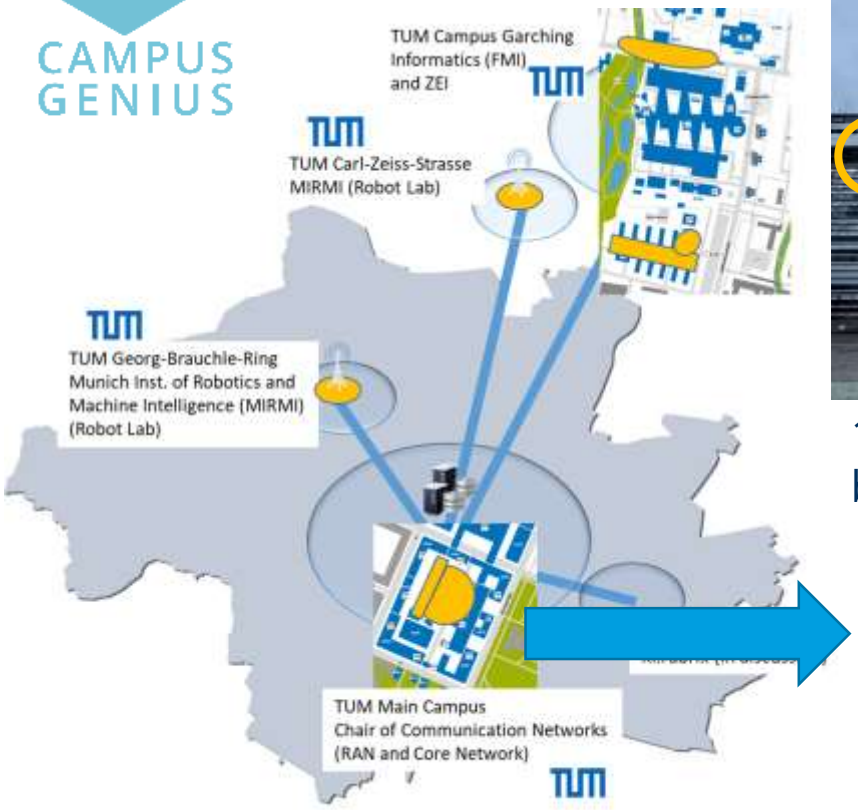
SpiNNcloud

bitteiler

# Examples for successful collaboration with Startups

CAMPUS GENIUS

5G Campus Network@TUM





10 indoor and 4 outdoor base stations (MIMO)

Olive Robotics

Flexible ROS-based plug-and-play robotics kits with sensors and communication modules
Here: AGV platform for context-based handover

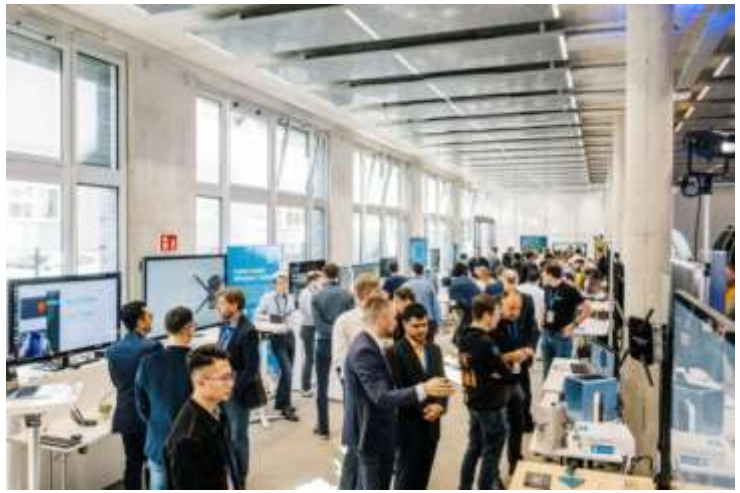
aeroLiFi

Setup of experimental platform with LiFi base stations and receives in our lab

# 6G-life & BMBF Startup Connect: Launchhub42

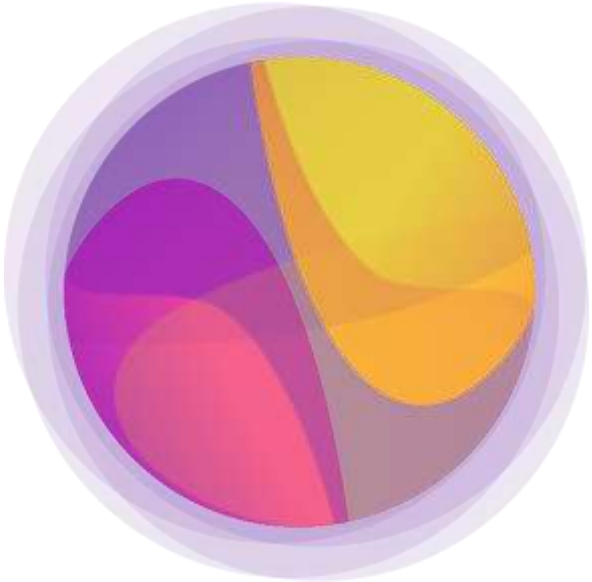
- BMBF lauched a special call for startup support (~ EXIST programme) specialized for startups in the are of communication and networks
- BMBF „StartUp Connect“
- 6G-life operates an incubator platform „Launchhub42“
- March 21/22, 2024: kick-off event in Berlin

LAUNCH HUB42

# 6G-life StartUp Contact Point

# Thank You!



www.6g-life.de