5G - FROM STANDARDIZATION TO DEPLOYMENT

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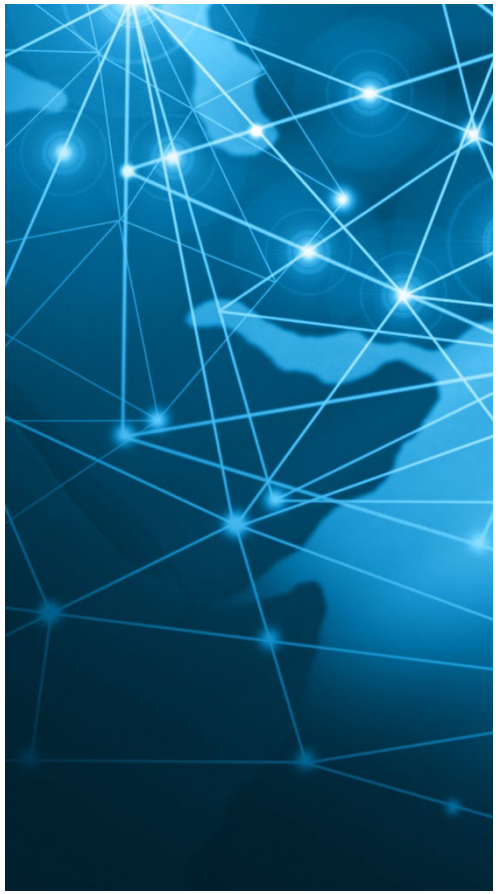
AGENDA



- 5G – A short introduction
- Technical Innovations in 5G
- 5G Standardization
- Use Case Based Technologies
- Vertical Applications
- Deployment
- Summary / Outlook

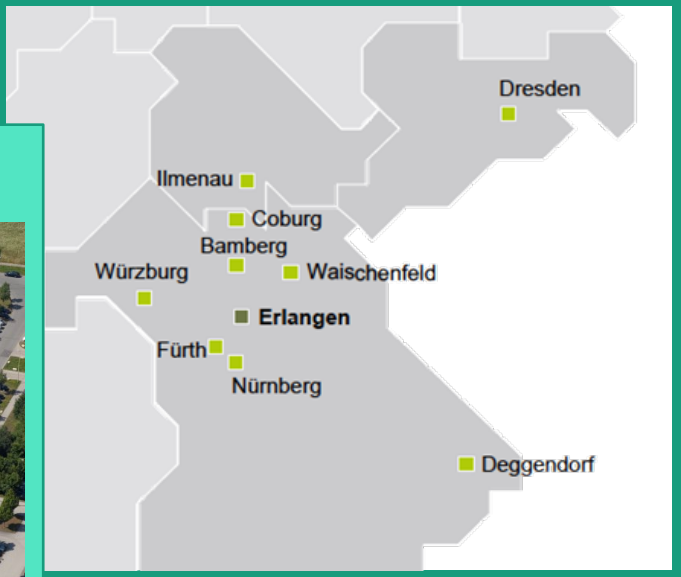
Fraunhofer Institute for Integrated Circuits IIS

Overview

- Fraunhofer IIS **data and facts**:
  - One of 72 institutes of the Fraunhofer-Gesellschaft in Germany
  - Founded in 1985
  - Approx. 900 employees
  - Budget of around €150 m
- Fraunhofer IIS **research areas**:
  - Audio and Media Technologies
  - Communication Systems
  - Navigation and Localization
  - X-Ray Technologies

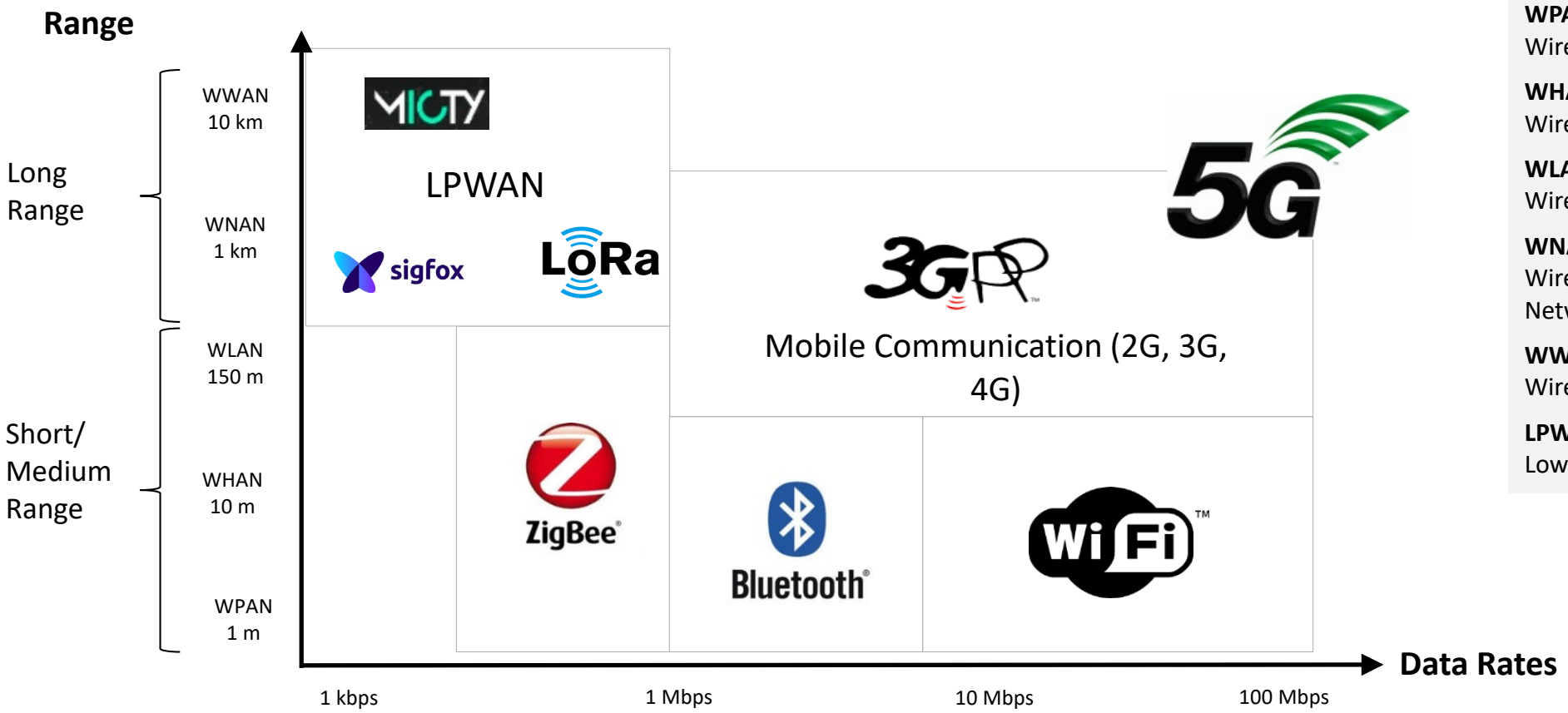
Fraunhofer IIS Erlangen

Locations of Fraunhofer IIS



5G – A short introduction

Wireless Communication Technologies



WPAN =
Wireless Personal Area Network

WHAN =
Wireless Home Area Network

WLAN =
Wireless Local Area Network

WNAN =
Wireless Neighborhood Area Network

WWAN =
Wireless Wide Area Network

LPWA =
Low Power Wide Area

5G – A short introduction

Evolution of Cellular Networks

1 G	2 G	2 ½ G	3 G	3 ½ G	3 ¾ G	4 G	4 ½ G	5 G
1981	1990	1993	2001	2006	2010	2015	2018	2020
C-Netz NMT AMPS TACS	**GSM[1]** CDMA IS-95A	**GPRS[2]** IS-95B	**EDGE[3]** **UMTS[4]** CDMA 2000	**HSDPA[5]** **HSPA+** 1xEV-D0	**LTE[6]** Rel. 8	**LTE-A[7]** Rel. 10	**LTE-A Pro** Rel. 13/14	**LTE / NR[8]** Rel. 15/16

[1] Global System for Mobile Communication

[2] General Packet Radio Service

[3] Enhanced Data Rate for Global Evolution

[4] Universal Mobile Telecom-munications System

[5] High Speed Packet Access

[6] Long Term Evolution

[7] LTE Advanced

[8] New Radio

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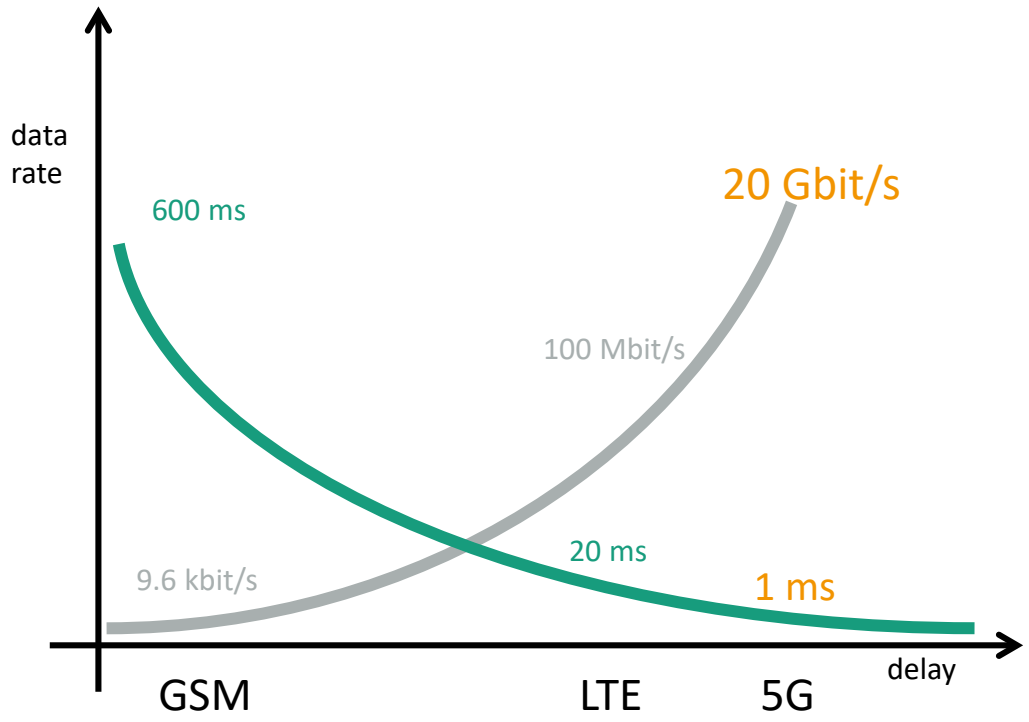
5G – A short introduction

Data Rates & Latency

EVOLUTION OF CELLULAR COMMUNICATION



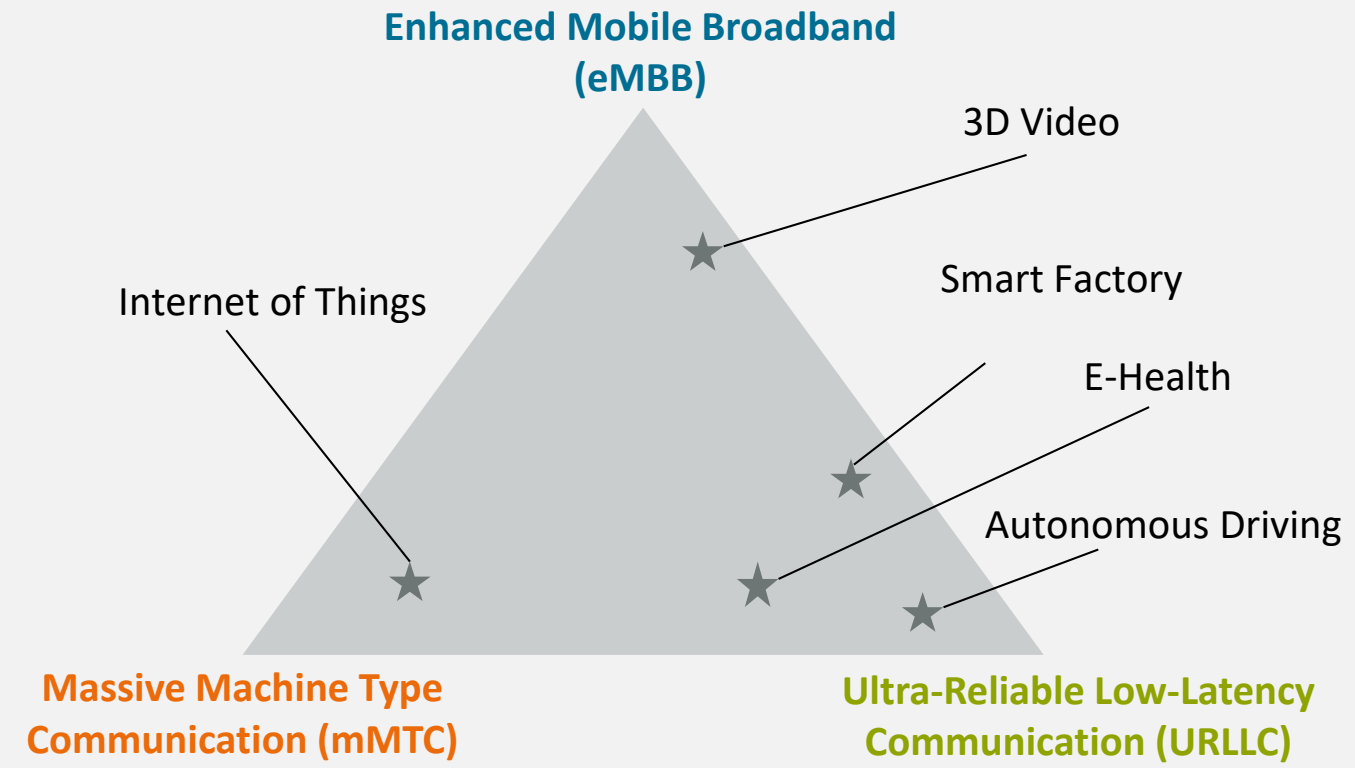
- **Data Rates**
  - from 9.6 kbit/s (GSM)
  - via 100 Mbit/s (LTE)
  - to **20 Gbit/s (5G)**
- **Latency**
  - from 600 ms (GSM)
  - via 20 ms (LTE)
  - to **1 ms (5G)**

5G Use Case Groups
An Overview

eMBB
Peak data rate:
up to 20 Gbit/s (Downlink)

URLLC
Real-time communication:
Latency < 1 ms

mMTC
High connection density:
1,000 – 1,000,000 devices/km²



Technical Innovations in 5G

ITU Defined Key Performance Indicators

- According to ITU-R M.2410-0 (11/2017)
- Use Case Group specific requirements

Enhanced Mobile Broadband

Peak data rate	Downlink 20 Gbit/s Uplink 10 Gbit/s
User experienced data rate	Downlink 100 Mbit/s Uplink 50 Mbit/s

Reliable, Low Latency Comm.

Latency - user plane	1 ms / 4 ms
Reliability	99.9999% (of packets)

Mobility

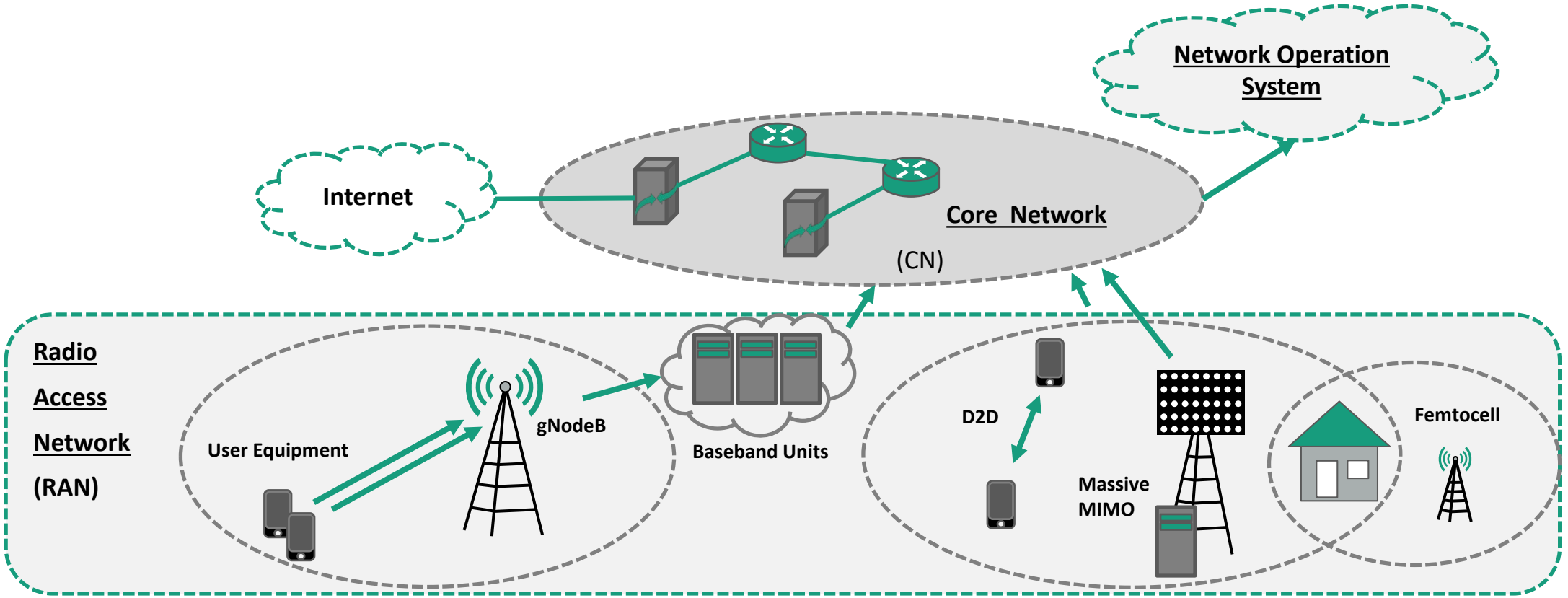
Mobility - different classes	Up to 500 km/h
Mobility - interruption time	0 ms

Massive Machine Type Communication

Connection density	1,000 – 1,000,000 devices/km²

Technical Innovations in 5G

System Architecture



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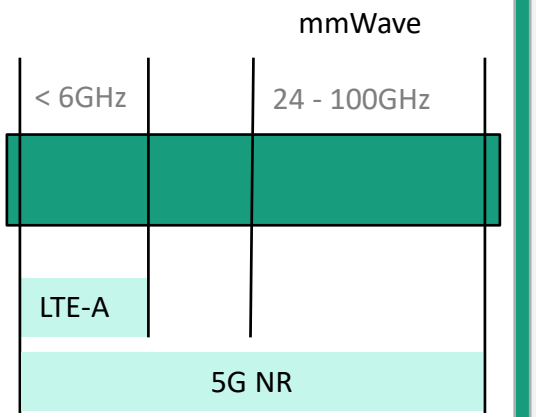
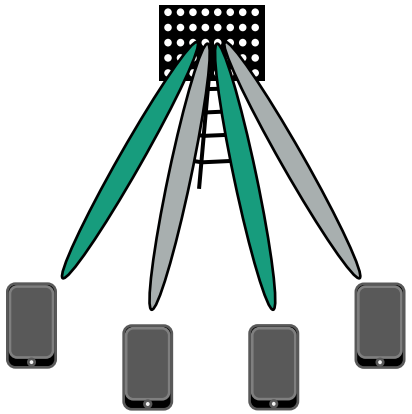
Technical Innovations in 5G

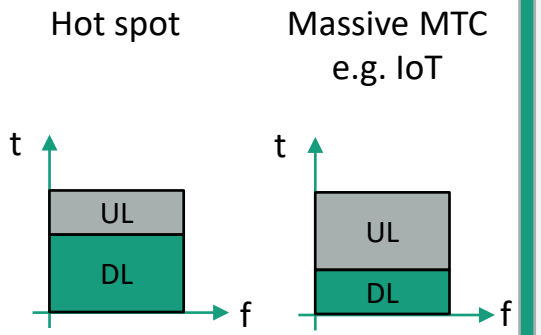
Major Technical Aspects



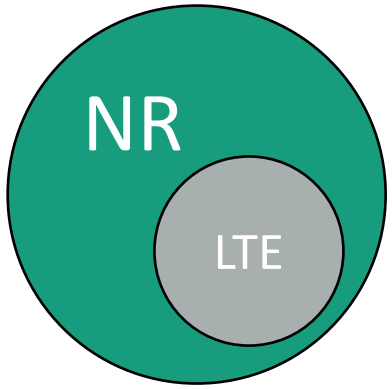
Ultra-broadband mmWave



MIMO Beam forming



Flexible Time Division Duplexing



5G: LTE + NR

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Technical Innovations in 5G

Frequency Bands for 5G

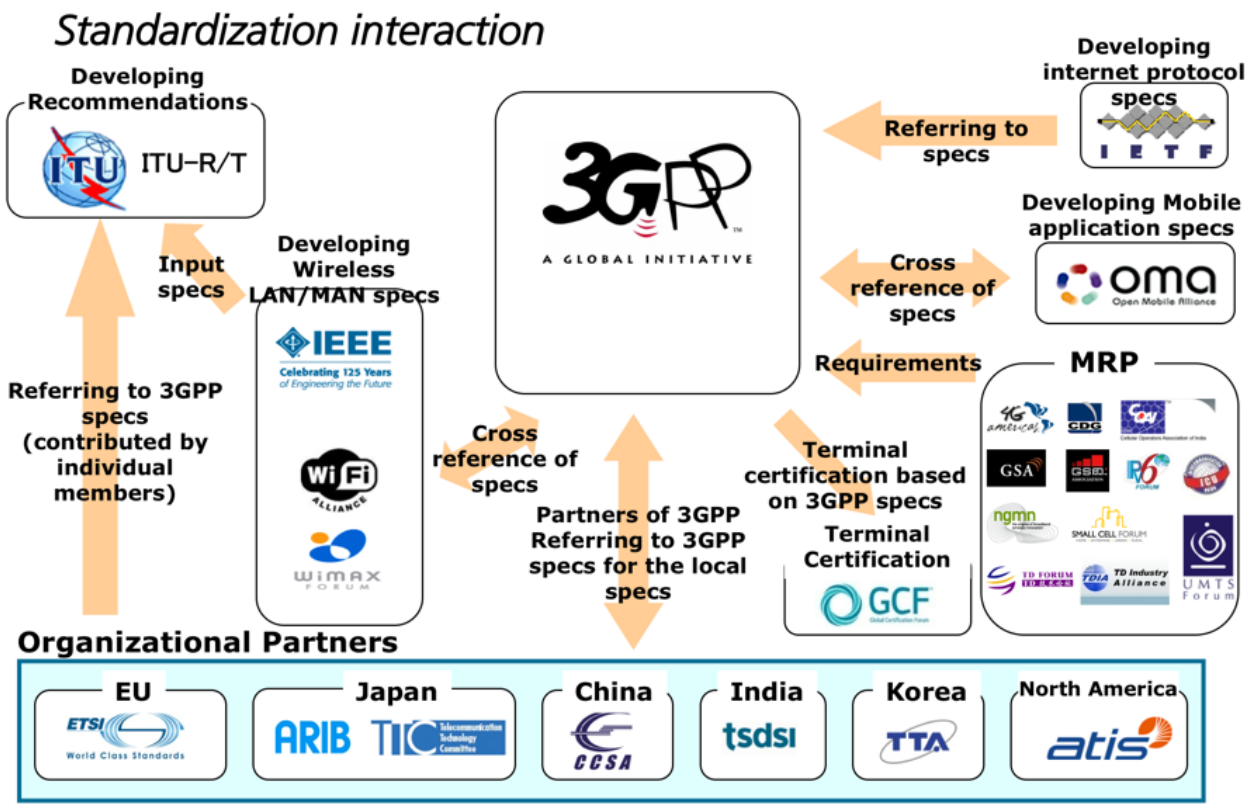
- For **5G NR two frequency ranges** (FR)
  - Frequency range 1 and 2
  - 3.5 GHz band: one of the initial bands for 5G
  - FR2 – millimeter wave range
- New 5G Study & Work Item

  “5G in unlicensed band” (NR-U)
  - 868 Mhz
  - 2,4 / 5 GHz

New Radio 3GPP TS 36.101-1/TS 38.104	
Frequency range designation	Corresponding frequency range (FR)
Frequency Range 1	450 MHz – 6.000 MHz
Frequency Range 2	24.250 MHz – 52.600 MHz

5G Standardization

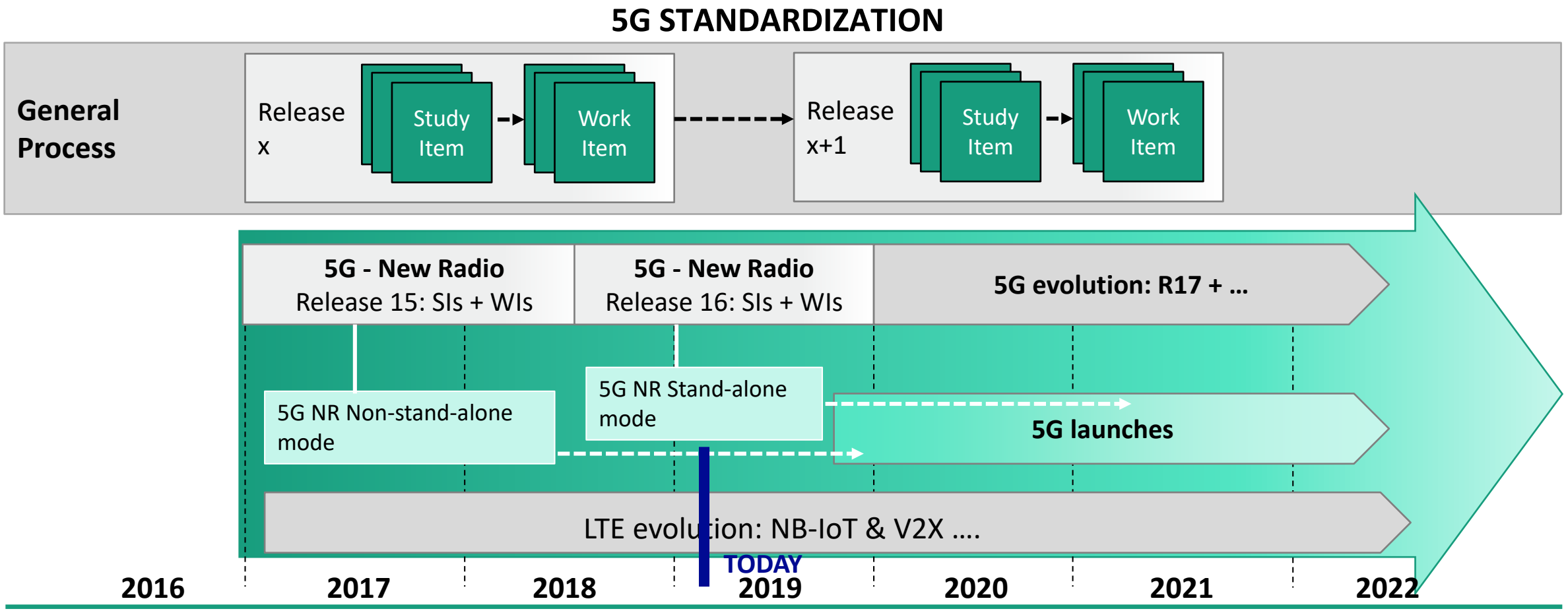
Overview



- The standardization committee **3GPP** coordinates the standardization of 5G
- Releases approx. every **18 months**
- Representatives from **industry and research** work together to develop the specifications of the next mobile network generation
- In 5G standardization the users („**Verticals**“) are **much more involved than in the generations before** → key users and industries bring in their requirements
- **German interests / companies** are represented e.g. by the 5G-ACIA (automation industry), 5GAA (automotive industry) or the BNetzA (exchange platform 5G standardization)

5G Standardization

General Process



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Use Case based Technologies

Overview

- **Device-to-Device (D2D) /** Vehicle-to-Everything (V2X)
- **5G via Satellite**
- **Unmanned Aerial Vehicles (Drones)**
- **5G Positioning**
- Multimedia Broadcast Multicast Service (MBMS)
- Internet of Things (IoT) / Machine-to-Machine (M2M)

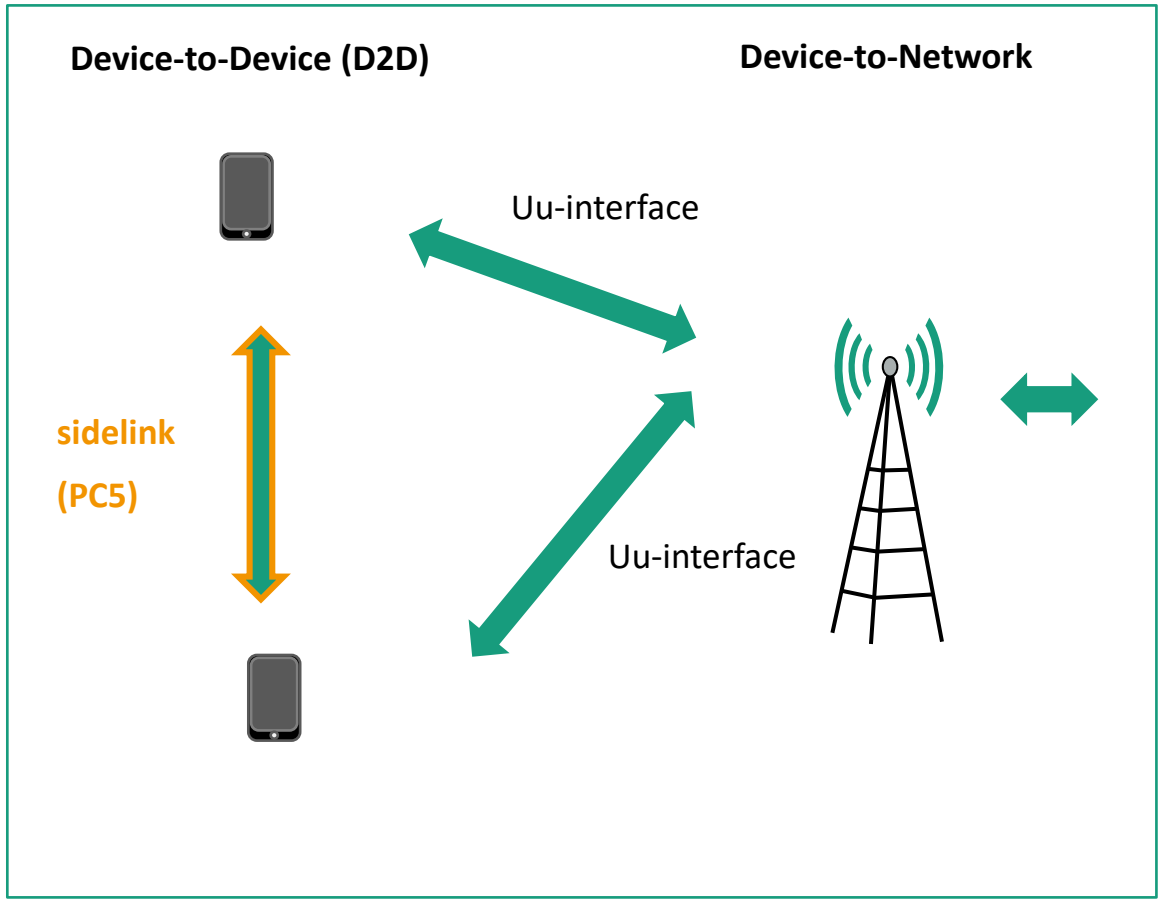
Use Case based Technologies

Device-to-Device (D2D) / Vehicle-to-Everything (V2X)

- **Direct communication between devices**

  → no network support required

  - D2D in vicinity – for proximity services
- Advantages of D2D direct communication
  - Low distance
  - Single “hop”
    - Less latency + low transmission power
    - Less interference → increased reliability
    - Resource reuse → data rate increase
  - No need for overall cellular coverage

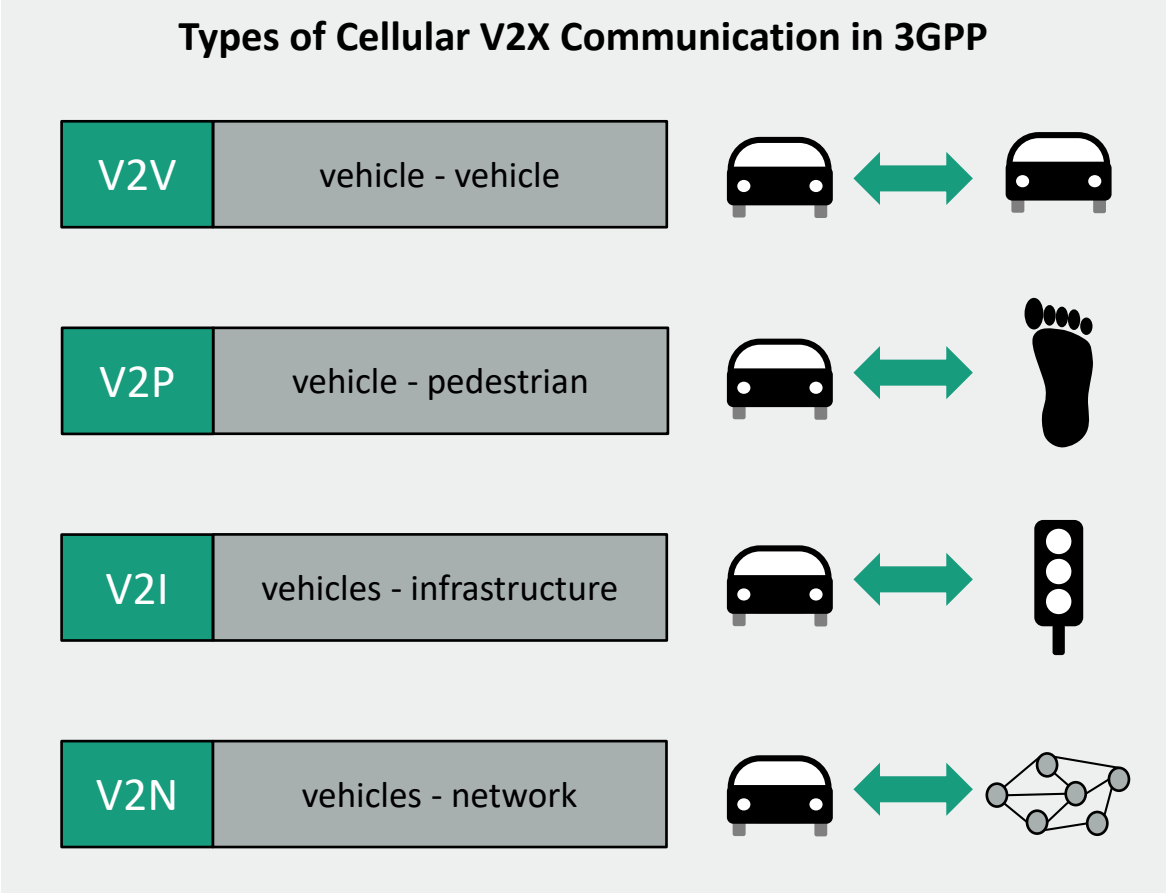


Use Case based Technologies
Vehicle-to-Everything (V2X)

Types of C-V2X (everything) communication

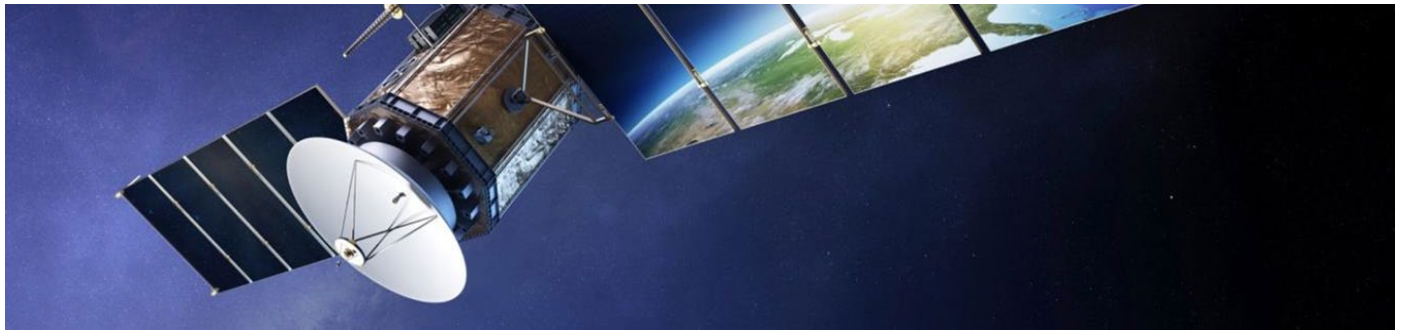
- between **vehicles**
  - Vehicle-to-Vehicle (**V2V**)
- between **pedestrians** and vehicles
  - Vehicle-to-Pedestrian (**V2P**)

  → Challenge: Battery consumption
- between **infrastructure** and vehicles
  - Vehicle-to-Infrastructure (**V2I**)
  - Roadside Unit (RSU) e.g. traffic signs
  - used for Mobile Edge Computing
- With cellular network: Vehicle-to-Network (**V2N**)



Use Case based Technologies

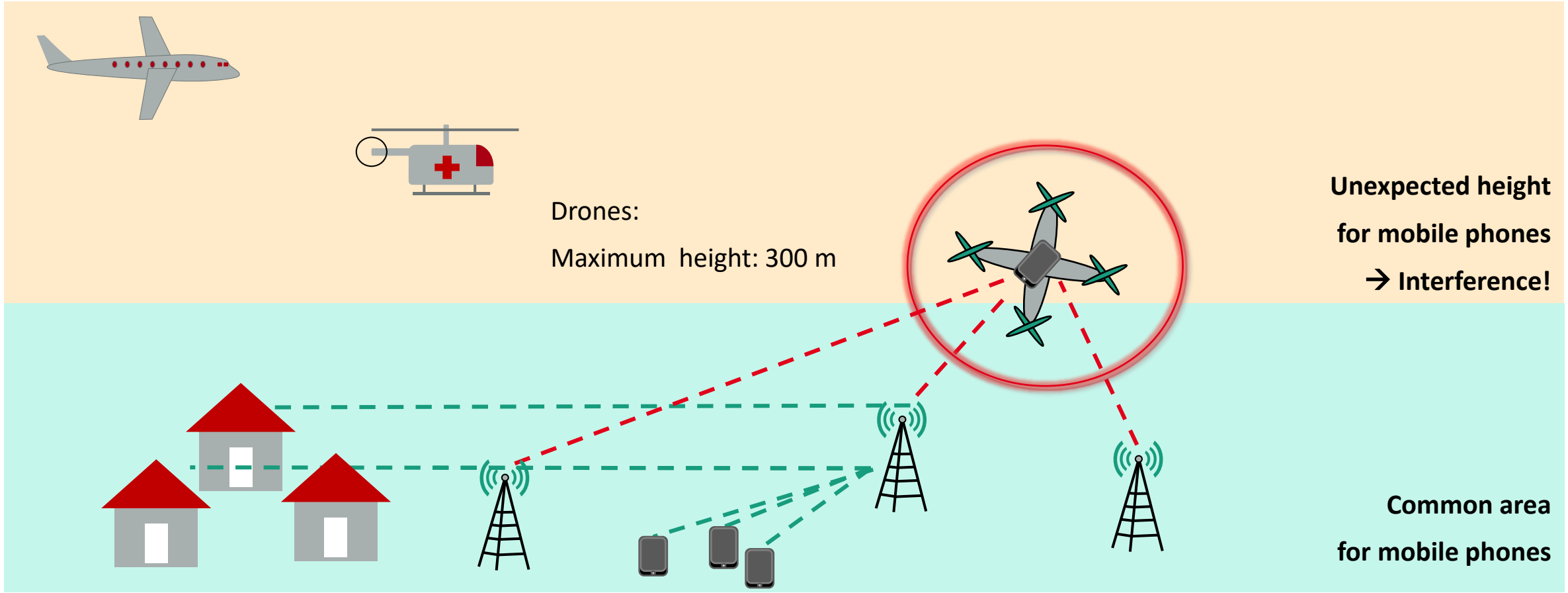
5G via Satellite



- Satellite Activities in 5G
  - Introduction of communication via satellite in 5G
  - 3GPP Study Item on Satellite/Non-Terrestrial Networks (NTN) in 5G
- Motivation for 5G via satellite
  - Ubiquitous 5G service by **extending the reach of 5G networks** to areas that cannot be covered by terrestrial 5G networks, e.g. for
    - IoT: sensor nodes in deserted areas
    - Public safety
  - Connectivity and delivery of 5G services for **airborne vehicles**
    - E.g. air flight passengers, drones, vessels

Use Case based Technologies

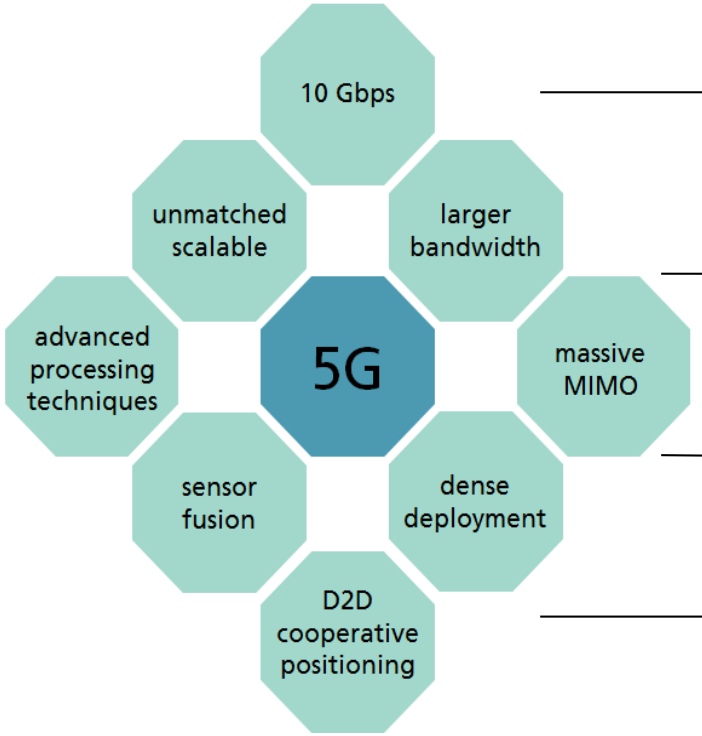
Unmanned Aerial Vehicle (UAV) / Drones



Use Case based Technologies

Positioning in 5G

Positioning in 5G offers huge benefits compared to 4G and solutions based on GNSS for use cases like Industry 4.0. These benefits are grounded on improvements in accuracy and availability due to a larger bandwidth of higher frequencies and dense deployments.



mm-Wave - mm-Wave transmission allows accurate positioning using larger bandwidths and taking advantage of the beamforming approaches

Massive MIMO - antenna arrays consisting of a large number of antenna elements to allow precise positioning

Dense Deployment - improves the performance through redundancy and achieving a better geometry.

D2D Positioning - due to D2D communication, mobile terminals can collaborate to help each other to determine their own position

Vertical Applications
Industries & Sectors

Automotive / Mobility Service Providers

- Car-to-Car-Communication for driver assistance systems
- Real time connection to a control center and traffic information systems

Manufacturing Industry / Industry 4.0

- Energy efficient and quality-guaranteed mass connectivity
- Automated machine-to-machine communication

Media / Broadcasting

- Nationwide provision of streaming content

Vertical Applications
Industries & Sectors

Logistics

- Transport industry can utilize autonomous driving
- Comprehensive tracking and condition monitoring of goods in shipping

E-Health

- Cellular telemedicine for improved care and treatment
- Better connection and cooperation between partners in the eHealth industry

Energy / Smart Grid

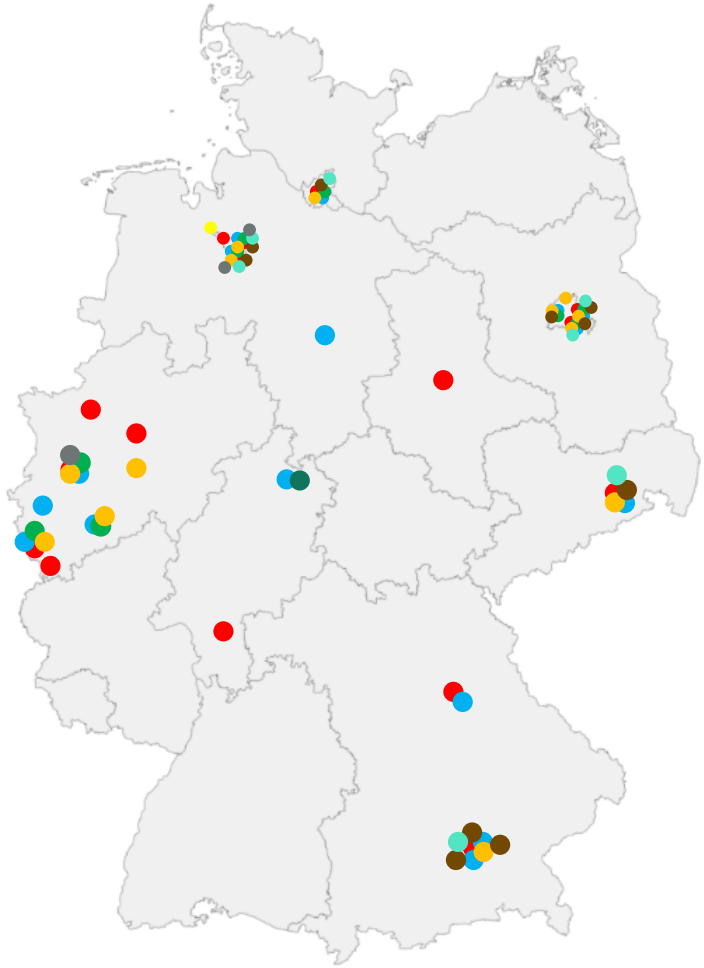
- Flexible and need-oriented production, supply and purchase of power
- Condition Monitoring

Deployment
Current Status

- **5G – currently at the early stage**
  - Rel. 15 defined as a basic NR “framework”
  - Deployment starts from 2019/2020 onwards, likely as non-standalone
  - 5G Products (Base Stations, UEs, …) will become available during 2019
  - Rel. 16 just started with stand-alone mode
- There are „5G“ Networks running – e.g. in China, Korea or USA
- Germany / Europe is more conservative
- German operators focus on LTE, roll-out is capacity and coverage driven
- Private (non-public) 5G networks covering production plants or industrial parks

Deployment

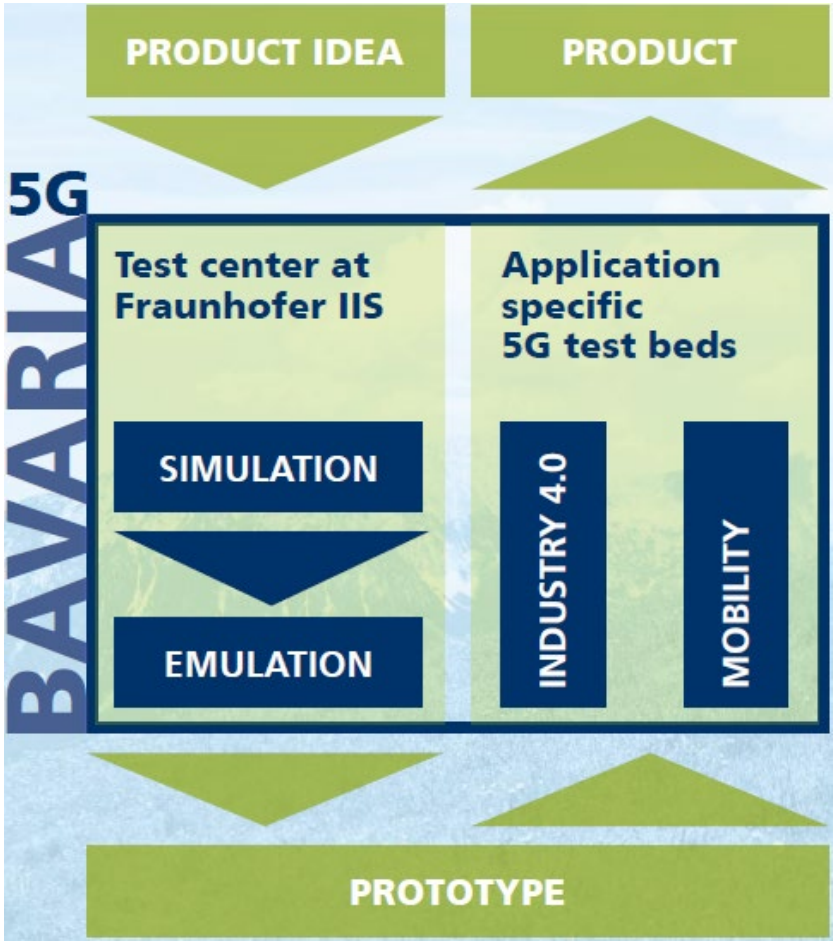
5G Testbeds in Germany



- Industrial Automation / Industry 4.0
- Autonomous & Connected Driving
- Logistics
- Smart Grid / Energy
- Media / Broadcasting
- E-Health
- Basic Research on 5G communication technologies
- “Intelligent Infrastructure”
- Massive IoT

Deployment

5G Bavaria



Test center at Fraunhofer IIS:

- **Simulations** and **emulations of 5G technologies**
- receive **timely feedback** on the usability of 5G for your specific application
- Fraunhofer IIS takes care of **setup**, **development and provision** of the simulation environment

Application specific 5G test beds:

- setup and operation of **various 5G test beds** in diffe-rent regions **across Bavaria**
- test the **possibilities and limits of 5G** even **before** its roll-out is completed
- **Real infrastructure** like motorways or industrials environments

Summary / Outlook

5G From Standardization to Deployment

Many Thanks!

- **5G – Evolution from 4th generation → no revolution**
  - Tight cooperation of LTE and New Radio (NR)
  - Standardization is ongoing and a permanent process
- **5G – a major steps forward**
  - Multiple new services, e.g. autonomous driving, Industry 4.0, Internet-of-Things (IoT)
  - Improved wireless technology, e.g. flexible use of mmWave frequency bands, massive Multiple Input Multiple Output (MIMO), flexible resource allocation
- Rollout and Availability strongly related to commercial aspects
- Will the “white spots” get eliminated with 5G? → No!

→ 5G may become the UNIVERSAL WIRELESS NETWORK