MOBILE TEST SUMMIT 2024

# THE FUTURE OF WIRELESS WITH 6G

**Mr. Reiner Stuhlfauth**
Technology Manager Wireless
Rohde & Schwarz

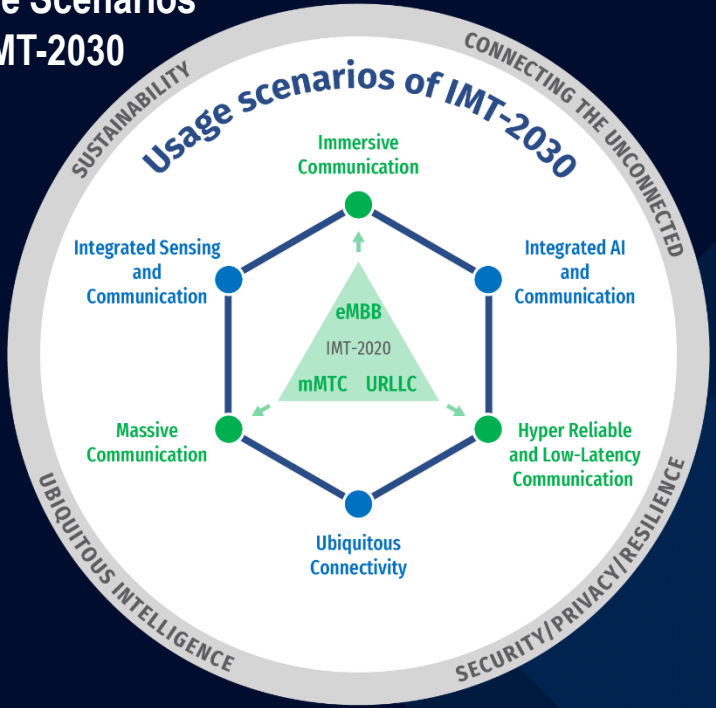
ROHDE&SCHWARZ
Make ideas real

# The “Unstructured“ evolution of 5G towards 6G

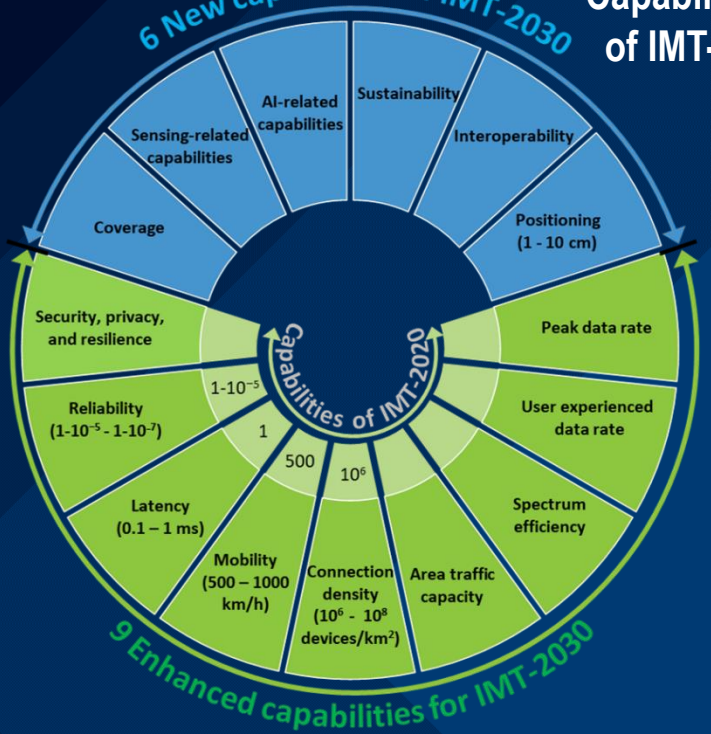

**Evolution and not a revolution**

# IMT-2030 capabilities and usage scenarios

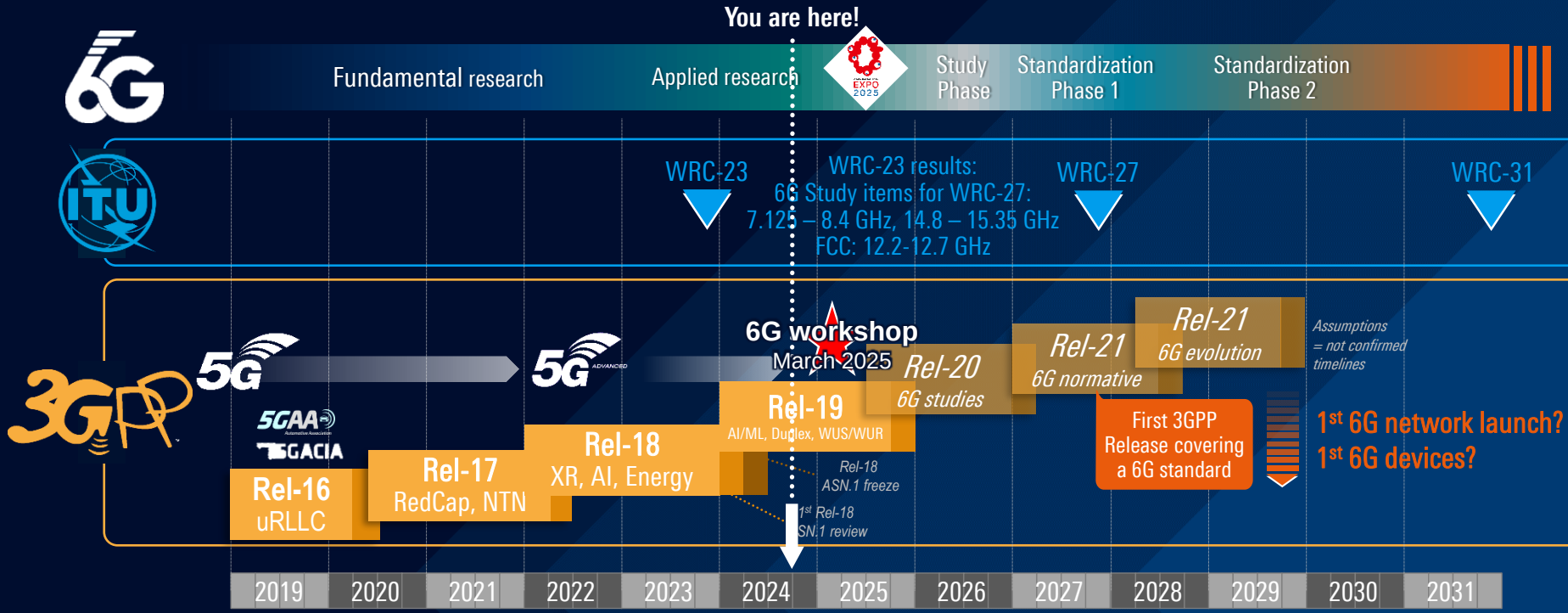
Usage Scenarios of IMT-2030




Capabilities of IMT-2030



# Shaping the future of mobile communication by standardization




[1] *IMT-2020 systems are called 5G, The ITU has already started a new technology trend report to prepare the work on "IMT-2020 and beyond" that is likely to become 6G*

# Article: “Reviewing wireless broadband technologies in the peak smartphone era: 6G versus Wi-Fi 7 and 8”

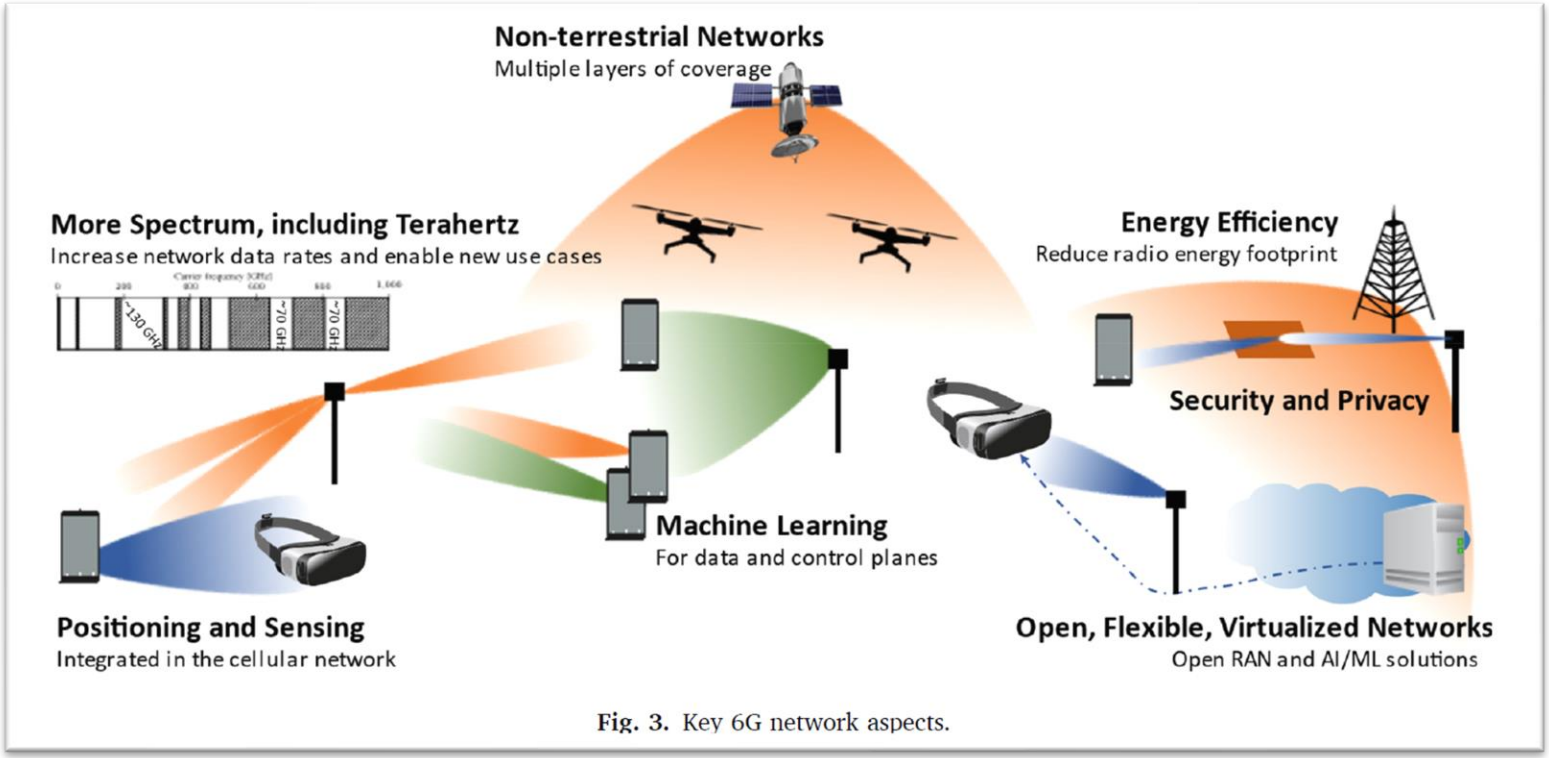
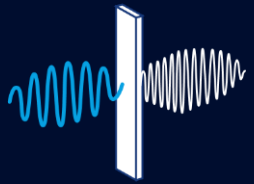



Fig. 3. Key 6G network aspects.

# RESEARCH AREAS FROM A T&M PERSPECTIVE

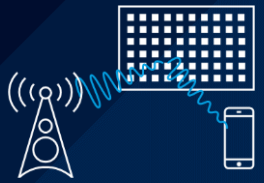
Spectrum for 6G: “FR3” and THz



Integrated sensing & communication

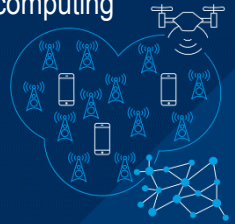
Artificial Intelligence and Machine Learning

Reconfigurable Intelligent Surfaces



Photonics, Visible Light Communication

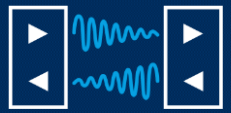
New network topologies, distributed computing



Multiple access, new waveforms, channel coding

Ultra-massive MIMO

The Metaverse and eXtended Reality (XR)



Full-duplex communication

Security & Trustworthiness

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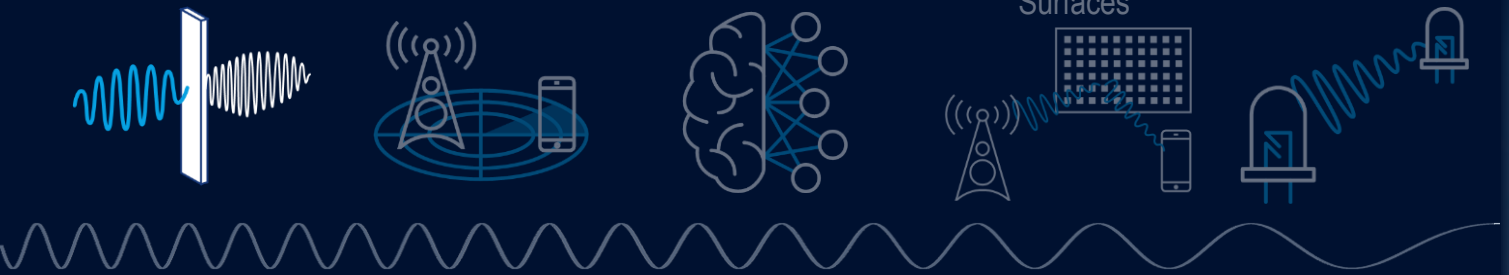
**THz communication, and "FR3"**

Joint communication & sensing

Artificial Intelligence and Machine Learning

Reconfigurable Intelligent Surfaces

Photonics, Visible Light Communication



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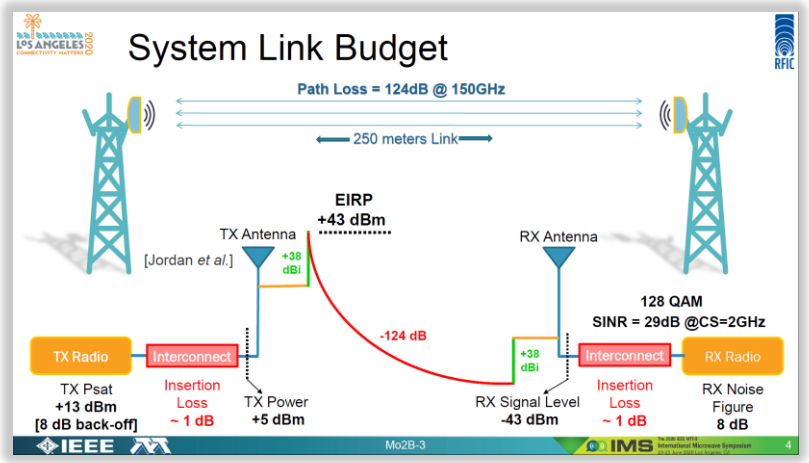
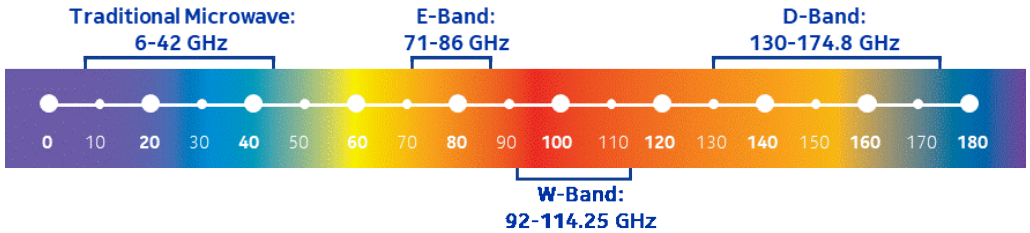
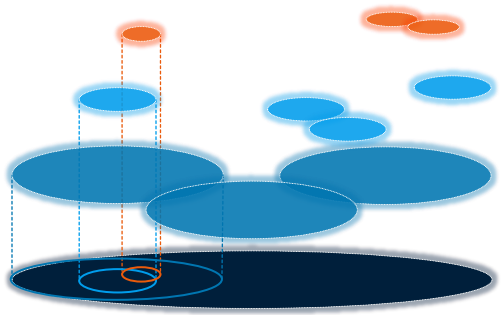
# MORE LIKELY THE INITIAL USE CASE FOR SUB-THz

## WIRELESS FRONT- AND BACKHAULING




- Initial use case for D-Band is wireless backhaul and fronthaul applications
  - Cellular: ultra-hot spots in combination with FR2?



Ultra-hot spots
> 100 GHz

Hot spot layer
< 48 GHz

Capacity layer
< 6 GHz

Coverage layer
< 1 GHz

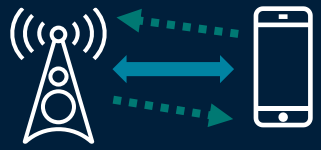
# FREQUENCY RANGE 3 „“FR3“- 7-24GHz?

“FR3“ extends the known RF behaviour of FR1 (e.g. wave propagation + RF chain) but offers much wider bandwidth!

7.125 GHz “undefined boundary“ 24 GHz

FR1 **FR3** FR2

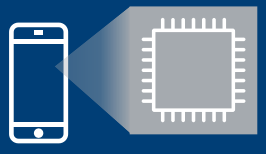
UL based channel estimation ⇨ **DL beamforming**



Infrastructure


Beam correspondance: DL CSI-RS + UL UCI ⇨ **closed loop**

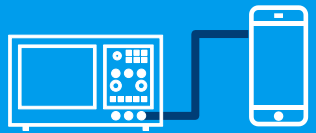
Additional band ⇨ **add. components** only, e.g. filter, PA, etc.



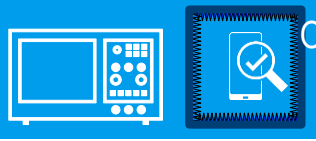
Device

Additional band ⇨ **System on chip needed**

**Conducted**



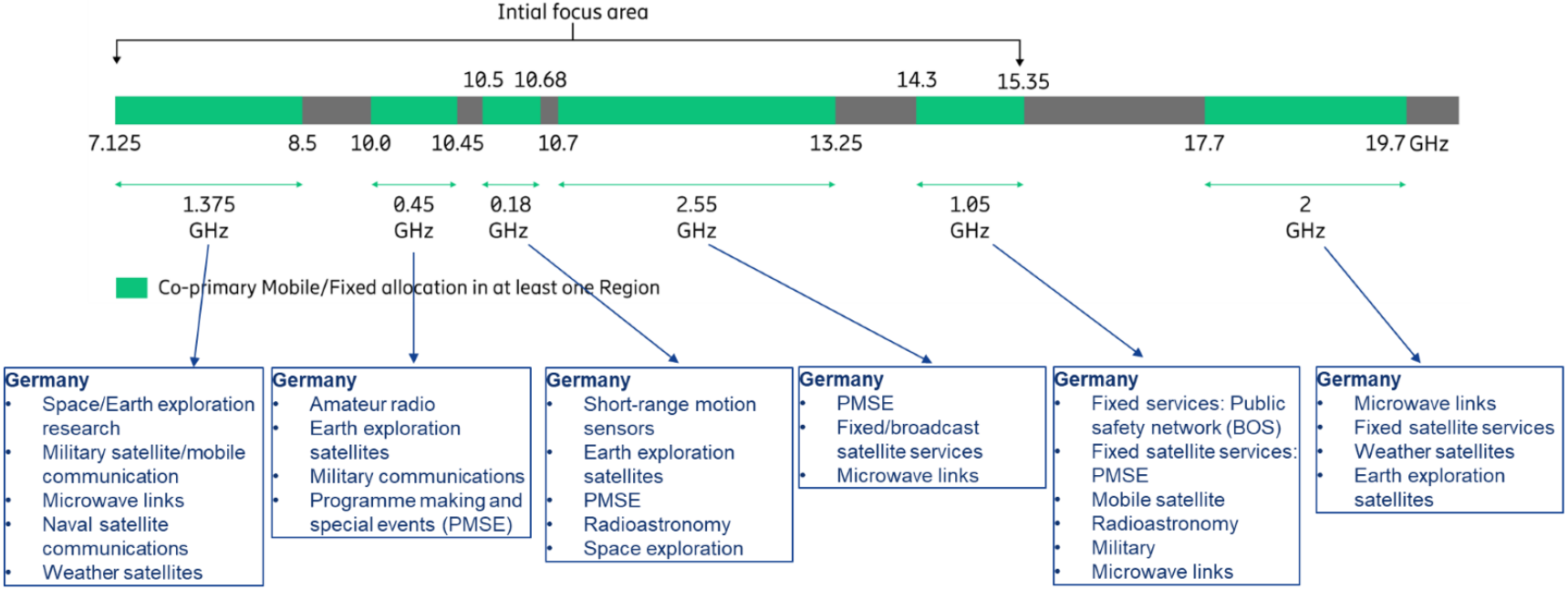
Test & Measurement



Over the Air

# FR3 – WHY IS IT DIFFERENT FROM LEGACY? BECAUSE IT IS OCCUPIED ALREADY ☹ SEE ERICSSON REPORT

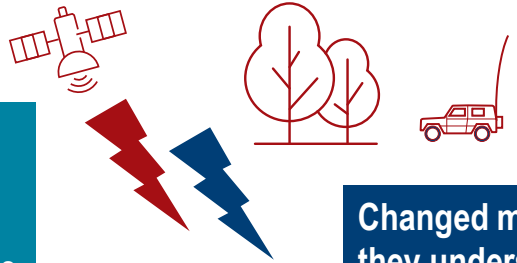
Example: Spectrum occupation „FR3“ in Germany, several incumbent users and free spots




Source: https://www.ericsson.com/assets/local/reports-papers/white-papers/6g-spectrum.pdf

# FR3, why is it different from legacy spectrum FR1 and FR2

**Challenge: "FR3" is already occupied by incumbent owners. Wireless needs to incorporate some spectrum coexistence methods and we need to improve spectrum efficiency!**

Incorporate interference cancellation methodologies
**6G = victim**

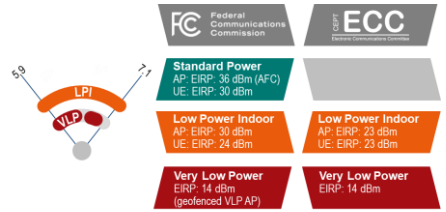
Incorporate interference reduction methodologies
**6G = aggressor**

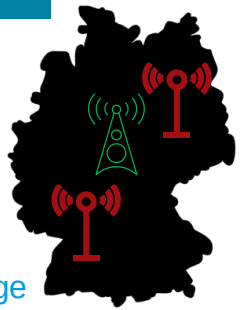
**Changed mindset within regulatory bodies, they understand spectrum crunch**

Past: Focus on TX side only: e.g. spectrum emission, ACLR limits, max. TX power

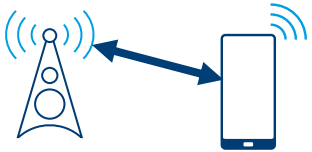
Future: Consider RX side as well: e.g. RX resistence & interference mitigation stragies

Example
WiFi7 with power reduction

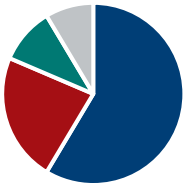


Example:
geolocation controlled spectrum usage



Example:
new methods for dynamic spectrum sharing



Example:
time of day controlled spectrum usage

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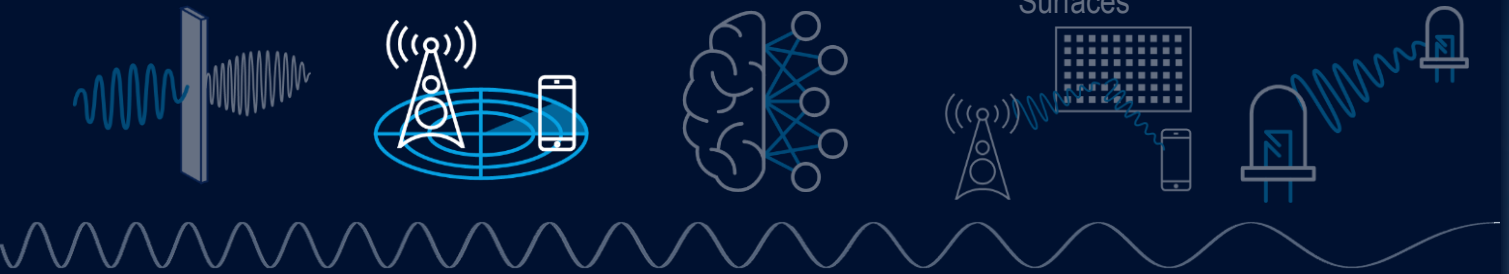
THz communication, and "FR3"

**Joint communication & sensing**

Artificial Intelligence and Machine Learning

Reconfigurable Intelligent Surfaces

Photonics, Visible Light Communication



Multiple access, new waveforms, channel coding

Ultra-massive MIMO

New network topologies, distributed computing

Full-duplex communication

Security & Trustworthiness

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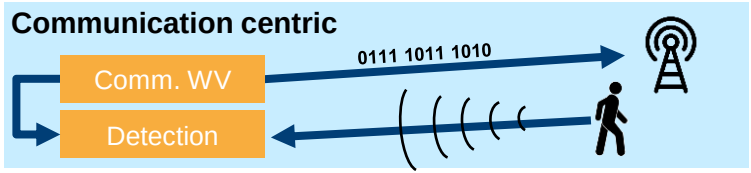
# JOINT COMMUNICATION AND SENSING (JCAS)

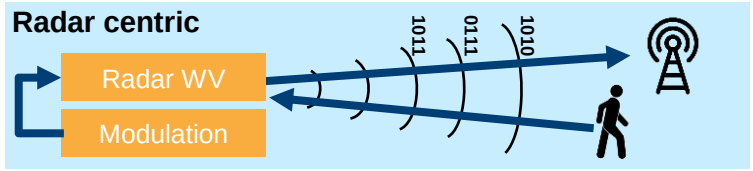
## MOTIVATION AND RESEARCH CHALLENGES

**Integrated JCAS system using single transmitted waveform and full-duplex operation:**

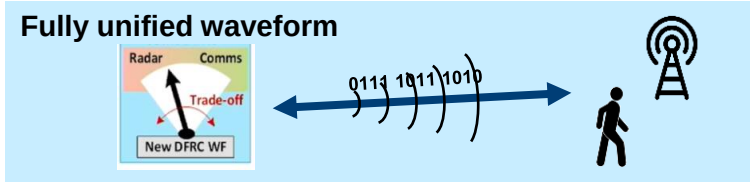
**Communication-centric** design, with guaranteed communication performance (e.g. OFDM-based)




**Radar-centric design**, optimized for sensing performance (e.g. using chirp signals as information carriers → PC-FMCW)

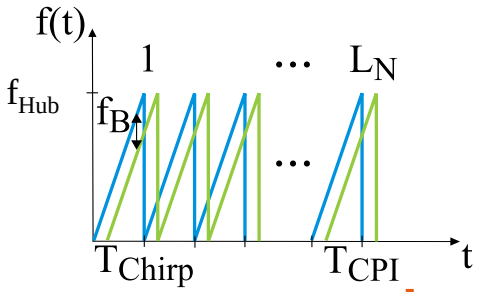



**Jointly optimized design**, with freely scalable sensing and communication performance trade-off



# Waveforms: Two entry points for evolution

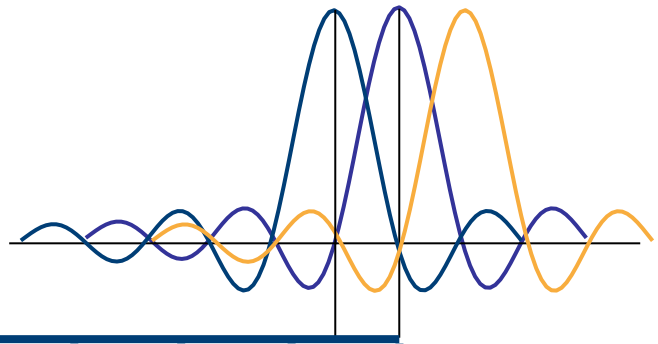
## Radar centric

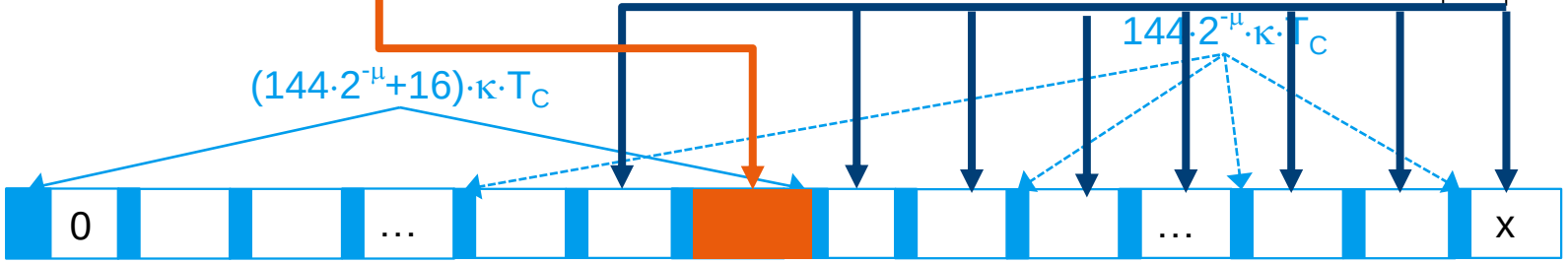



Transmit Signal
Receive Signal

Research example:
Blank one OFDMA symbol in
a 5G NR frame and insert FMCW chirp

## Communication centric

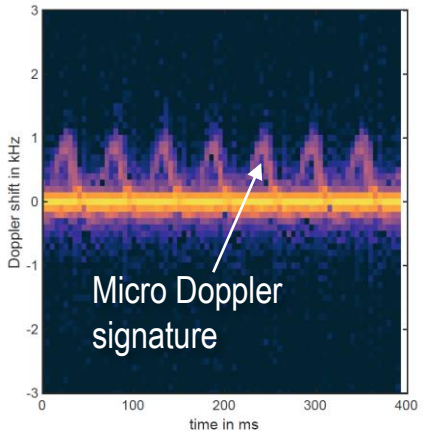




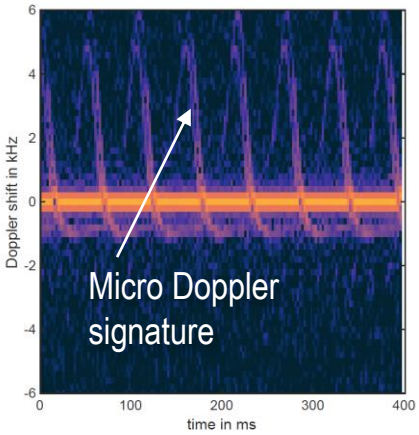
# Time-domain channel measurements for FCAS research

## Characterization of Helicopter Rotor Blade Modulation in UHF and Microwave Bands


**Doppler Spectrogram CH53 Helicopter**




4.9 GHz




27.1 GHz

"Characterization of Helicopter Rotor Blade Modulation in UHF and Microwave Bands", submitted to MILCOM2024

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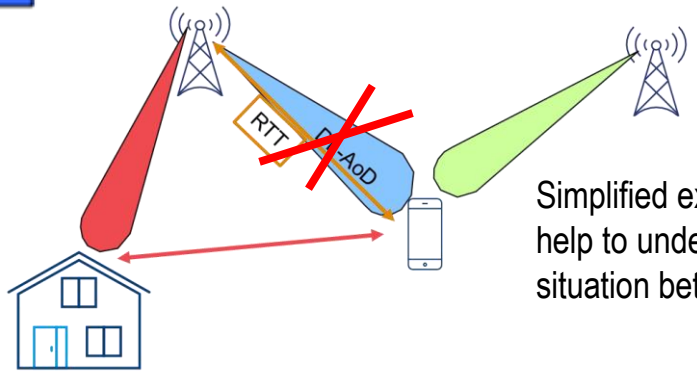
# 5G NR – AI first use cases

## AI to learn channel, predict and reduce #CSI signals needed

**PAST**
consider channel status as constant in between CSI reporting intervals

**NEW**
AI model predicts the „real“ channel conditions and allows some flexibility

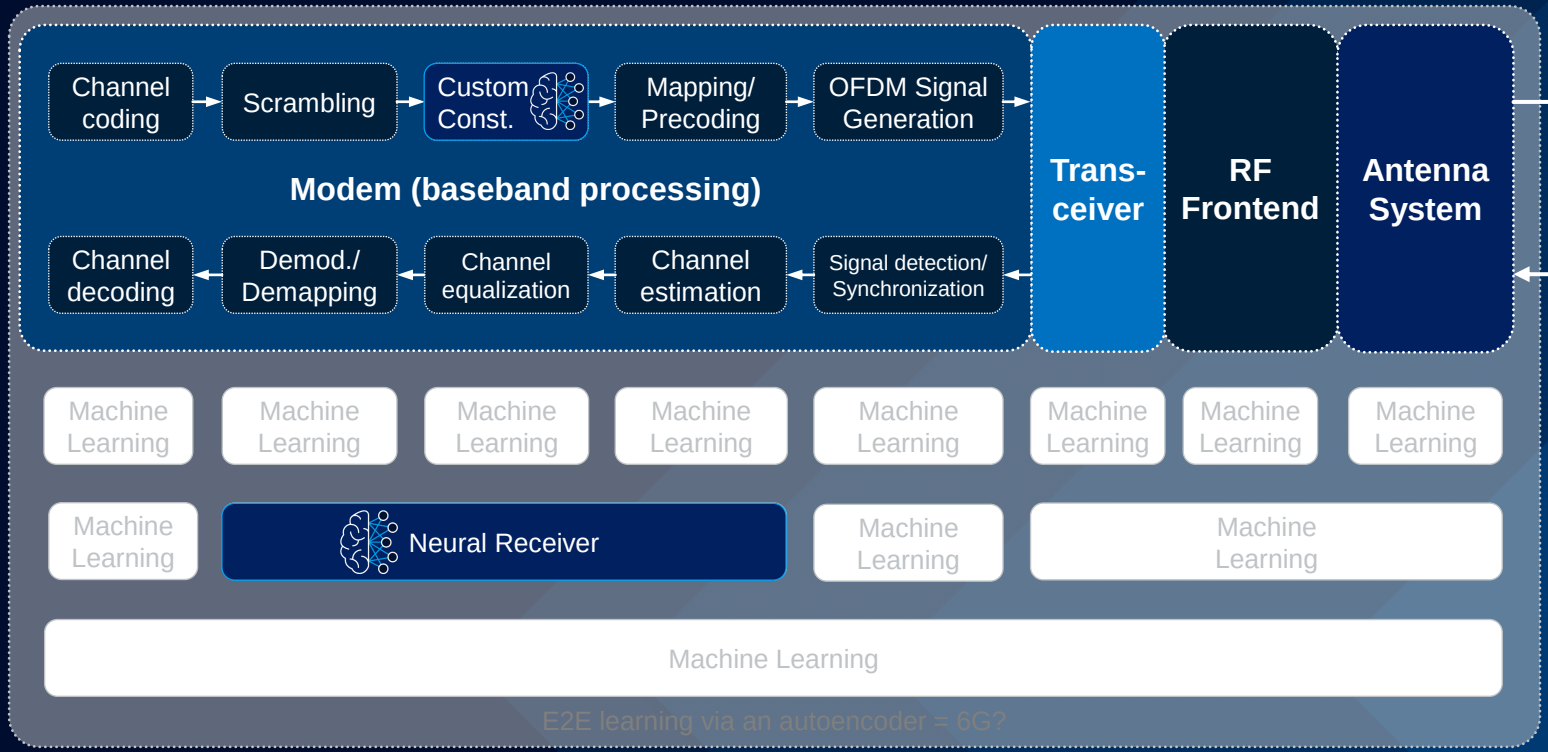

AI to enhance the position estimates
+ verify position determination




Simplified example: AI may help to understand the real situation better

# Towards an AI-NATIVE AIR INTERFACE FOR 6G

## ADVANCING THE NEURAL RECEIVER WITH CUSTOM CONSTELLATION




ML applied to individual processing blocks

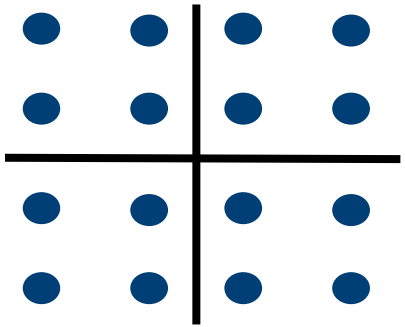
ML replaces multiple processing blocks

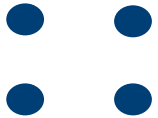
ML used to jointly optimize TX, RX and baseband processing;

ML designs part of 6G PHY/MAC itself

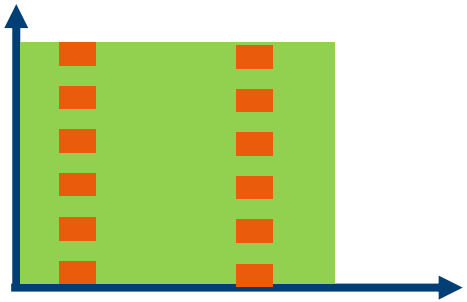
# Modulation scheme constellation aspects

**Reminder 16QAM**



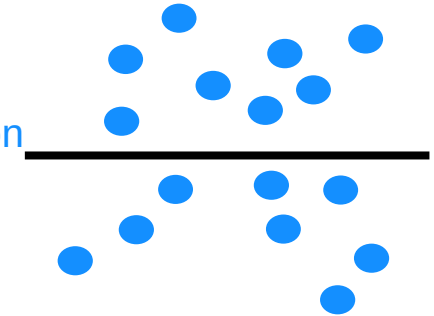


But: every quadrant is identical



As radio channel (Fading) deteriorates the signal, we need pilots e.g. DMRS for channel estimation and equalization

**Idea:**
If we apply a scenario specific, pseudo-random looking constellation diagram, we may understand the constellation position as kind of reference signals



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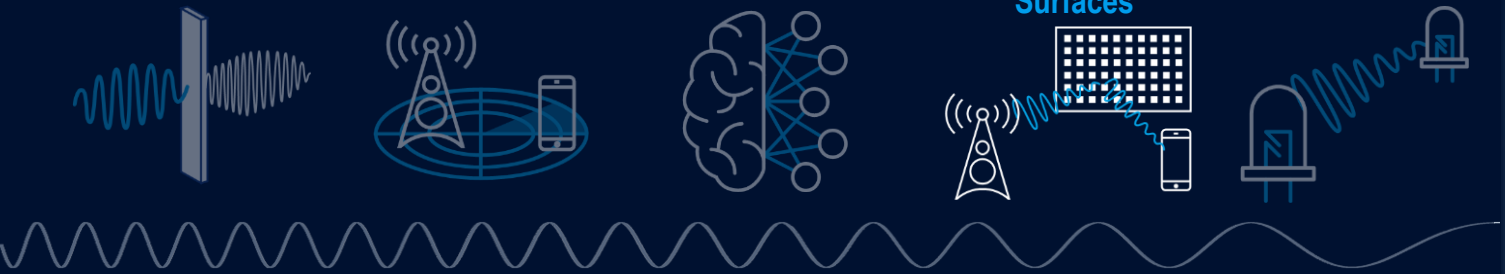

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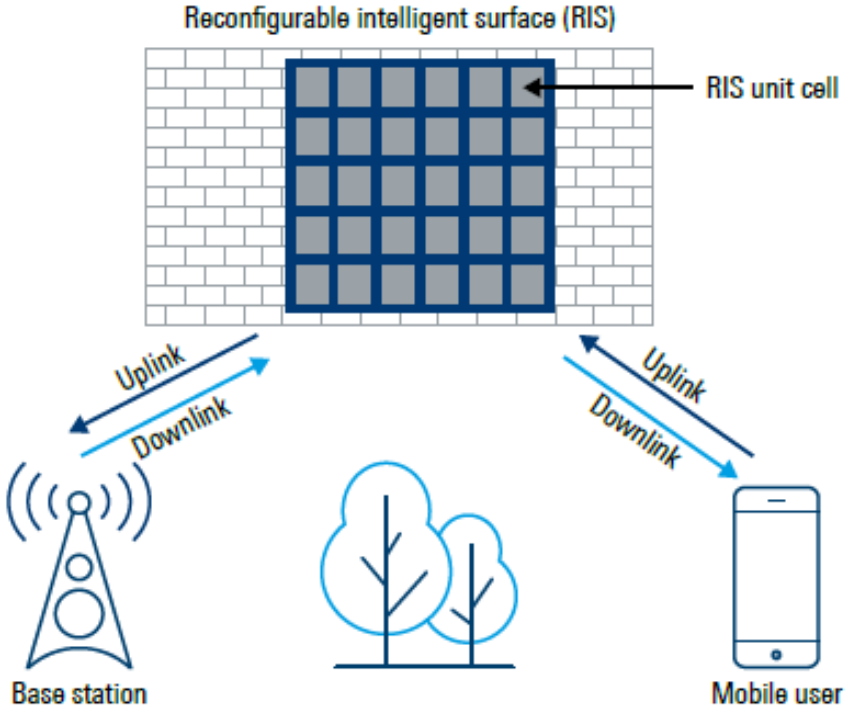
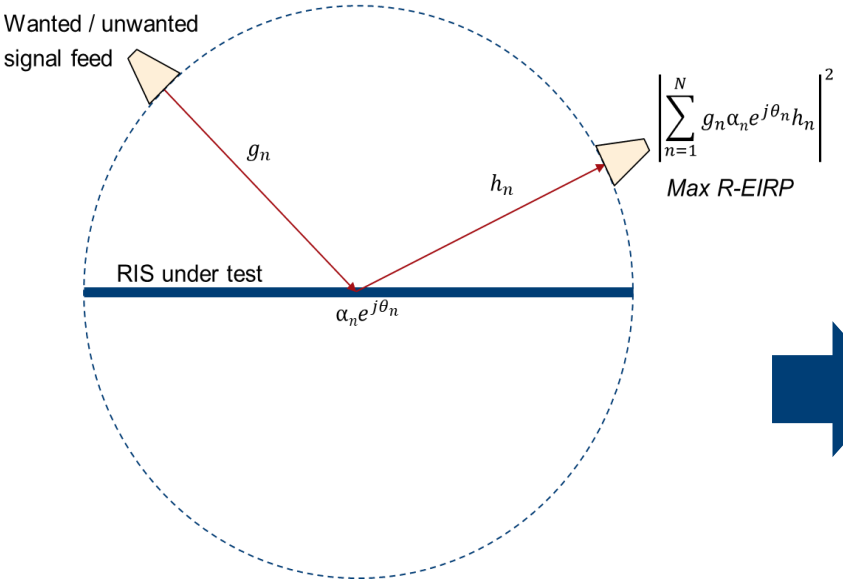
# Adjust the channel – along with the signal

$$r(t) = h(t)s(t) + n(t)$$

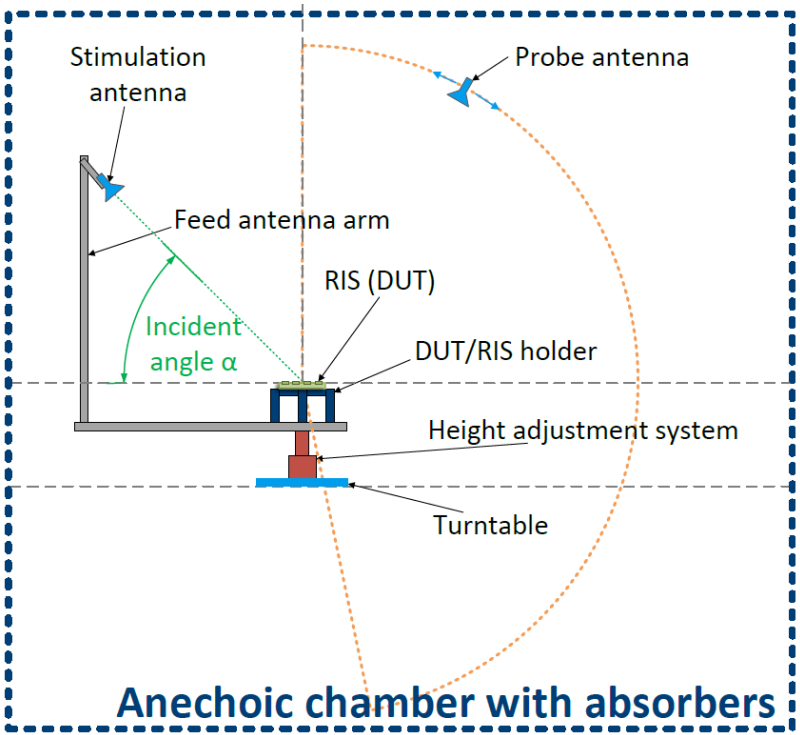
- The classical approach to maximize reception quality:
  - Adapt s(t) transmission scheme to target channel h(t), e.g., CP-OFDM for the multipath channel, carrier frequency, and bandwidth, pre-coding/equalization, modulation and coding schemes, etc.
- RIS offers an adaptation of channel h(t) to maximize reception quality.



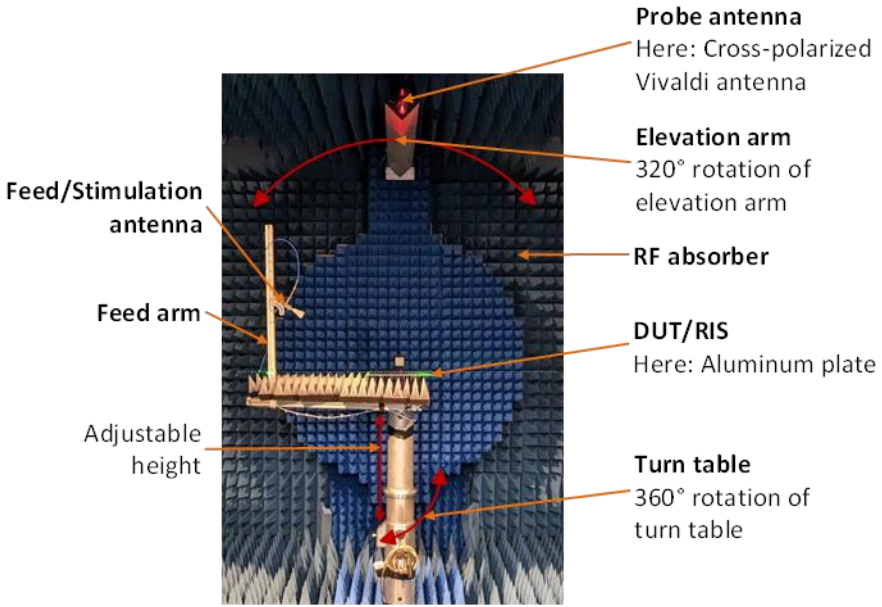
# Radiated RIS measurement principle

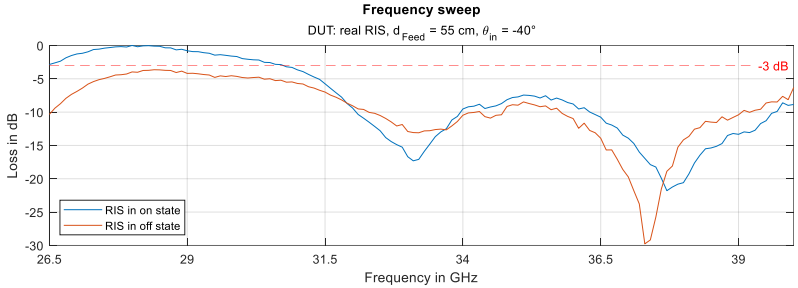


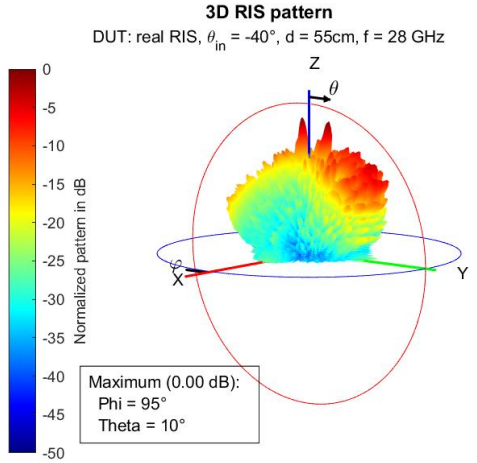

Source: ETSI ISG RIS GR002



# Spectrum for 6G:
## Reconfigurable Intelligent Surfaces



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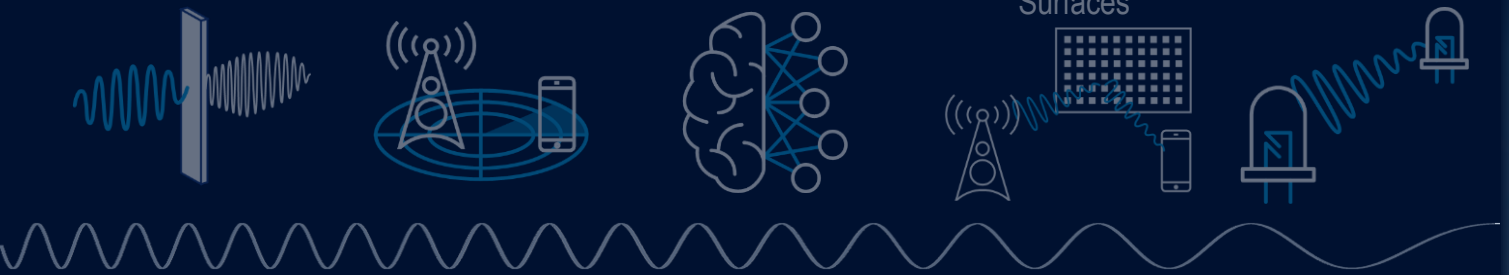

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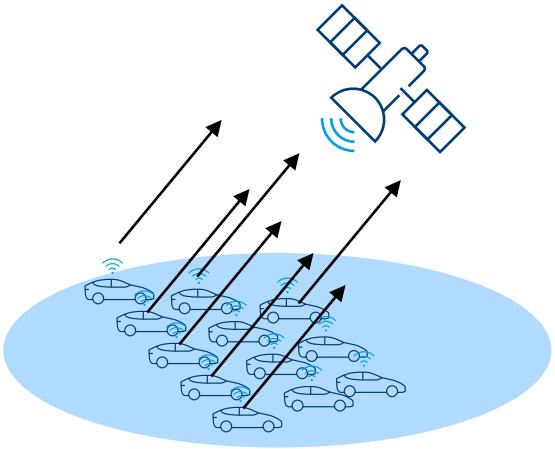
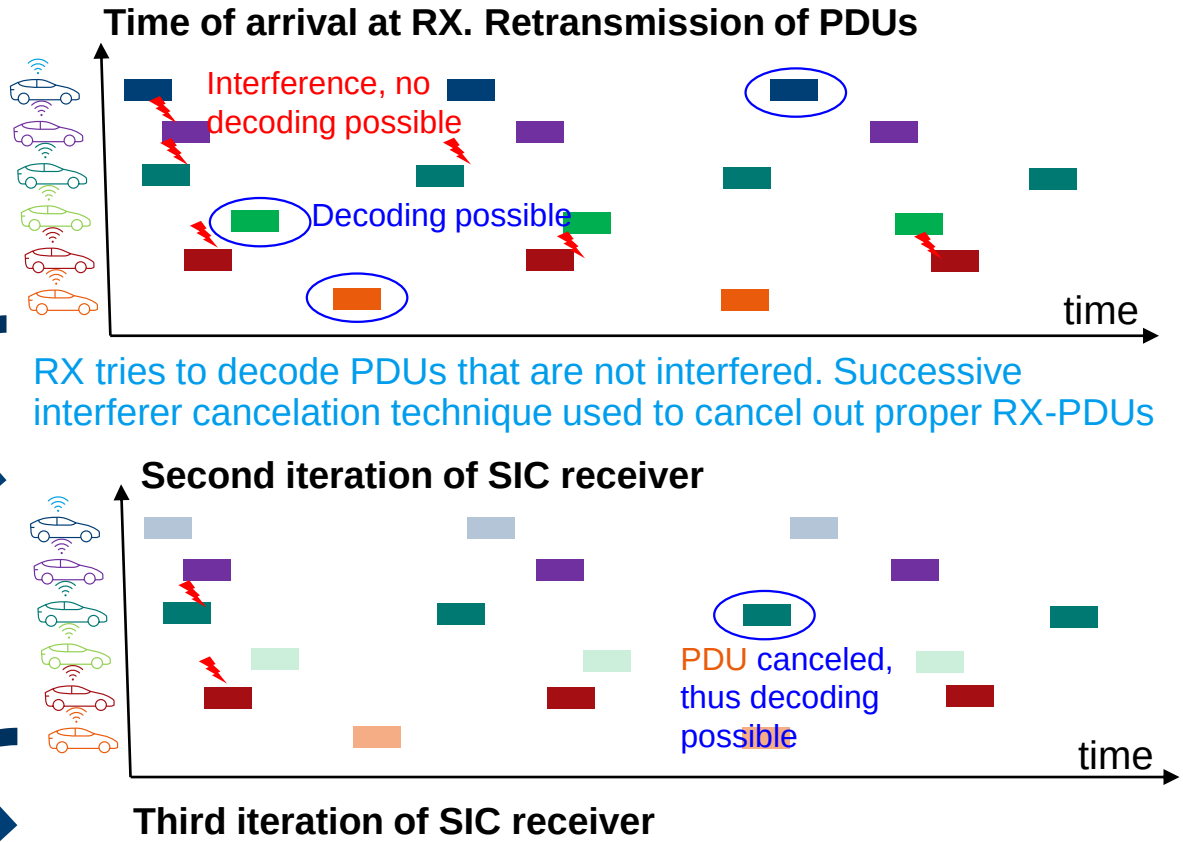
# Grant free multi user iot access

Multiple UE transmit grant free and pseudo randomly. Retransmission aperiodic

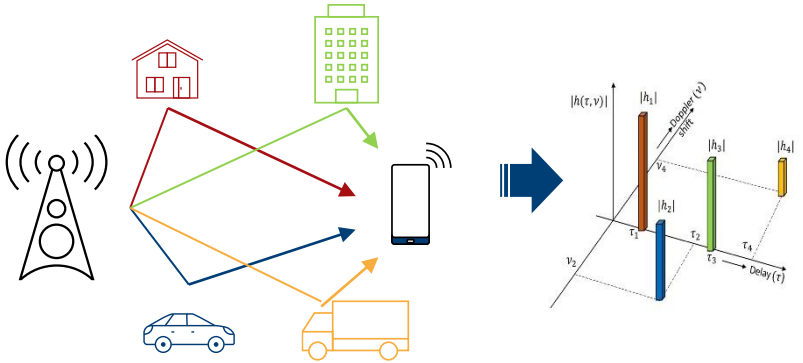


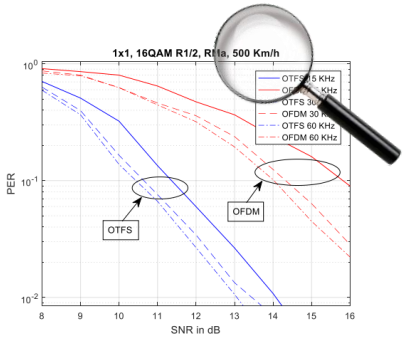


# Another Waveform of Interest
# OTFS - Orthogonal Time Frequency Space Modulation

- For TDM and FDM the signal is localized in time or in frequency → time selective or frequency selective fading
- **Idea: Go to the Delay-Doppler (DD) domain**

- Doppler Delay Modulation (DDM)
  - Information is carried over DD domain pulse
  - Delay period $\tau_p$ ; Doppler period $\nu_p = \frac{1}{\tau_p}$
  - Zac transform $z_t$, used to transform the DD signal to a TD signal $x(t)$




Ref: R1-1609825, 3GPP TSG RAN WG1 Meeting #86bis, 2016

# RESEARCH AREAS FROM A T&M PERSPECTIVE

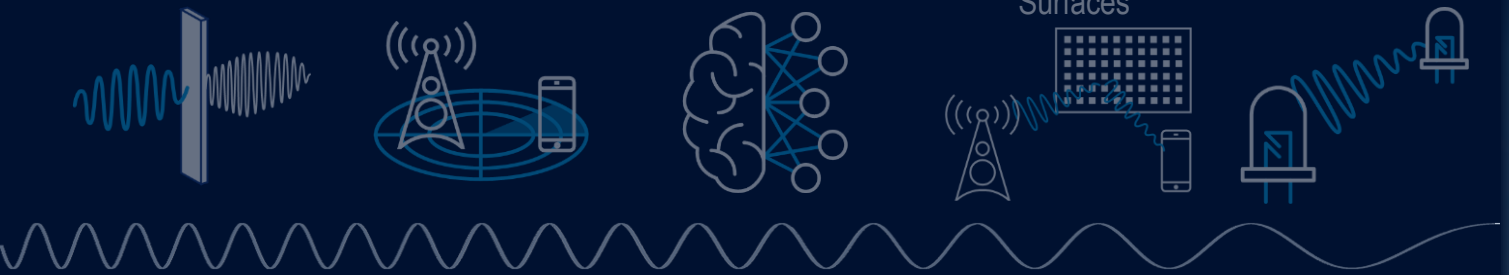
THz communication, and “FR3”

Joint communication & sensing

Artificial Intelligence and Machine Learning

Reconfigurable Intelligent Surfaces

Photonics, Visible Light Communication



Multiple access, new waveforms, channel coding

**Ultra-massive MIMO**

New network topologies, distributed computing

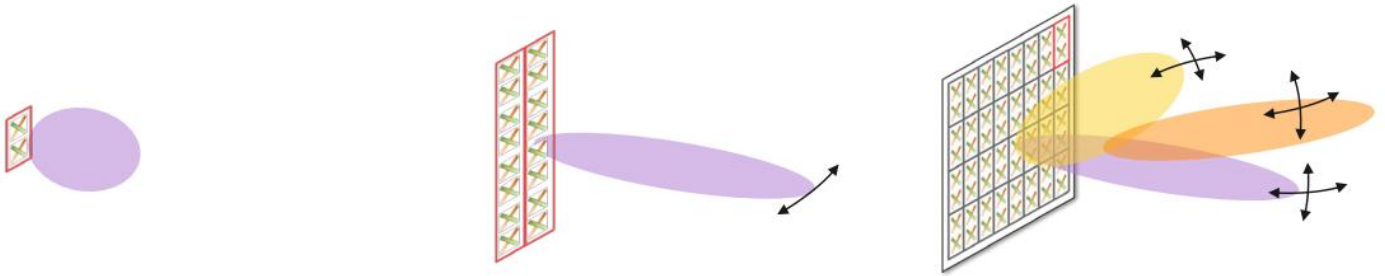
Full-duplex communication

Security & Trustworthiness

*A high-level overview of all these research areas is provided in one of our #THINKSIX videos.*

# Ultra-Massive mimo uses antenna arrays

**6G is the continuation of beamforming and MIMO aspects: SU-MIMO and MU-MIMO**



Small array
Two radios
Low gain, fixed beam

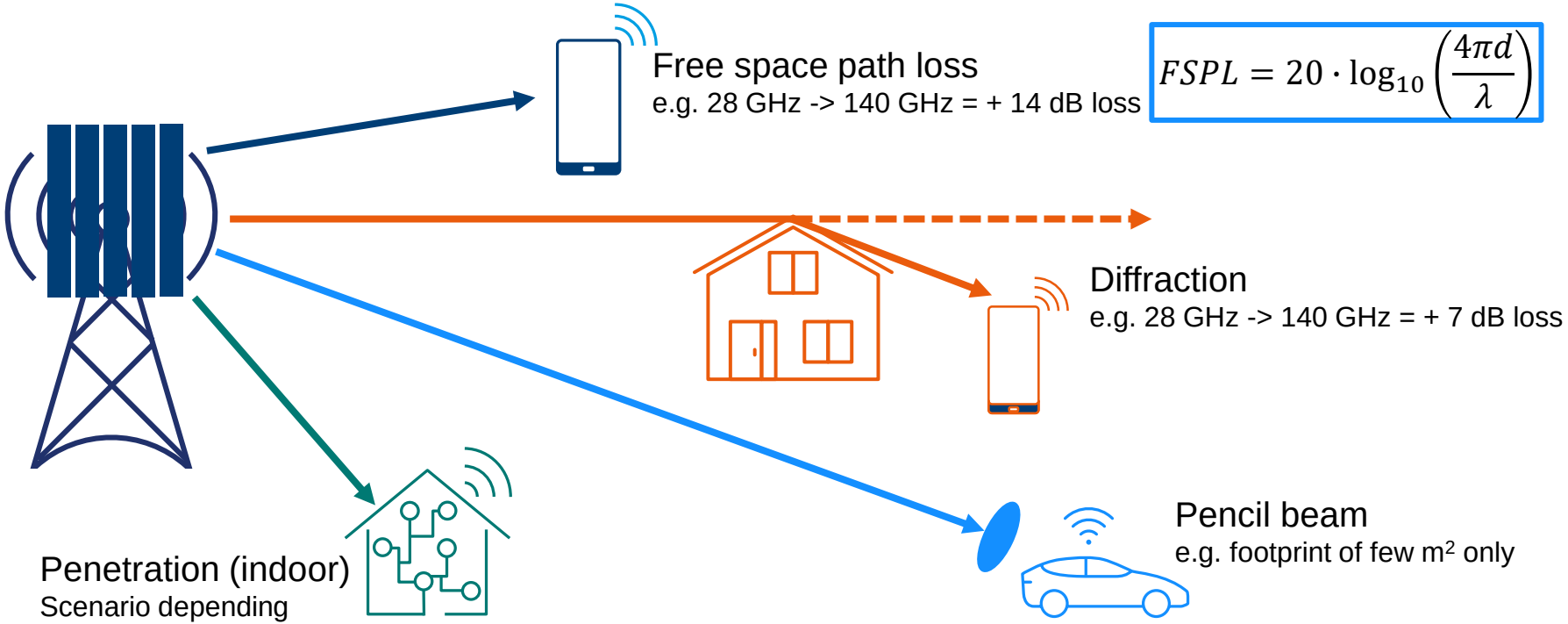
**Conventional antenna**
Large array
Few radios
High gain, limited beam flexibility

**Massive MIMO**
Large array
Many radios
Multiple steerable and shapeable beams

Source: Ericsson | The Massive MIMO Handbook

# Ultra-Massive mimo – only one slide on challenges

**6G is the continuation of beamforming, and MIMO, but few things to consider ☹**



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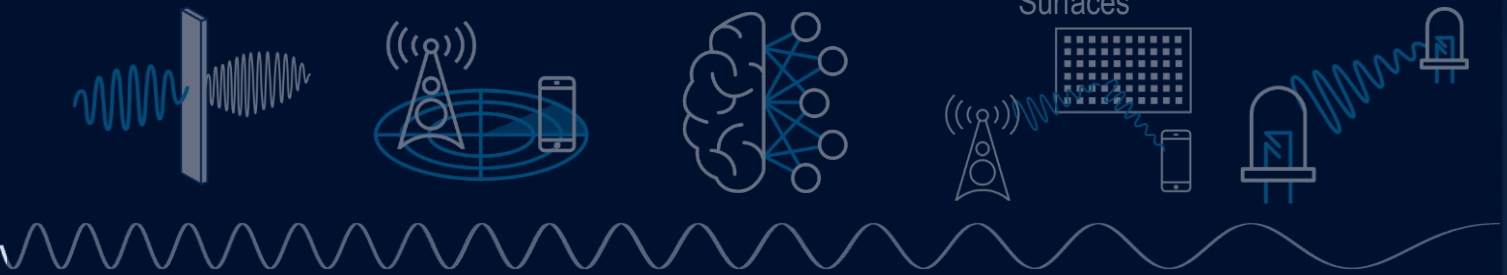

Multiple access, new waveforms, channel coding

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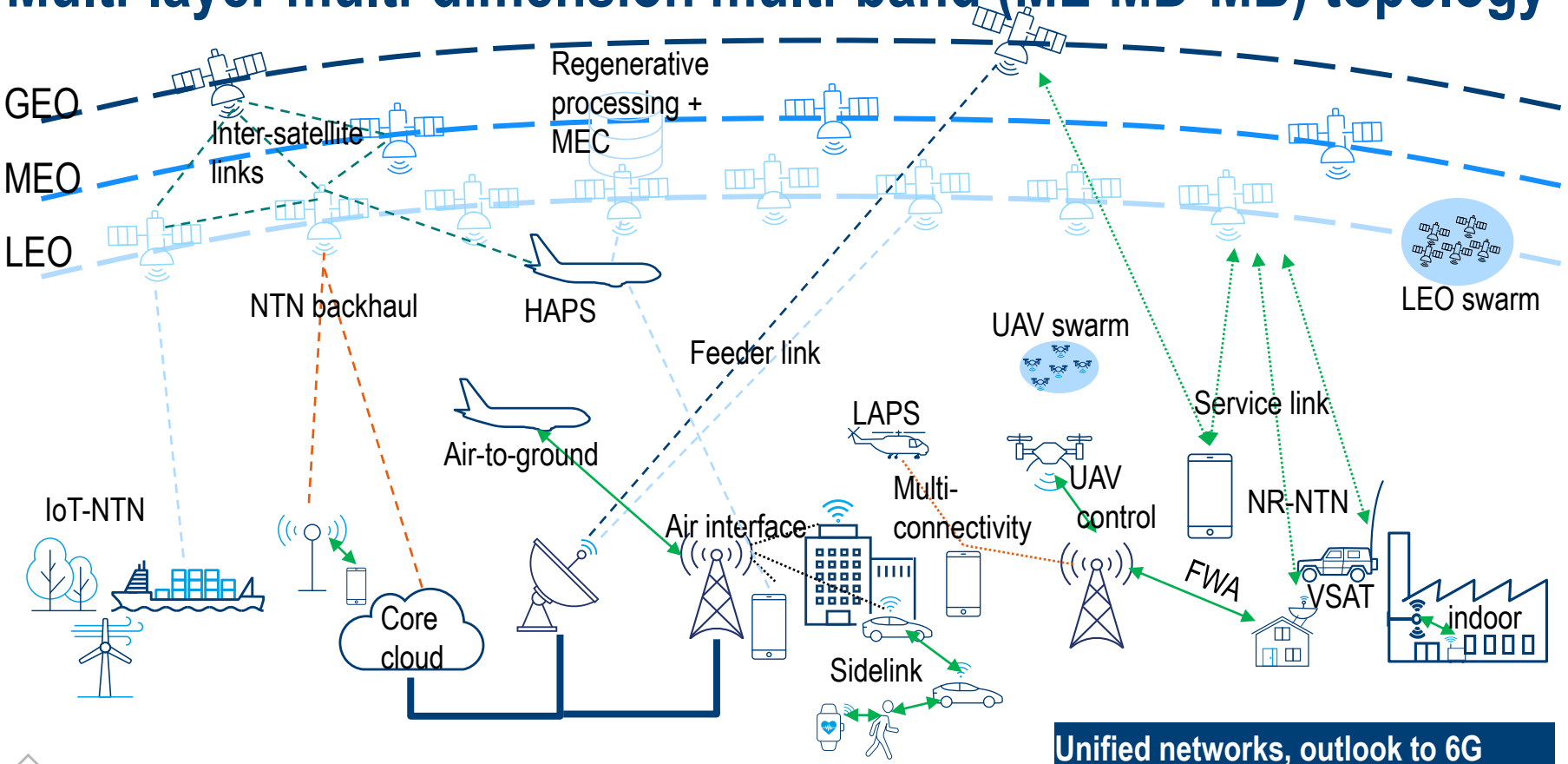
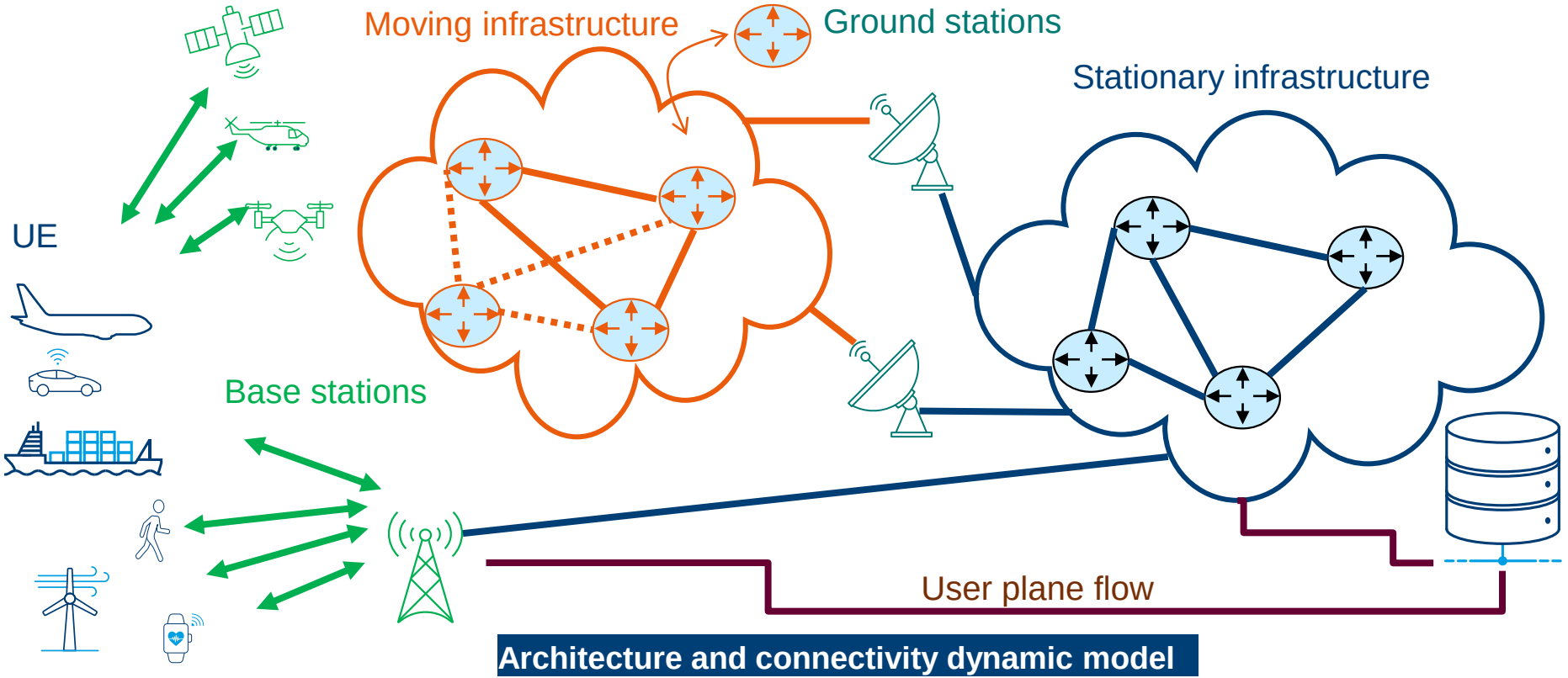
# Multi-layer multi-dimension multi-band (ML-MD-MB) topology



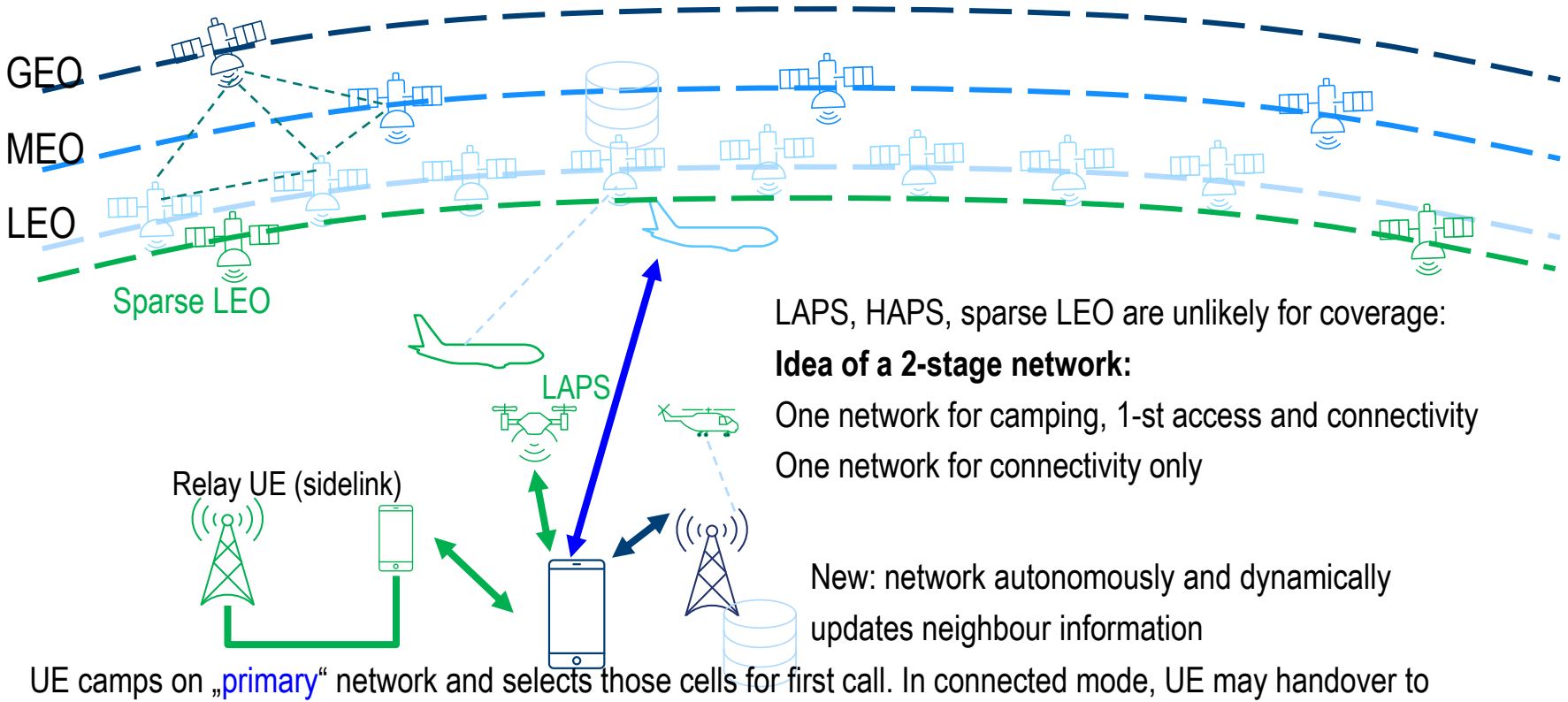

**Unified networks, outlook to 6G**

# 6G-NTN: cloudification and virtualization




**Architecture and connectivity dynamic model**

# UE accessing the network – architectural aspects




LAPS, HAPS, sparse LEO are unlikely for coverage:

**Idea of a 2-stage network:**

One network for camping, 1-st access and connectivity

One network for connectivity only

New: network autonomously and dynamically updates neighbour information

UE camps on „primary“ network and selects those cells for first call. In connected mode, UE may handover to „secondary“ network

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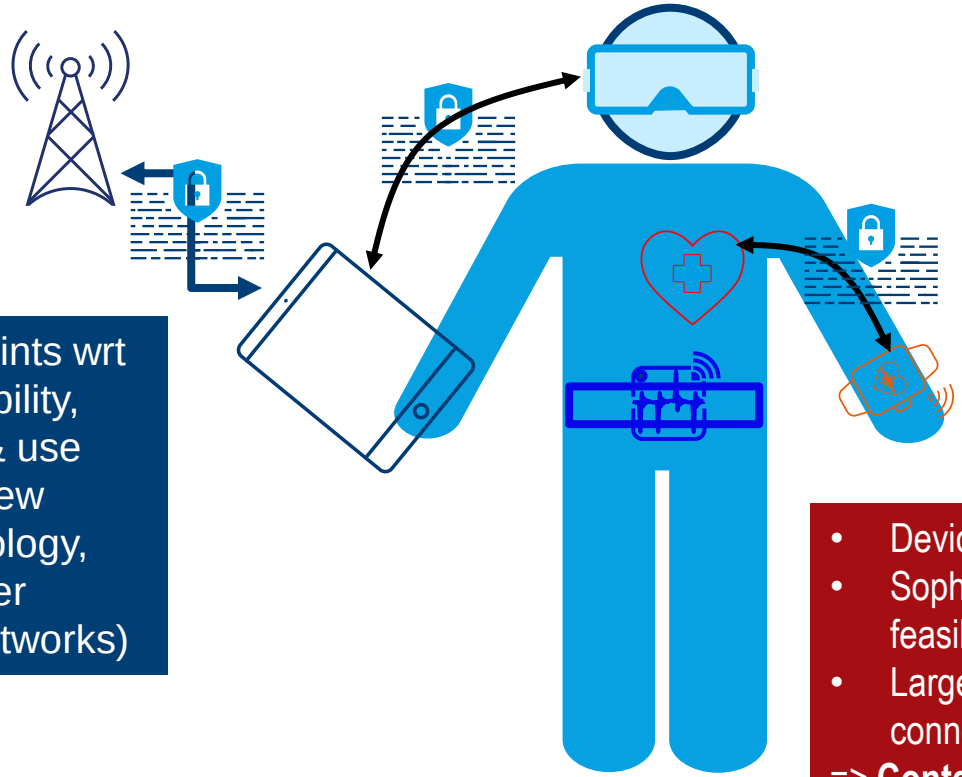
# 6G novel PHY layer architecture ideas

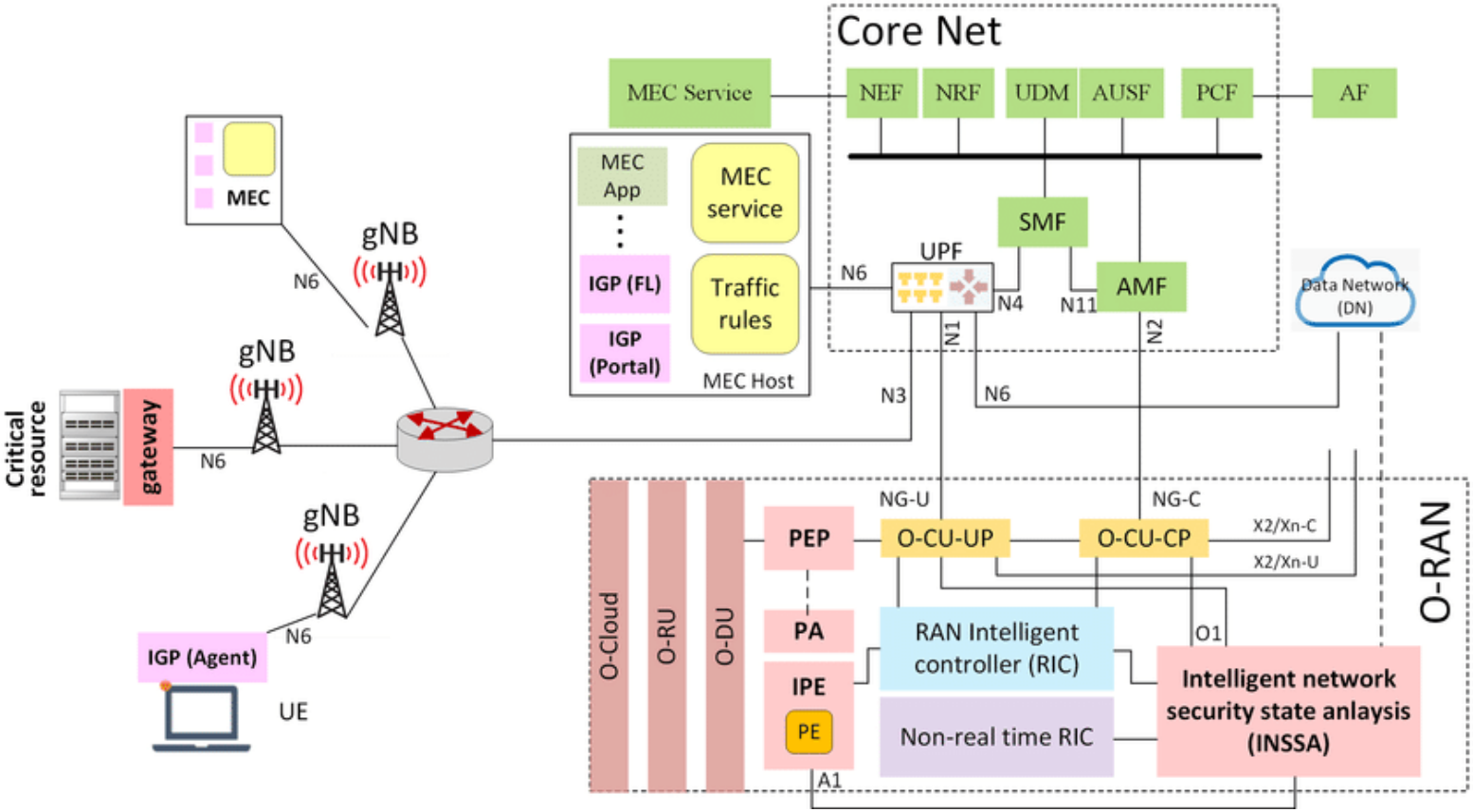


New constraints wrt device capability, form factor & use cases and new network topology, i.e. multi-layer (personal networks)

- Devices may not have a SIM
- Sophisticated encryption may not be feasible
- Large number of devices and on-the-fly connections

=> **Context awareness security model**

# 3GPP security: O-RAN and zero trust architecture



# SUMMARY

- Deployment of 5G networks is in full swing! Clear evolution path provided by the industry's standardization organization
- Academia and key industry players are exploring the boundaries and started looking into next generation of wireless communication aka 6G
- New, challenging technology components may complement the existing concept of cellular networks or even provide revolutionary aspects
- Rohde&Schwarz is actively engaged in this phase of fundamental research, providing our expertise in test and measurement to make ideas real

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Make ideas real