HEXA-X-II and SNS Stream B Project workshop

Wireless Communication Technologies and Signal Processing

Enablers from Hexa-X-II WP4/WP5

Hamed Farhadi (Ericsson),
Claude Desset (IMEC)

Hexa-X-II

hexa-x-ii.eu

Outline

- Overview of value-based holistic radio design
  - Radio design components
  - Radio design requirements
  - Device classes
  - Radio scenarios
- Enablers

Holistic radio design components

Holistic radio design: Considers the entire radio system as a whole, and the interdependencies between different elements.

Radio device capabilities
- Radio hardware
- Transmission schemes and signal processing algorithms
- Access schemes

Deployment scenario
- Type of deployment
- Frequency band
- Radio devices

Use case specifications:
- Type of environment
- Mobility
- Connection density
- Type of devices
- Service requirement

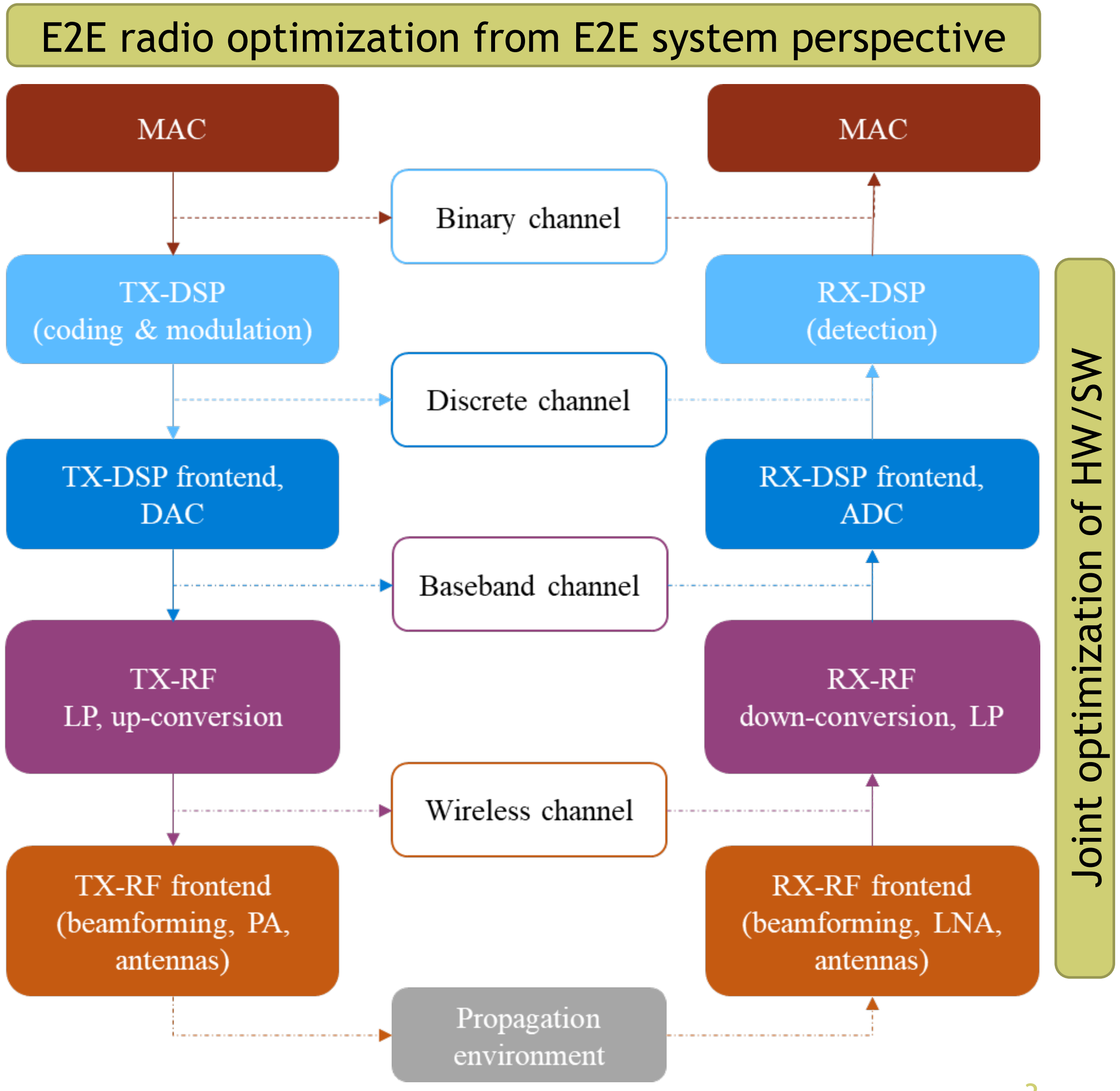
Optimization for improving KVIs while fulfilling performance KPIs.

Optimization of transmission schemes

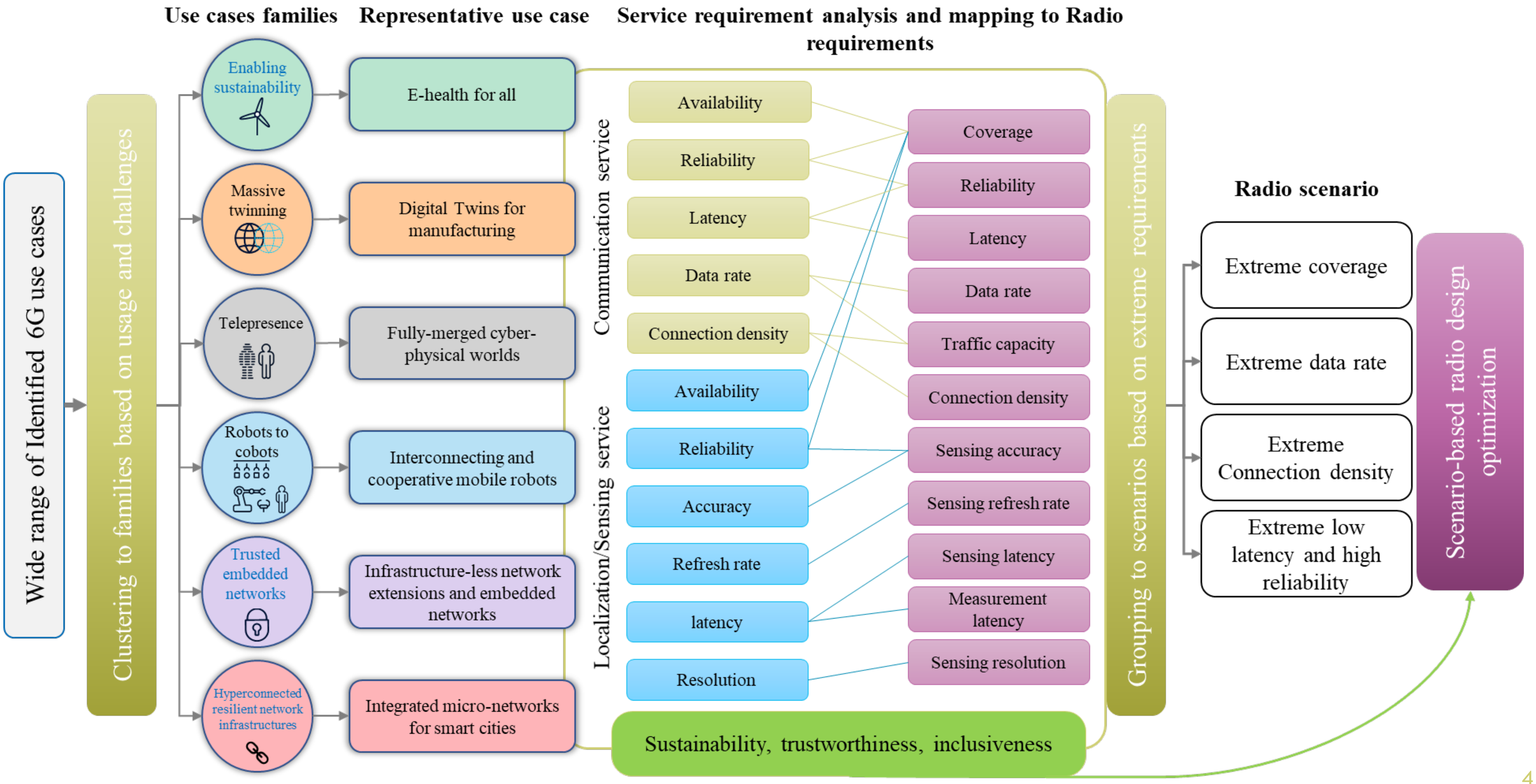
- Transmission schemes
Radio device (DSP): impact of DSP capabilities
- Radio device (DSP-Frontend, DAC, ADC): impact of DAC/ADC resolution

Optimization of frequency range and deployment

- Radio device (RF converters, LPs): impact of phase noise
- Frequency band and bandwidth
Radio device RF-frontend (antenna and beamforming, PA, LNA): impact of noise figure, PA non-linearity
- Type of environment
Mobility
Type of deployment



Selected use cases and defined radio scenarios



Radio scenarios KPIs

- Derived by analysing the service requirements of representative use cases and mapping to radio requirements

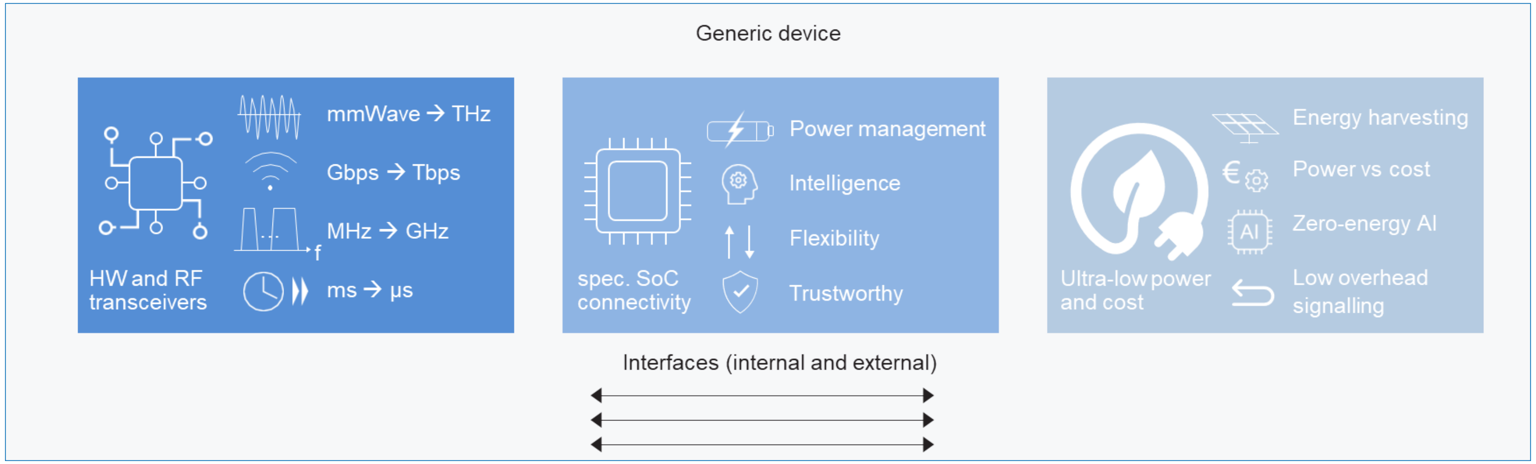
Radio scenario	Use cases	ITU usage scenarios	Data rate	Reliability	Latency	Connection density	Coverage	Sensing-related capabilities
Extreme coverage	E-health for all	Ubiquitous connectivity	Low Medium < 1 Gbit/s	Variable	Variable	Variable	Ultra-wide Extreme-wide Availability (99.99%-99.999999%)	Variable
Extreme data rate	Digital twins for manufacturing	Artificial intelligence and communication Immersive communication	Ultra-high Extreme-high (10-100 Gbit/s)	Variable	Variable	Low Medium $<10^4$ device/km^2	Local	Variable
Extreme connection density	Fully merged cyber-physical worlds and merged reality game/work Immersive smart cities & integrated micro-networks for smart cities	Immersive communication Massive communication	Medium High < 10 Gbit/s	Variable	Variable	Ultra-high Extreme-high (10^6-10^8) device/km^2	Variable	Variable
Extreme low latency and high reliability	Interacting and cooperative mobile robots Infrastructure-less network extensions and embedded networks	Hyper reliable and low-latency communication Integrated sensing and communication	Low < 10 Mbit/s	Ultra-high Extreme-high (99.999%-99.99999%)	Ultra-low Extreme-low (0.1-10) ms	Variable	Local	Ultra-high Positioning accuracy (0.1-1) cm

Key Definition

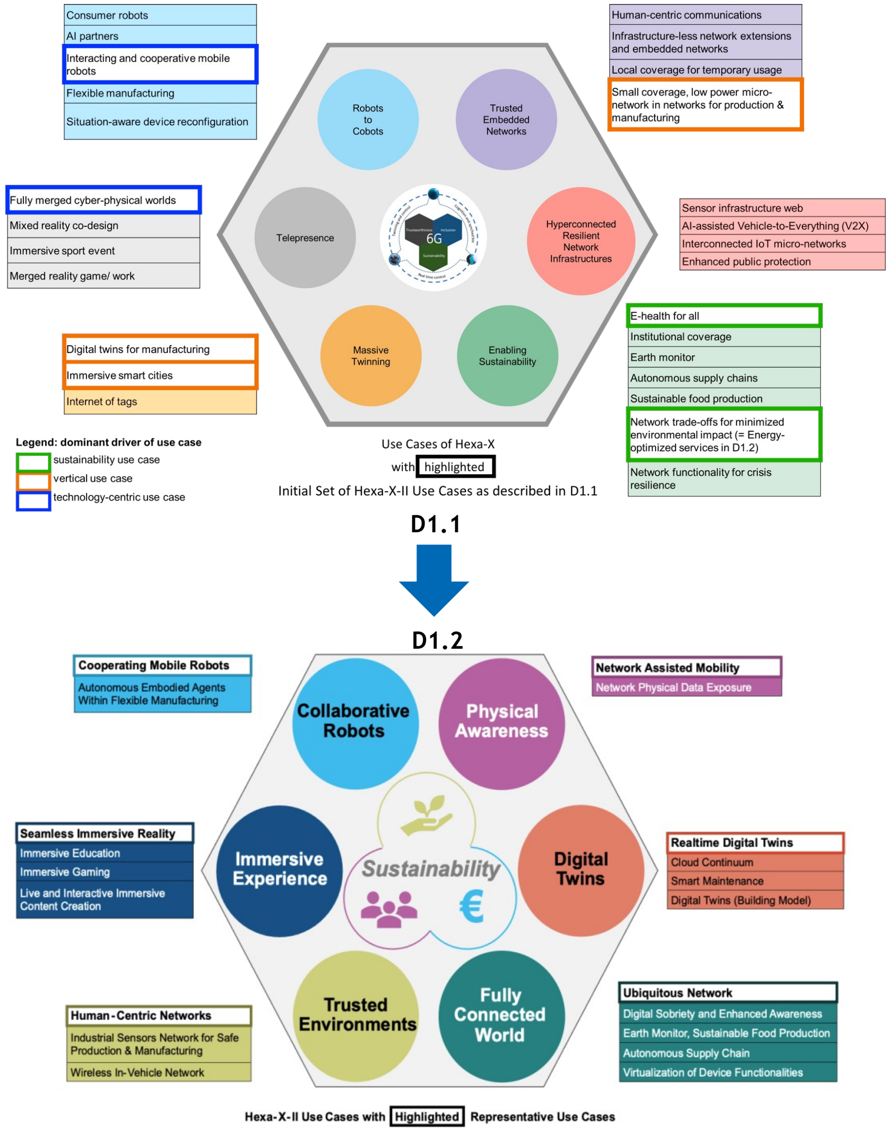
What is a device?

- D5.2 deliverable defines a device specifically as **an end-device that is connected to the network infrastructure via a radio interface and which generates and/or consumes data** (i.e., that runs an application) and shall be uniquely identifiable in the 6G system.

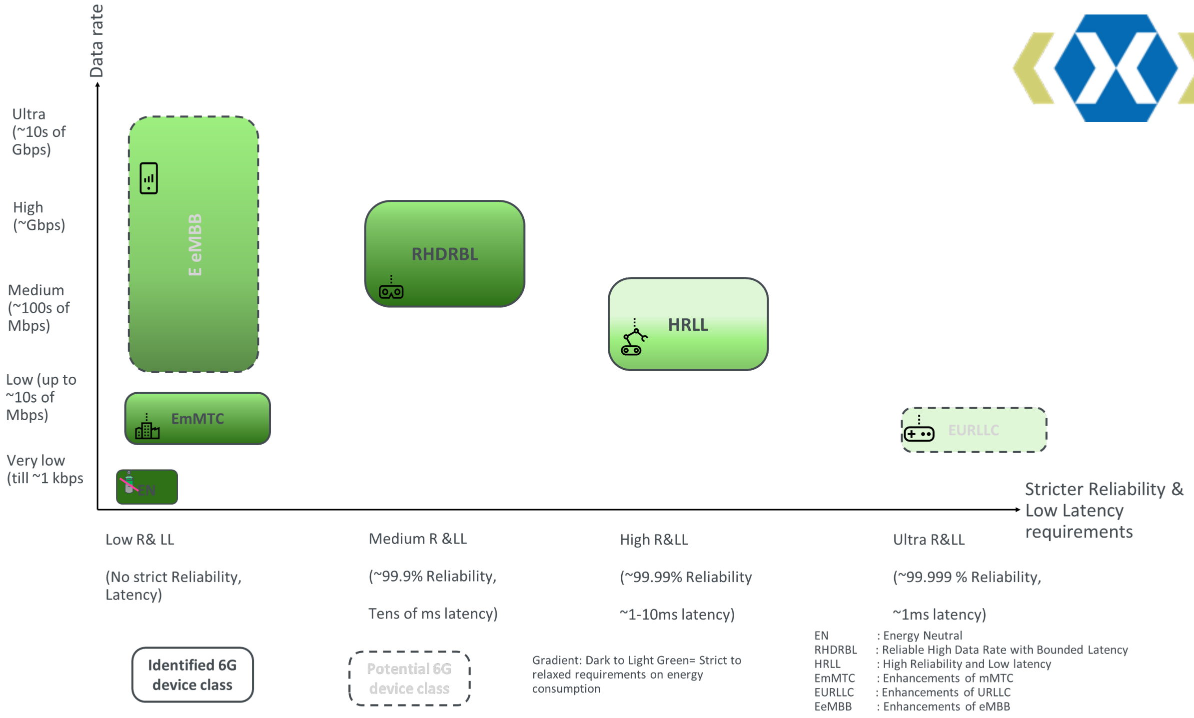
- As shown in figure below, the considered device consists of RF transceiver circuitry, a System-on-Chip (including a CPU, memory, and peripherals), and the necessary firmware and software.



6G device classes



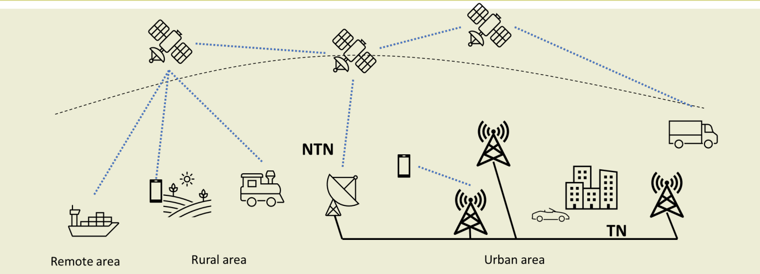
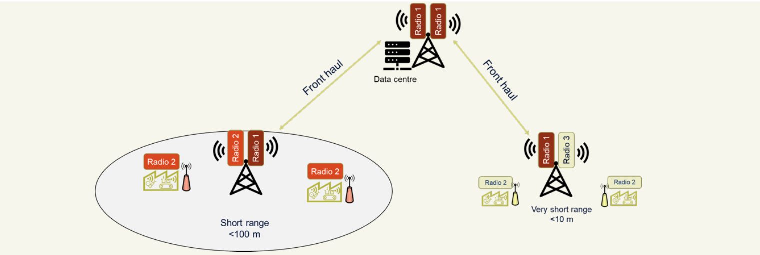
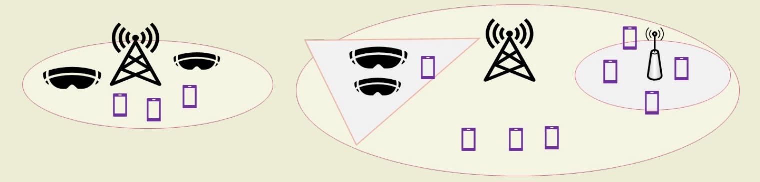
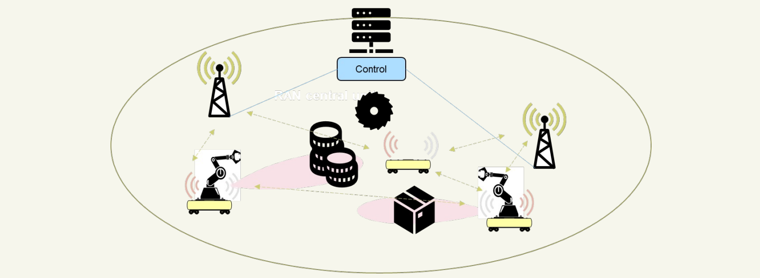
D1.2 use-cases will be analyzed to ascertain the impact on & precise the identified device classes.



- **Four 6G device classes:**
  - Energy Neutral (EN)
    - *Energy harvesting based & very low data rates. E.g., zero-energy devices*
  - Reliable High Data Rate with Bounded Latency (RHDRBL)
    - *Guaranteed bit rate @ bounded latency. E.g., AR/VR glasses*
  - High Reliability and Low Latency (HRLL)
    - *High reliability serving industrial use-cases. E.g., Cobots, AGVs*
  - Enhancements of mMTC (EmMTC)
    - *Mostly battery operated @ low data rates. E.g., LPWAN IoT devices*
- **Additional potential 6G Device classes:**
  - Enhancements of eMBB (EeMBB)
  - Enhancements of URLLC (EURLLC)

Radio scenarios parameters

- Sub-scenarios can be defined by different combinations of scenario parameters

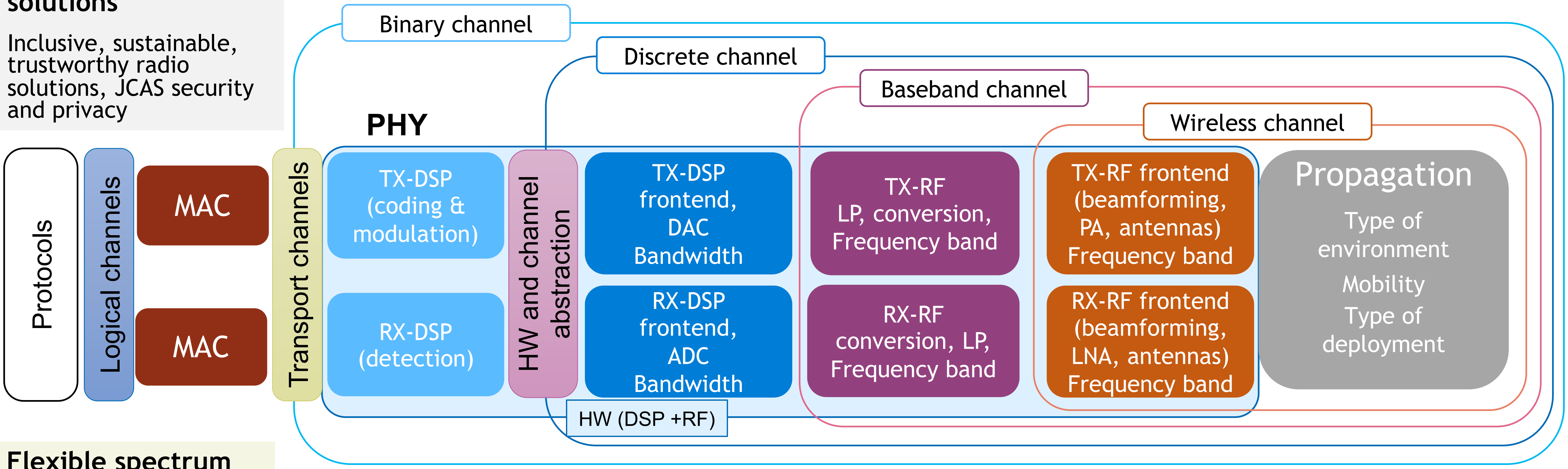
Radio scenario	Use case	Environment	Deployment option	Radio devices	Mobility	Frequency	Example
Extreme coverage	E-health for all	Mobile indoor Public indoor Outdoor (urban, suburban, rural)	Long range Short range Fixed/temporary Mobile infrastructure TN/NTN integration	Enhanced 5G (mMTC, eMBB) devices Energy neutral devices	Static Low, Medium High Very-high Ultra-high	Sub-GHz Sub-6 GHz 7-15 GHz Satellite frequency ranges	
Extreme data rate	Digital twins for manufacturing	Controlled and semi-controlled indoor and outdoor	Small cell D2D Sensor network with a gate way Embedded network	Access points for backhaul Gateway for sensors Local devices (sensors, actuators)	Static Low mobility Controlled mobility	mmWave or sub-THz Mixed and unlicensed for local connections	
Extreme connection density	Fully merged cyber-physical worlds	Urban indoor/outdoor with high density of users High-rise	High density of cells Macro cell Micro cell	Reliable high data rate with bounded latency devices	Static Low Medium	mmWave 7-15 GHz high bandwidth	
Extreme low latency and high reliability	Interacting and cooperative mobile robots	Indoor Embedded network	Small cell On premises infrastructure Sensor network	High reliability & low latency devices	Static Low mobility Controlled mobility	Private frequency Sub-GHz Sub-6 GHz 7-15 GHz mmWave, sub-THz for sensing	

Holistic radio design framework

- Enablers are categorized based on their roles in the radio design

KVIs focused solutions

Inclusive, sustainable, trustworthy radio solutions, JCAS security and privacy



Flexible spectrum access solutions

Sharing, coexistence, low-latency random access

Signal processing and algorithms

Waveform, modulation, coding, radio resource allocation, AI-enabled air interface

Radio link modelling

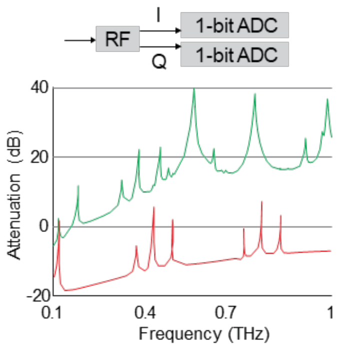
Channel modelling, Link-level signal modelling

Architecture and deployment

Radio HW architecture, D-MIMO, RIS, JCAS

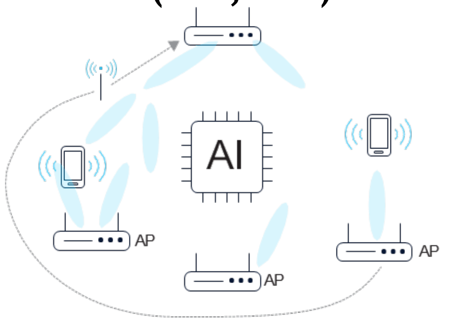
Key radio design enablers

Towards THz communications



- Channel modelling
- Waveforms and modulations
- Massive MIMO
- Distributed MIMO
- Link-level simulator

Intelligent radio air-interface design (FR1, FR2)

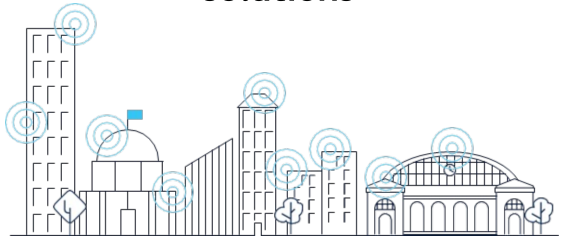


- AI solutions for HW impairment compensation, resource allocation, channel prediction, beamforming, ..
- Modulation and coding
- D-MIMO transmission
- RIS-assisted transmission

Joint communications and sensing

- Sensing architectures
- Waveforms optimization
- Resource allocation and protocols
- Security, resilience and cross-functional benefits

Flexible spectrum access solutions



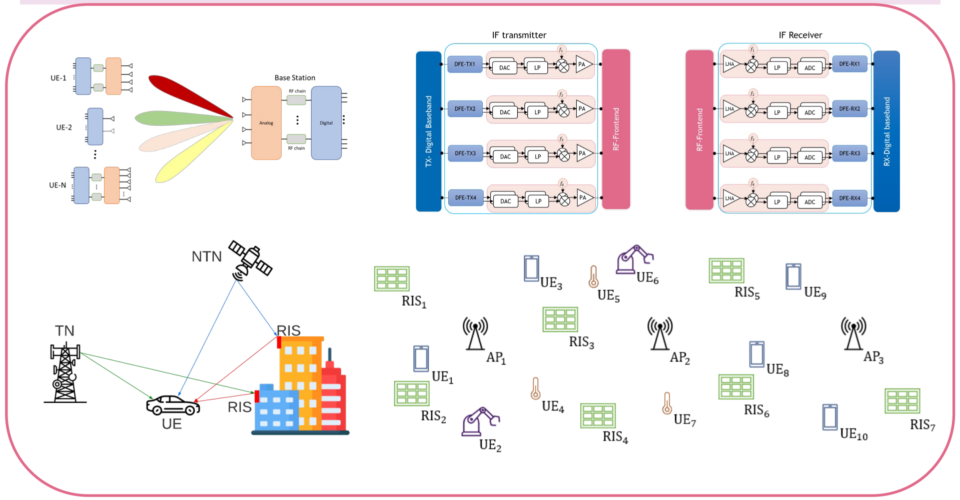
- Spectrum sharing and coexistence
- Multi-RAT spectrum sharing
- Low-latency random access
- Risk-informed random access

Sustainable, trustworthy and inclusive holistic radio design

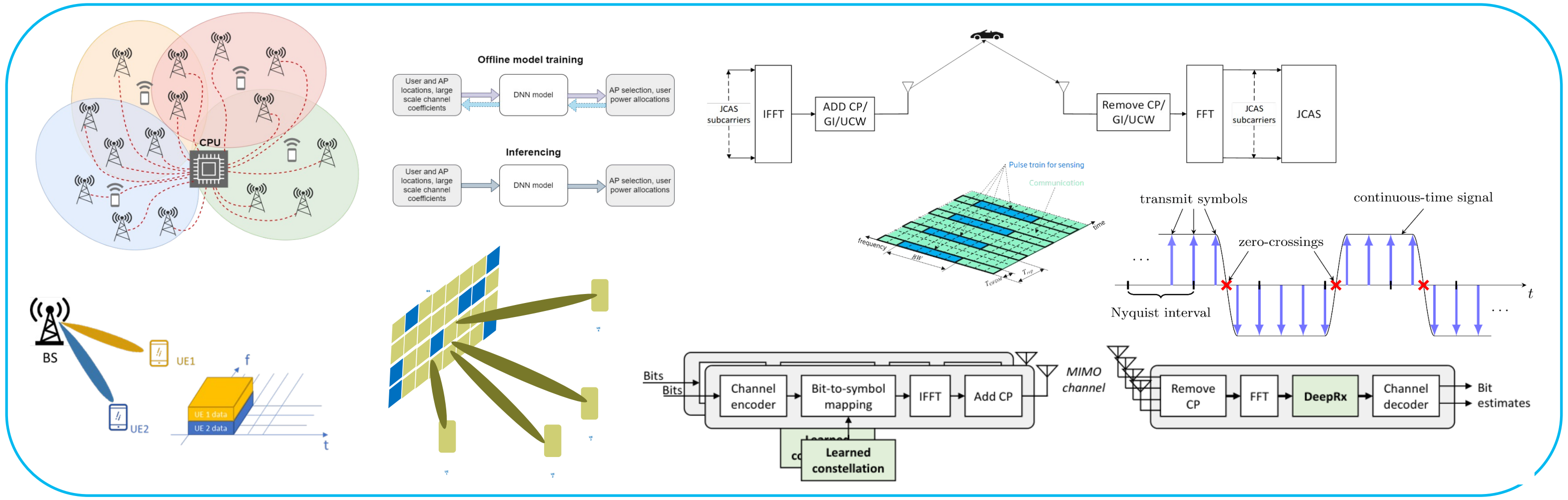
- Flexible design
- Inclusive radio
- Sustainable solutions
- Trustworthy solutions

Groups of radio design enablers

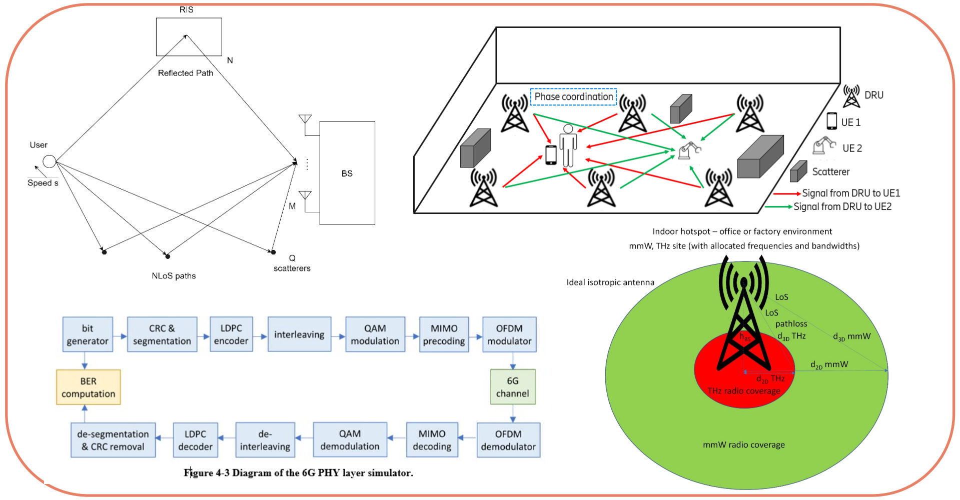
Architecture and deployment: Transceiver, MU-MIMO, D-MIMO, RIS, JCAS, TN/NTN



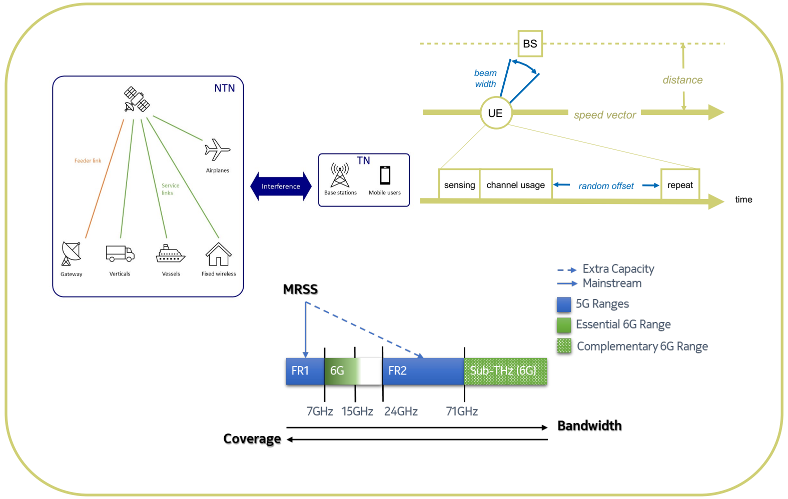
Signal processing and algorithms: Waveform, modulation, coding, radio resource allocation, AI-air interface for CSI prediction, precoding, PA post compensation, …



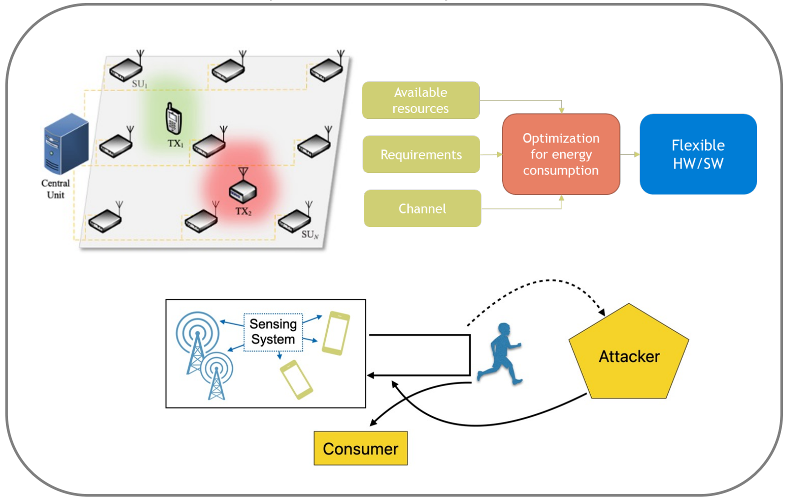
Radio link modelling: Channel modelling, Link-level signal modelling, EMF, coverage



Flexible spectrum access solutions: sharing, coexistence, random access

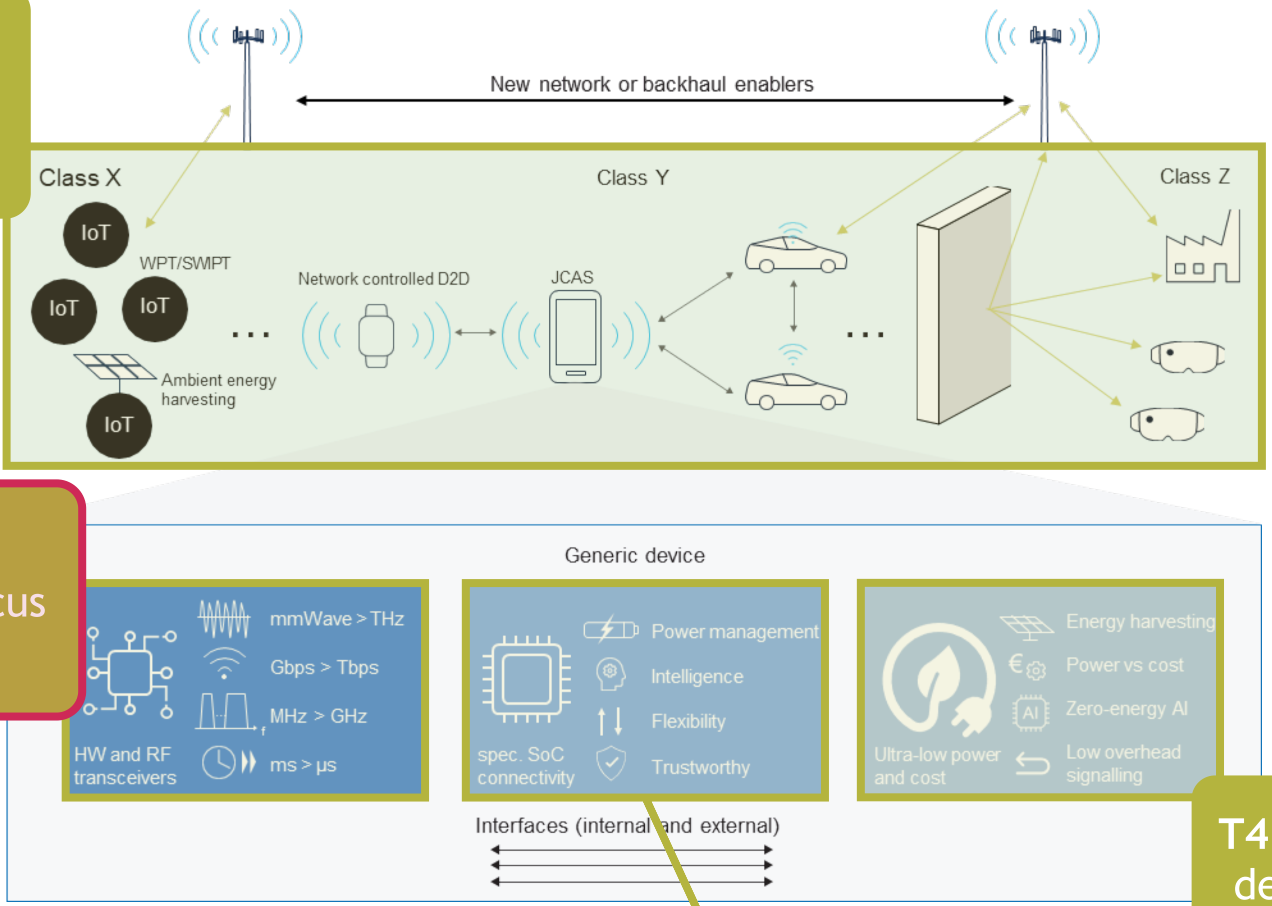


KVIs focused solutions: sustainability, security, resilience



Future devices and flexible Infrastructure

T1: Classification of novel **6G device classes** and infrastructure enablers



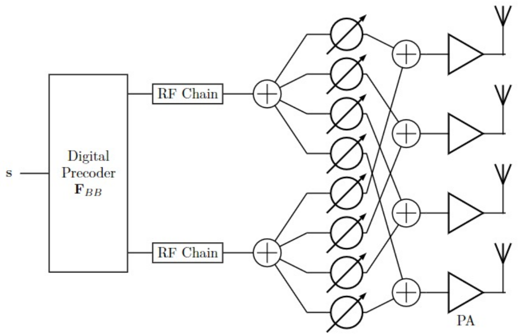
T2: HW and **RF transceivers** for 6G (focus on sub-THz and RIS)

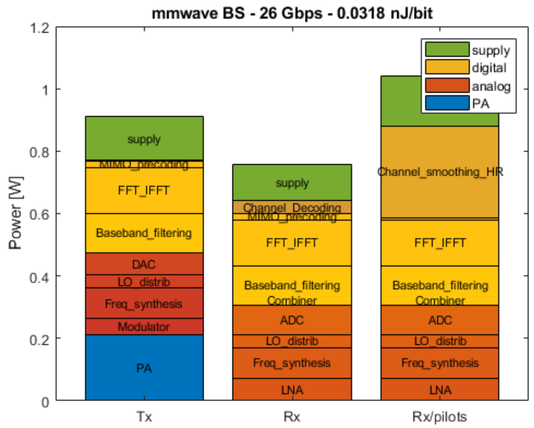
T3: **Trustworthy SoC** design, specialized AI/DSP accelerators

T4: **Ultra-low power**/cost devices (focus on energy neutral & zero energy)

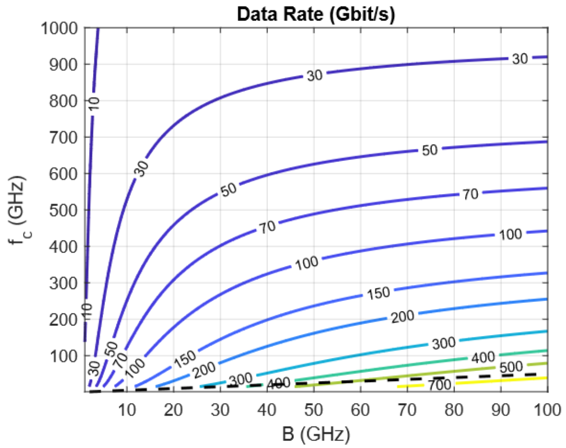
Sub-THz transceivers
models, optimizations & alternative architectures

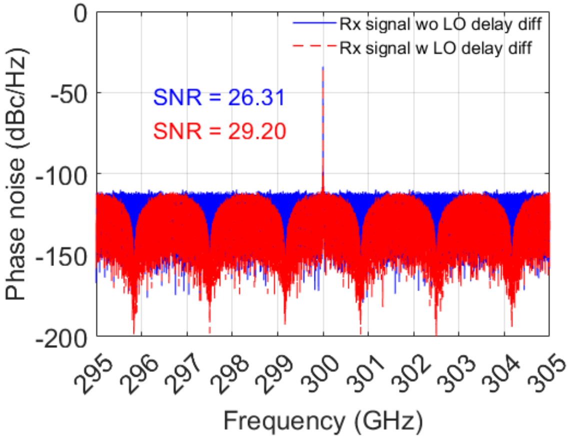
- Hybrid MIMO dimensioning for energy efficiency



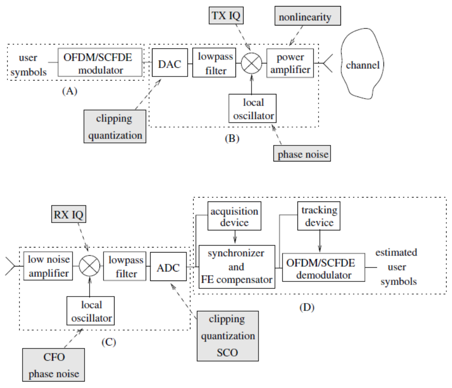


- Phase-noise limited performance & asymmetrical LO

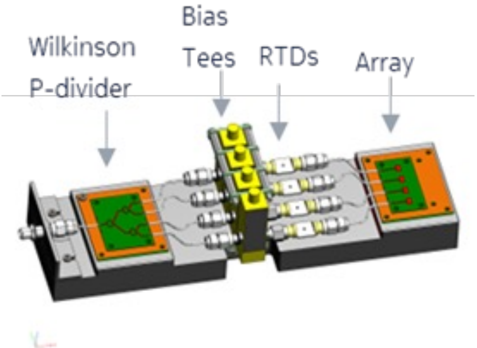


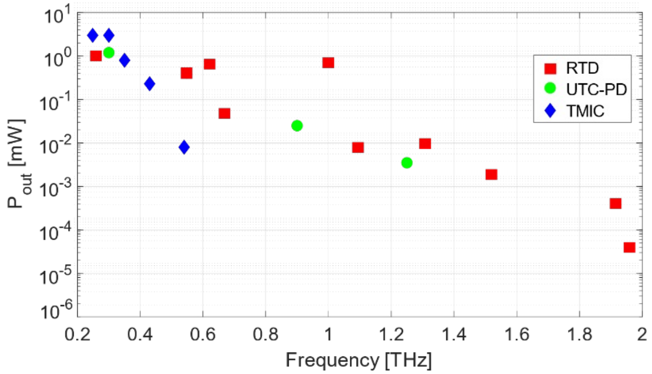


- Models for main HW non-idealities

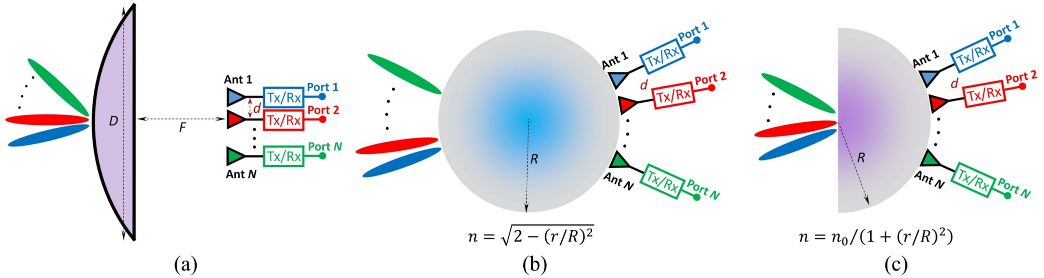


- RTD-based architecture

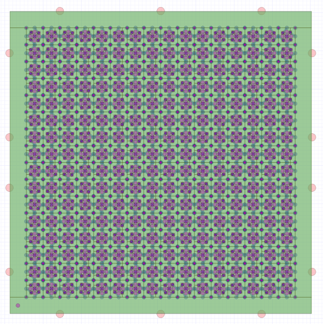




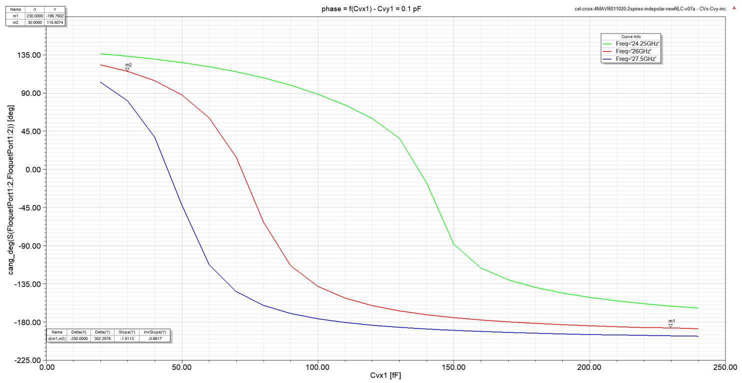
- Antenna lenses



Sub-THz transceivers
RIS design

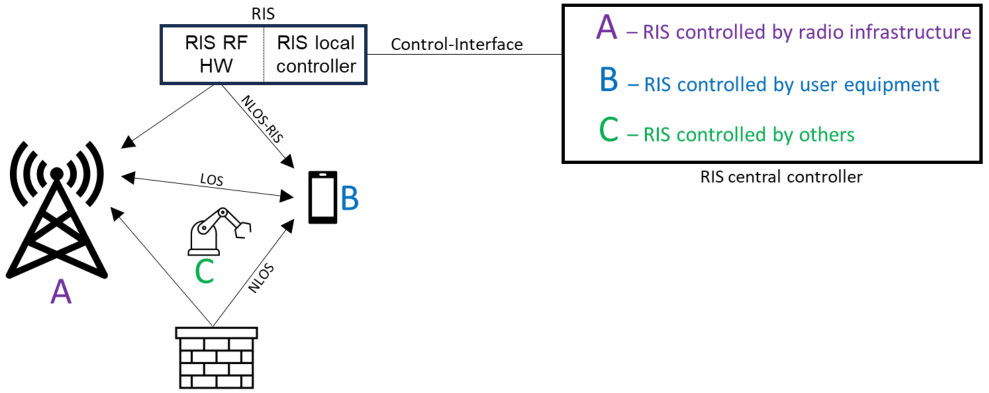


- Reconfigurable RIS tiles
  - 16x16 Tile Prototype:
    - Reflection phase coefficient versus inverse voltage calibration: Incidence tests
    - Beamforming tests



  - Reflection coefficients as function of varactor capacitance and frequency
    - Bandwidth of influence

- RIS system integration
  - Key properties
  - Control functionality
  - Control interface



More details

D5.2 - Characteristics and classification of 6G device classes

Available on Hexa-X-II website

HEXA-X-II

A holistic flagship towards the 6G network platform and system, to inspire digital transformation, for the world to act together in meeting needs in society and ecosystems with novel 6G services.

Deliverable D5.2
Characteristics and classification of 6G device classes

Co-funded by the European Union

6GSNS

Hexa-X-II project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101095759.

Date of delivery:	31/10/2023	Version:	1.0
Project reference:	101095759	Call:	HORIZON-JU-SNS-2022
Start date of project:	01/01/2023	Duration:	30 months

D5.3 - Initial design and validation of technologies and architecture of 6G devices and infrastructure

Available in March 2024

HEXA-X-II

A holistic flagship towards the 6G network platform and system, to inspire digital transformation, for the world to act together in meeting needs in society and ecosystems with novel 6G services

Deliverable D5.3
Initial design and validation of technologies and architecture of 6G devices and infrastructure

Co-funded by the European Union

6GSNS

Hexa-X-II project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101095759.

Date of delivery:	dd/mm/2024	Version:	0.2
Project reference:	101095759	Call:	HORIZON-JU-SNS-2022
Start date of project:	01/01/2023	Duration:	30 months

More details

D4.2 - Radio design and spectrum access requirements and key enablers for 6G evolution

Available on Hexa-X-II website

HEXA-X-II

A holistic flagship towards the 6G network platform and system, to inspire digital transformation, for the world to act together in meeting needs in society and ecosystems with novel 6G services

Deliverable D4.2

Radio design and spectrum access requirements and key enablers for 6G evolution

Co-funded by the European Union

6GSNS

Hexa-X-II project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101095759.

Date of delivery:	31/10/2023	Version:	1.0
Project reference:	101095759	Call:	HORIZON-JU-SNS-2022
Start date of project:	01/01/2023	Duration:	30 months

D4.3 - Early results of 6G radio key enablers

Available in May 2024

HEXA-X-II

A holistic flagship towards the 6G network platform and system, to inspire digital transformation, for the world to act together in meeting needs in society and ecosystems with novel 6G services

Deliverable D4.3

Early results of 6G Radio Key Enablers

Co-funded by the European Union

6GSNS

Hexa-X-II project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101095759.

Date of delivery:	30/04/2024	Version:	0.1
Project reference:	101095759	Call:	HORIZON-JU-SNS-2022
Start date of project:	01/01/2023	Duration:	30 months

Document properties:

Document Number:	D4.3
Document Title:	Early results of 6G Radio Key Enablers
Editor:	Ahmad Nimr (TUD)

HEXA-X-II

HEXA-X-II.EU //

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101095759.

Use-cases and some example (new) devices realizing them

- Cobot (IoT/M2M)
- Mix of URLLC and eMBB services device

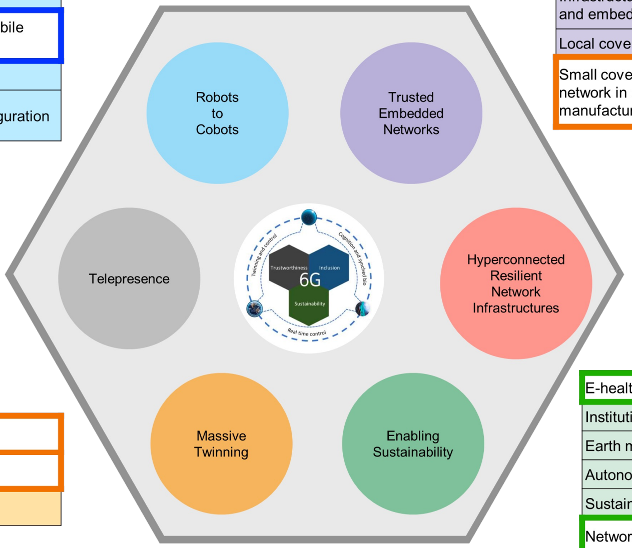
- (Reliable & available) XR devices
- On-body sensors and actuators + connectivity hubs….

- Zero energy devices
- (bio-friendly) Tags, zero e-Waste IoT

Consumer robots
AI partners
Interacting and cooperative mobile robots
Flexible manufacturing
Situation-aware device reconfiguration

Fully merged cyber-physical worlds
Mixed reality co-design
Immersive sport event
Merged reality game/ work

Digital twins for manufacturing
Immersive smart cities
Internet of tags



Use Cases of Hexa-X

with highlighted

Initial Set of Hexa-X-II Use Cases as described in D1.1

1

Legend: dominant driver of use case
- sustainability use case
- vertical use case
- technology-centric use case

Human-centric communications
Infrastructure-less network extensions and embedded networks
Local coverage for temporary usage
Small coverage, low power micro-network in networks for production & manufacturing

Sensor infrastructure web
AI-assisted Vehicle-to-Everything (V2X)
Interconnected IoT micro-networks
Enhanced public protection

E-health for all
Institutional coverage
Earth monitor
Autonomous supply chains
Sustainable food production
Network trade-offs for minimized environmental impact (= Energy-optimized services in D1.2)
Network functionality for crisis resilience

- Resilient/available IoT devices
- Trustworthy/intelligent aggregator devices

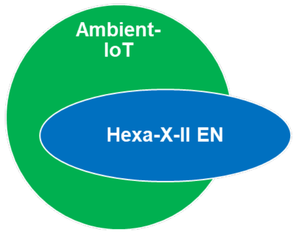
- IoT devices

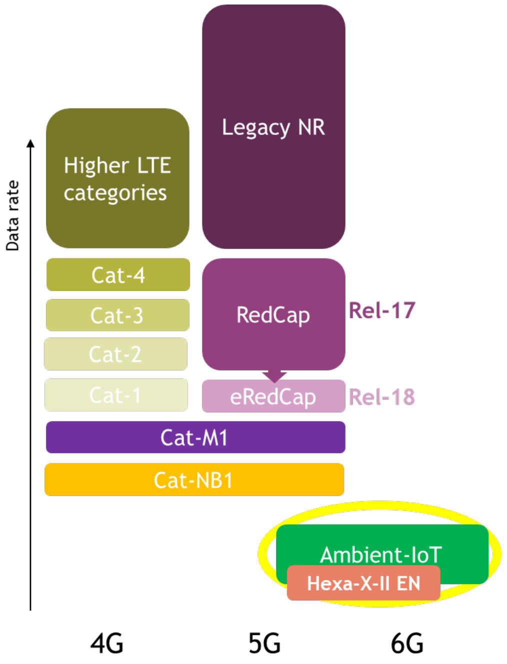
- Implantable devices
- Zero energy devices
- (bio-friendly) Tags, zero e-Waste IoT

- Main takeaways:
  - One device might serve multiple use-cases and have suitable implementation/design adaptations for specific use-case
  - Multiple devices are often needed to realize a single use-case.

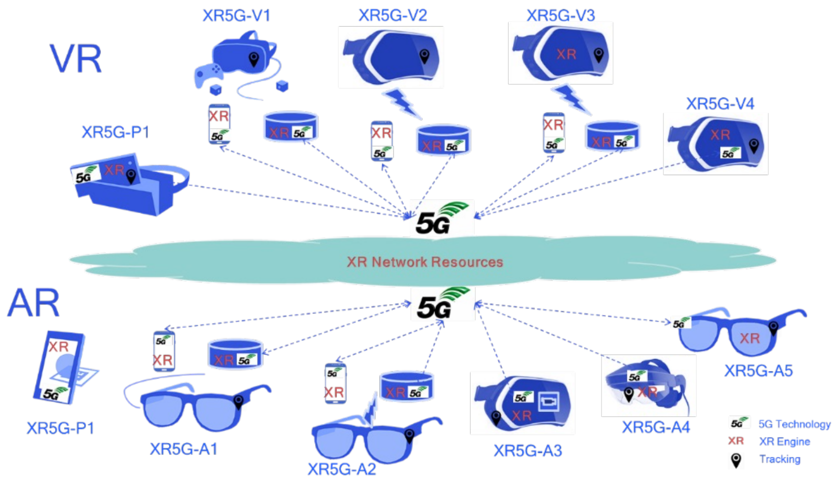
Device Class overview

- **Class #1: Energy Neutral devices**
  - Energy Neutral device is about a device segment below NB-IoT, i.e., very cheap and small devices





- **Class #2: Reliable High Data Rate with Bounded latency devices**
  - Device class where applications needs high data rate with bounded latency
  - High availability and device orientation & location accuracy influences QoE
  - High requirements on computation, traffic and benefits from AI enabled compute engine.



Device Class overview

- **Class #3: High Reliability & Low Latency devices**
  - Reliable with seamless connectivity and communication capabilities
  - Autonomous to make informed decisions and operate in diverse environment
  - Latency requirement are often stringent due to real time operation, timely processing and decision making.

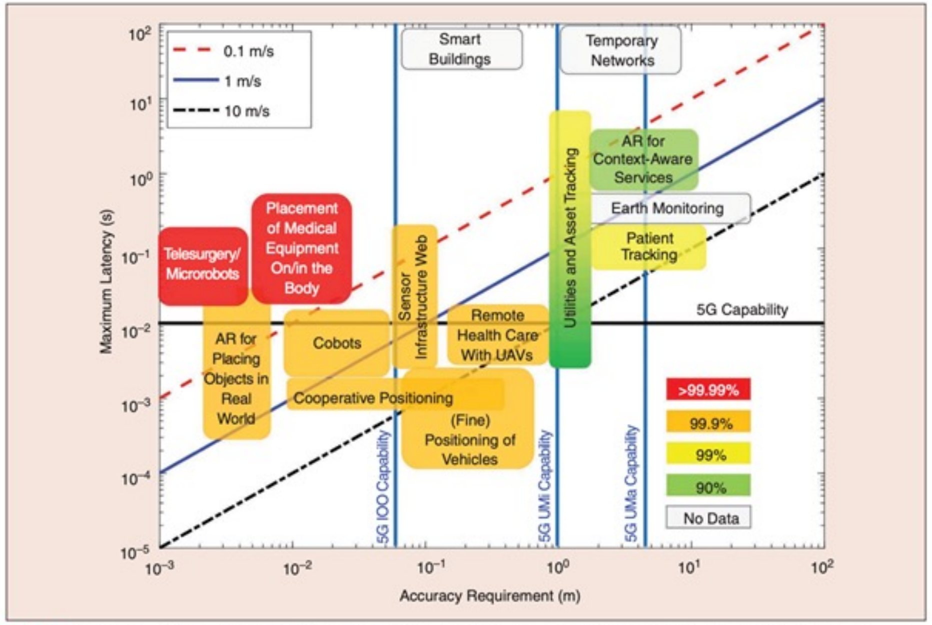
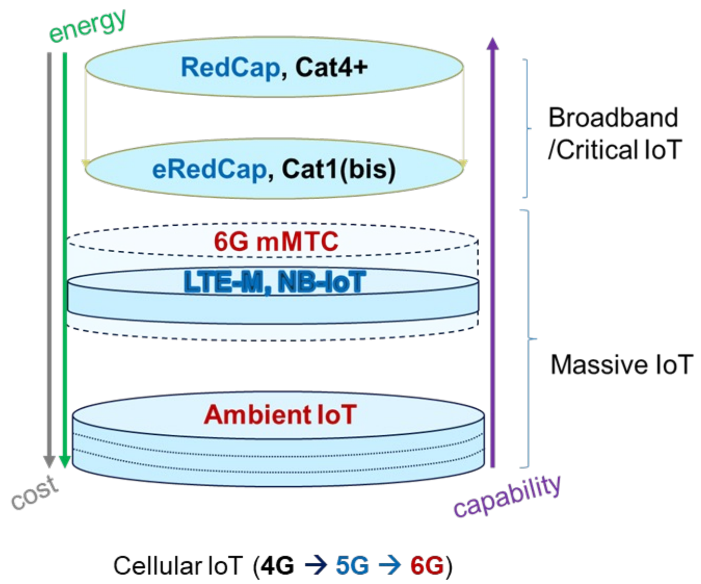


FIGURE 3 The accuracy, latency, and availability requirements for positioning use cases. The diagonal lines represent the maximum tolerable latency under the specified mobility so that the accuracy requirement can still be met. Latency is determined based on the mobility such that devices/objects move only 10% of the target accuracy. IOO: indoor open office; UMi: urban micro; UMa: urban macro.

- **Class #4: : Enhancements of mMTC devices**
  - To improve on the power consumption, enable slightly higher data rates (up to few Mbps),
  - Expected to add requirements on reliability, may incorporate AI/ML techniques (e.g., AI-based channel estimation) etc. when compared to 5G devices



Device Class overview

From the use-case analysis and applying characterization criteria, D5.2 arrives at the following four device classes (and distinguishing them using some key criteria) and is summarized in the Table below. Among the groups of characterization criteria, we attached more weight to ones from energy and communication/radio performance to determine distinct device classes. This gives a good overview of the parameters that impact the energy and (radio) performance of the end-to-end system.

Further analysis is planned based on the upcoming deliverable on updated HEXA-X-II use-cases & associated KPIs and outlook for other new device classes or potential ones influencing these are mentioned in conclusions section. The result of analysis will be part of later WP5 deliverable.

Device class name → Criteria	Energy Neutral (EN) device class	Reliable High Data Rate with Bounded latency (RHDRBL) device class	High Reliability & Low Latency (HRLL) device class	Enhancements of mMTC (EmMTC) device class.
Energy	During operation, Energy neutral (very low energy consumption)	Low energy (low energy consumption could take precedence over reliability)	Low energy consumption as possible (without compromising on reliability)	Low energy consumption
Data rate	Very low	High	Medium	Low
Latency	No mandatory requirements	Bounded latency	Low latency	No mandatory requirements
Reliability	No mandatory requirements	Medium	High	Low
Availability	No mandatory requirements	Medium	High	Low

Note 1: Relative indications (very low - low - medium - high - ultra) are used in this table to depict the distinction between the device classes. Some indicative numbers are available in Chapter 4 introduction & within the respective device class sections and depends on the specific deployments. This is planned to further refined in upcoming deliverables from WP5 based on KPIs from WP1.
Note 2: Zero energy devices, a device type that was identified in the use-case section are mapped into Energy neutral device class.

6G Radio design requirements

- Performance requirements related to services

Air interface communication requirements	Performance metrics
Data rate	Peak data rate, throughout, capacity, spectral efficacy, sum rate, average rate, packet rate.
Coverage	Range (spatial separation distance), beamwidth, signal-to-noise ratio (SNR), coverage probability, outage probability.
Air interface latency	The time needed to transmit and receive L2 packet successfully.
Air interface reliability	Bit error rate (BER), frame error rate (FER), block error rate (BLER), symbol error rate (SER), normalized mean square error (NMSE).
Radio sensing requirements	**Performance metrics**
Location/sensing accuracy	Error norm value (distance between true and estimated value) corresponding to a certain percentile of the location error norm.
Sensing latency	The time between initialization of sensing/localisation procedure and acquiring localisation/sensing estimate.
Orientation accuracy	The orientation error norm value corresponding to a certain percentile (e.g., 90%, 99%) of the orientation error norm.
Location coverage	The area or volume or fraction of a space in which the localization error is below a certain limit.
Sensing resolution	The smallest difference in a dimension (e.g., range, angle, Doppler) between objects to have measurably different values.
Sensing detection probability	The probability that a target is detected given that it is present .

- General performance requirements

Implementation and operation	Performance metrics
Energy efficiency	Ratio of output power to the total consumed power, energy consumption to achieve certain performance goal (such as energy required to transfer a bit).
Complexity	Amount of hardware resources, computational complexity of algorithms.
Cost	Cost of design, implementation, deployment, and operation.

- Design value requirements

Value requirements	Performance metrics
Inclusiveness	Coverage, global standard, proper number of manageable interfaces, affordable devices.
Trustworthiness	Reliability, security, resilience, integrity.
Sustainability	Values and needs of the end-users, energy consumption, life cycle assessment (LCA) of material, electromagnetic field (EMF) exposure.

MIMO techniques

Enablers belong to architecture and deployment and signal processing

Enablers	Topics	Scope
D-MIMO schemes and architectures	• Coherent joint transmission • Non-coherent joint transmission • Scalable transmission • Distributed massive MIMO for machine type communication • RIS-assisted IAB • Decentralized transmission • One-bit ADC for multi-cell setup • Multi-antenna location-dependent coded caching • EMF evaluations for distributed transmissions	• Study the feasibility of analogue fronthaul, model blockage and reduce its likelihood in coherent joint transmission • Enhance diversity in non-coherent joint transmission with orthogonal codes • AI/ML-based approaches for resource allocation to enable scalability • Outage probability in centralized and distributed massive MIMO setups • Performance analysis of RIS in integrated access and backhaul (IAB) networks, with focus on reliability and throughput in backhaul links • Study cooperative beamforming strategies with bi-directional training • Evaluate 1-bit ADCs/DACs with power tuning in multi-cell setups • Investigate a multi-antenna content delivery scheme based on coded caching for high data-rate connectivity and strict delay constrains • Simulation for EMF exposure assessment for different antenna precoding
Massive MIMO schemes and architectures	• Hybrid analogue-digital architectures • Fully digital architectures with low-resolution ADCs/DACs	• Beam search in sub-THz D-MIMO network assisted with sub-6 GHz links • Analytical framework for comparing different architectures in terms of spectral and energy efficiency
RIS-assisted transmission	• RIS control procedure, interface and integration • D-MIMO assisted with RIS • Channel estimation for RIS • Learn RIS-reflecting modulation (RM)	• Analyse the signal level obtained with RIS in a simplified scenario • Design control procedures for RIS integration in radio networks • Control procedures for externally controlled RIS • Provide guidelines for deployment, selection and control of RISs • ML-based channel estimation for RIS aided systems under mobility conditions • ML-based approach to learn the signalling set for

Waveforms and modulation schemes

Focus on signal processing considering RF transceiver HW impact

Enablers	Topics	Scope

Waveforms and modulations	• Feasibility of the mainstream 6G waveforms at sub-THz frequencies	• Evaluate the suitability of waveforms for sub-THz frequency ranges
		  • Candidate waveforms: OFDM and SC-based waveforms
		  • Analysis of energy and spectral efficiency, PN tolerance and scalability

	• Zero-crossing modulation (ZXM)	• 1-bit ADC with temporal oversampling and information encoded in time-domain
		• Study the viability of ZXM as a waveform for specific scenarios in the presence of ample spectrum
		  • Energy and spectral efficiency
		  • Robustness to non-idealities

	• Polar constellations	• Analysis of new types of constellations combined with a multicarrier waveform • Robustness against PN and Doppler shift
	• Learned MIMO waveforms	• Investigation of end-to-end learning approaches to obtain waveforms that facilitate signal detection without the need of pilots

Joint communication and sensing

Enablers in the category of architecture and deployment, signal processing, and KVI focused solutions

Aspects	Topics	Scope

Sensing deployment	• NTN-aided localisation
	• Integrated communication and monostatic sensing
	• Integrated monostatic and bistatic sensing
	• Multi-static sensing
		• Investigating multiple sensing and localization deployment scenarios to provide a positioning/sensing solution that is:
		  • Accurate
		  • Available

Waveforms, frame structures, & resource allocation	• Flexible baseband transceiver for JCAS
	• Waveform learning for JCAS
	• Optimization of OFDM-based bistatic sensing
	• Resource allocation in/for:
	  • Multiband hybrid-beamforming transceiver
	  • 6D tracking in JCAS scenarios
	  • Inter-UE sensing
	• Power consumption of JCAS
		• Investigating methods to re/co-use communications infrastructure (waveforms and frames) for sensing and localisation purposes
		• Optimal precoding and resource allocation through model-based and data-driven techniques
		• Studying the power consumption of UEs under various sensing deployment scenarios and KPI requirements.

Security & Privacy	• Privacy and security for JCAS • UE-related security aspects of JCAS • Jammer localisation	• Studying security aspects of JCAS systems from the point of view of both the UE and the network • Investigating methods to locate jammers for mitigation purposes

Summary

- Spectrum access solutions

Enablers	Topics	Scope
Spectrum sharing, coexistence	• assumptions and models to determine sharing possibilities • TN-NTN spectrum coexistence and sharing • multi-RAT spectrum sharing	Spectrum is valuable and scarce. The ability to leverage spectrum that is already allocated to existing services is essential. Additional emerging non-terrestrial connectivity leads to new interference scenarios requiring further research.
Low-latency random access	• sub-THz access methods • risk-informed random access	Many services require low-latency access to spectrum for a good and reliable user experience. Sub-THz propagation characteristics as well as localised services require rethinking of spectrum access methods.

Sustainability	*Inclusion*	*Trustworthiness*
NW- and device-side energy efficient solutions.	Fair access to spectrum for all.	Dependable access to spectral resources.

KVIs focused solutions

Enablers	Topics	Scope

Flexible radio design	• Gearbox PHY
	  • Flexible hardware architecture
	  • Flexible transmission schemes
	• Proactive resource management
		• Provide multiple radio/PHY options to meet the diverse requirements of use cases (data rate, latency, reliability) to
		  • Improve energy efficiency
		  • Improve resource utilization
		  • Improve coverage

Inclusive radio interface	• TN/NTN enhancements
	• Integration with HAPS
		• Integrating terrestrial networks with non-terrestrial networks
		  • Connectivity to remote and rural areas
		  • Connection diversity for critical applications in urban areas
		  • 6G network for sustainability

Sustainable radio solutions	• Optimization framework for gearbox PHY switching
	• E2E optimization framework for energy efficiency
		• Optimization and selection of radio configurations
		  • Reduce overall energy consumption and achieve environmental sustainability
		  • Reduce the energy consumption and meet EMF exposure requirements

Trustworthy radio solutions	• PHY security • Jamming resilience schemes	• Physical layer based secret key generation (SKG) • Resilience against jamming attacks and resilience against unexpected failures

Link-level modelling and simulation

Enablers	Topics	Scope

Channel modelling	• Channel models at Sub-THz frequencies
	• Coverage analysis at THz frequencies
		• Study of signal behaviour at sub-THz frequencies in different scenarios and sites
		  • Channel models for fading, blockages and other propagation mechanisms for the (100-300 GHz) range
		  • Guidelines for modelling frameworks (e.g., stochastic and deterministic models)
		• Study of coverage
		  • Radio coverage at THz frequencies (300 GHz–3 THz)
		  • Compare coverage achievable at THz frequencies with that at sub-THz frequencies using theoretical analysis

Link-level signal modelling	• Link modelling of 6G physical layer
	• Hardware modelling of RIS
		• Provide a comprehensive analysis of the potential and main limitations of communications in the sub-THz band
		  • Develop a link-level simulation tool for 6G PHY that includes propagation model in the sub-THz frequency band
		• RIS modelling to be incorporated in link-level simulation tool
		  • Simulate model radiation patterns of RIS and compare simulated results to measurements in the FR2 frequency band