



6G series workshop by Hexa-X-II

Characteristics and classification of 6G device classes

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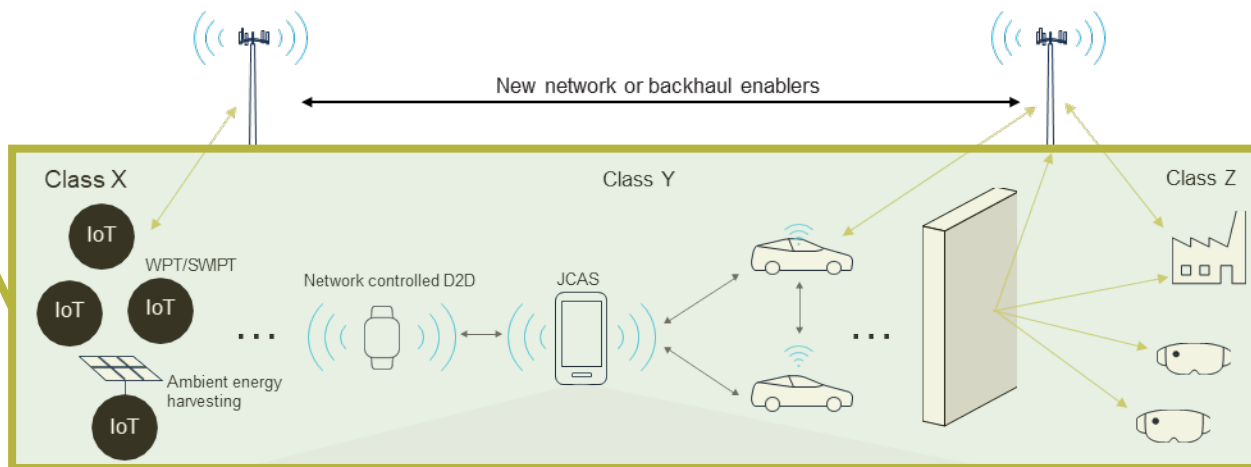
Hexa-X-II

hexa-x-ii.eu

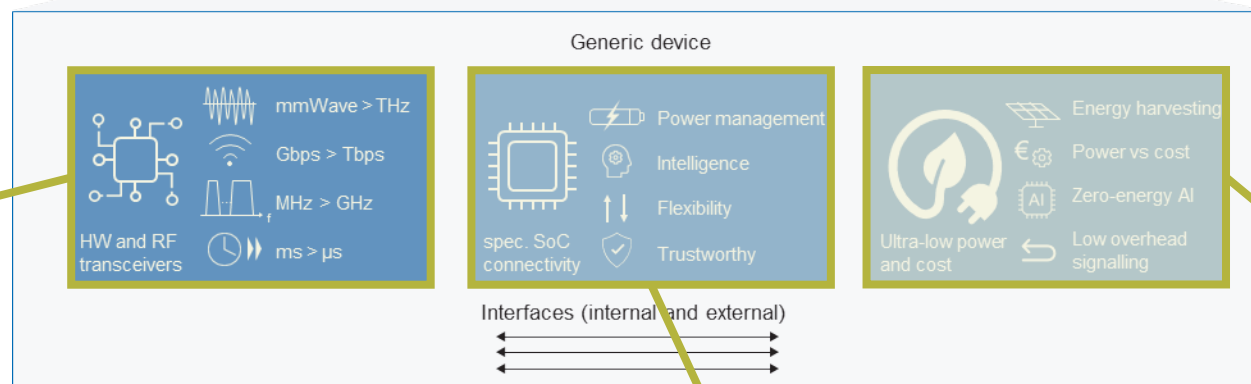




T5.1: Classification of novel **6G device classes** and infrastructure enablers



T5.2: HW and RF transceivers for 6G



T5.4: Ultra-low power/cost device and communication designs

T5.3: General purpose vs. specialized **SoC connectivity**



Classification of 6G device classes

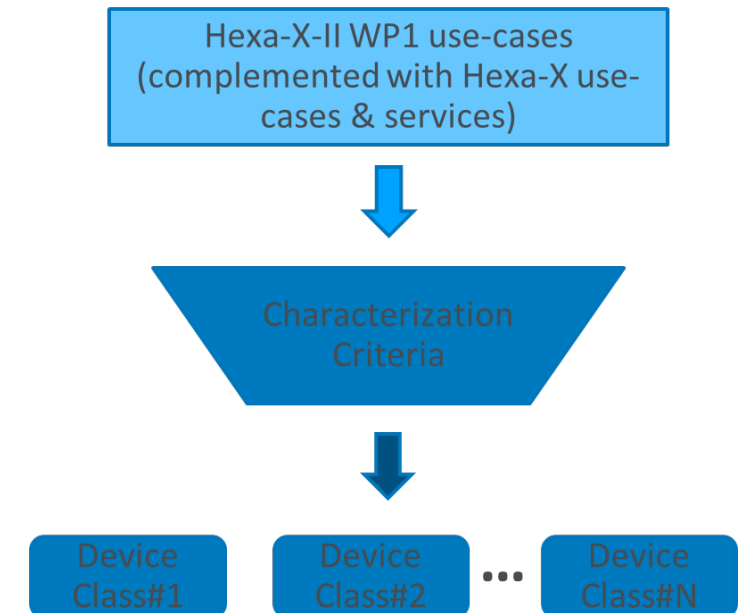
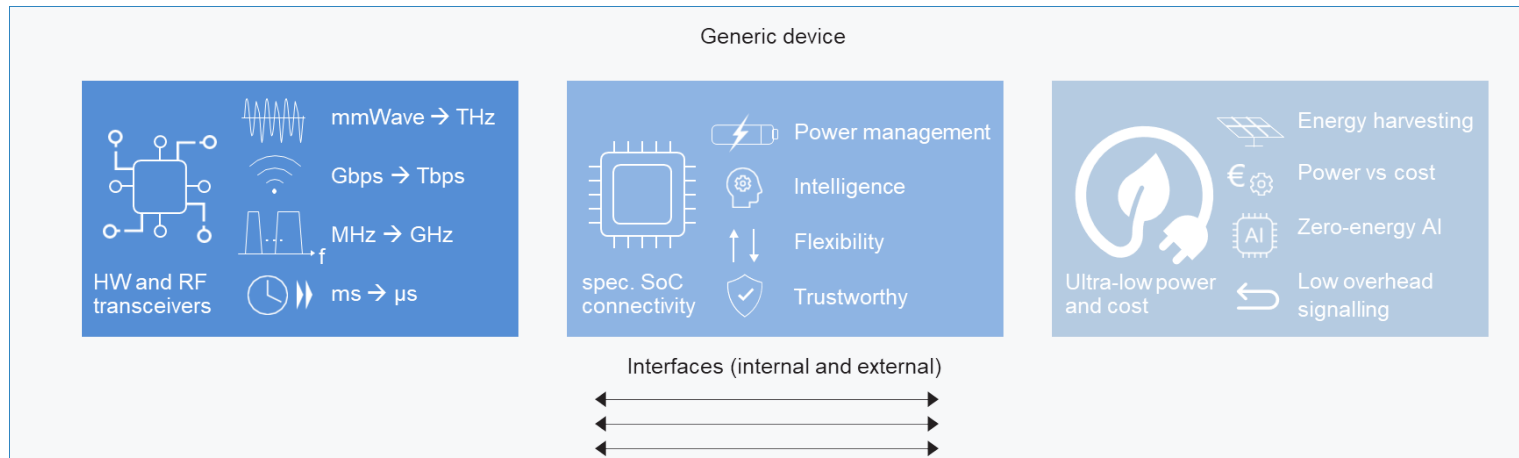
A brief summary of Hexa-X-II deliverable D5.2



Key Definition

What is a device in Hexa-X-II?

- Hexa-X-II defines a device specifically as an end-device that is connected to the network infrastructure via a radio interface, uniquely identifiable, and which generates and/or consumes application data
- The considered device consists of RF transceiver circuitry, a System-on-Chip (including a CPU, memory, and peripherals), and the necessary firmware and software.





Use-cases and devices realizing them

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

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

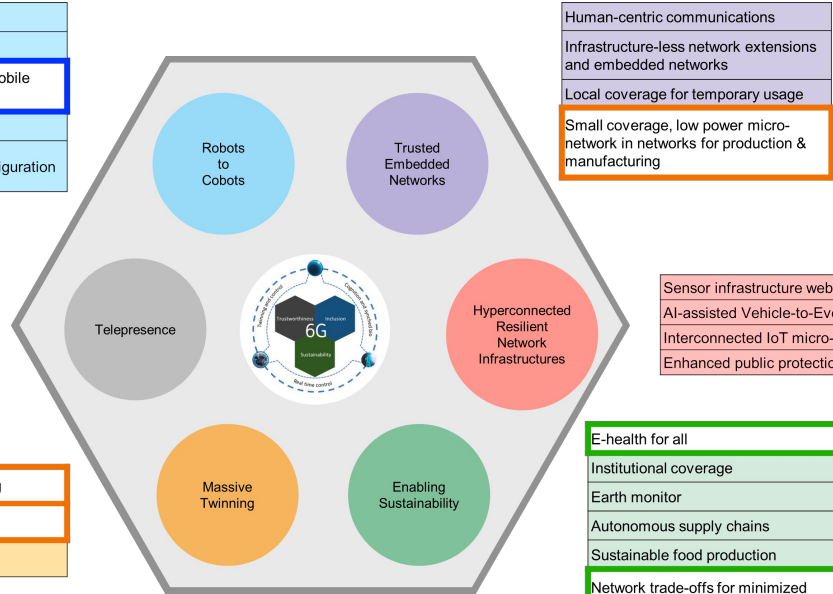
- (Reliable & available) XR devices
- On-body sensors and actuators + connectivity hubs....

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

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

Digital twins for manufacturing
Immersive smart cities
Internet of tags

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

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

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

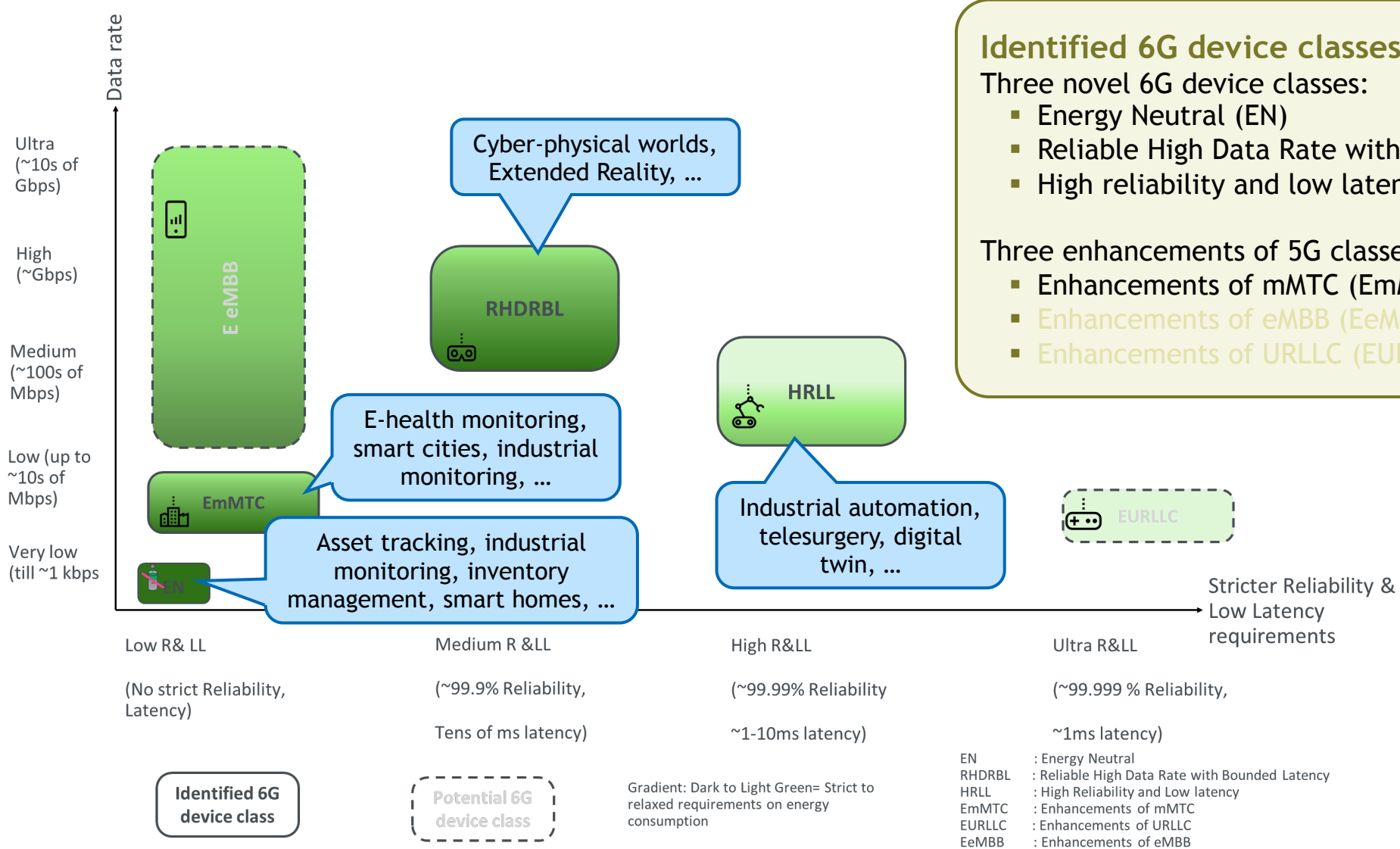
Characterization criteria



- Set the basis to understand if **different 6G devices** fall into a one device class or another.
- There are **numerous characteristics** concerning a device, such as its energy consumption, operating spectrum, authentication, etc.
- The **granularity is set at a coarse level** to serve as a guide and depending on the exact implementation etc.

Group	Characteristic	Group	Characteristic
Energy	Energy source	AI & computation	Computation capability
	Energy storage		
	Energy consumption during (1) operation (2) idle/sleep Device lifetime	Localization & sensing	Location accuracy
Lifetime	Orientation accuracy		
Mobility	Device mobility		Localization/sensing latency
Communication	Authentication	Security	Security capability
	Synchronization		
	Time aware system component		
	Spectrum		
	Traffic flow		
	Data rate		
	Latency		
	Reliability		
	Availability		
	NTN support		

Identified 6G device classes



- ### Identified 6G device classes
- Three novel 6G device classes:
- Energy Neutral (EN)
 - Reliable High Data Rate with Bounded Latency (RHDRBL)
 - High reliability and low latency (HRLL)
- Three enhancements of 5G classes (eMBB, URLLC, mMTC):
- Enhancements of mMTC (EmMTC)
 - Enhancements of eMBB (EeMBB)
 - Enhancements of URLLC (EURLLC)

EN : Energy Neutral
 RHDRBL : Reliable High Data Rate with Bounded Latency
 HRLL : High Reliability and Low latency
 EmMTC : Enhancements of mMTC
 EURLLC : Enhancements of URLLC
 EeMBB : Enhancements of eMBB



6G device and infrastructure enablers

A peek into Hexa-X-II deliverable D5.3

Hexa-X-II - WP5

6G device enablers

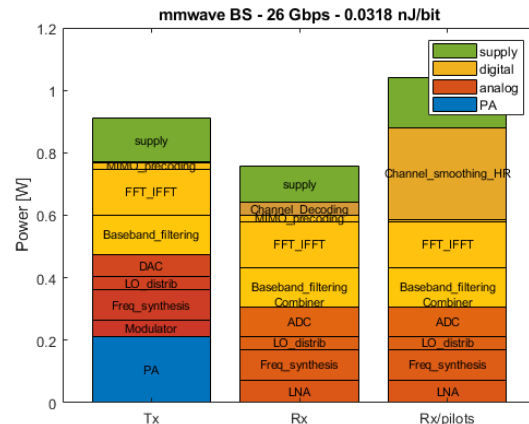
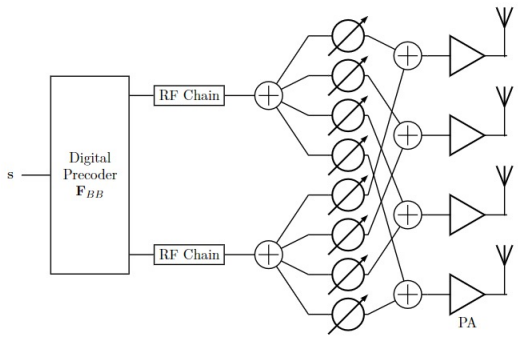


T5.1: Device types	T5.2: HW and RF transceivers for 6G	T5.3: Specialized SoC connectivity	T5.4: Ultra-low power devices and comms
Reliable High Data Rate with Bounded Latency (RHDRBL)	<ul style="list-style-type: none"> ▪ Sub-THz transceivers ▪ Reflective Intelligent Surfaces 	<ul style="list-style-type: none"> ▪ AI/DSP accelerators ▪ Secure SoC architecture 	
High Reliability & Low Latency (HRLI)	<ul style="list-style-type: none"> ▪ Reflective Intelligent Surfaces 	<ul style="list-style-type: none"> ▪ AI/DSP accelerators ▪ Secure SoC architecture 	
Enhancements of mMTC (EmMTC)		<ul style="list-style-type: none"> ▪ Secure SoC architecture 	<ul style="list-style-type: none"> ▪ Energy-aware low-overhead protocols
Energy Neutral (EN)		<ul style="list-style-type: none"> ▪ Multi-source energy harvesting ▪ Secure SoC architecture 	<ul style="list-style-type: none"> ▪ WPT/ backscatter ▪ Energy-aware low-overhead protocols

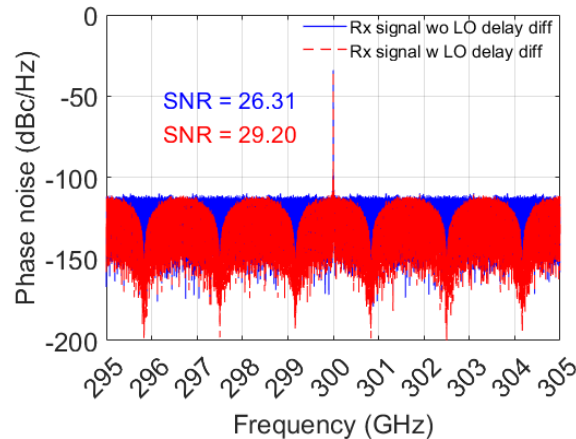
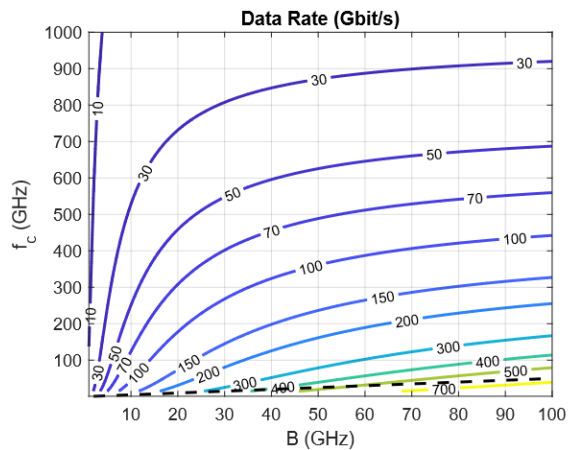
Sub-THz transceivers



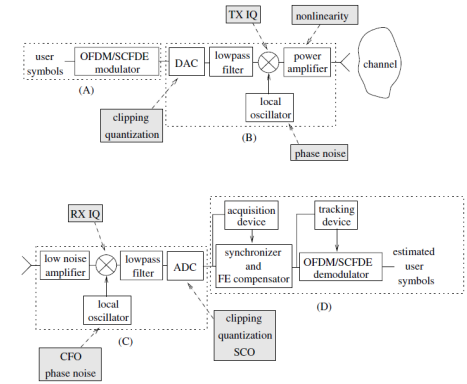
1. Dimensioning of sub-THz architectures



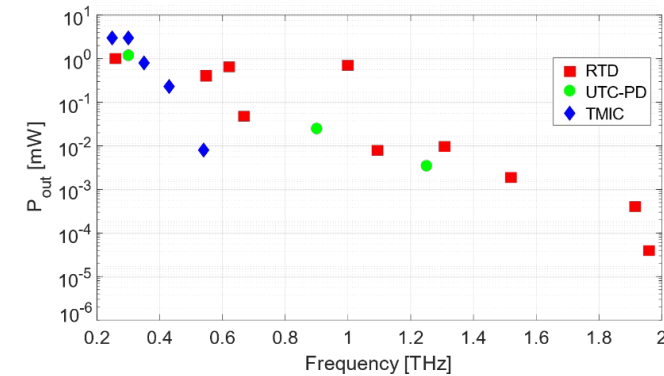
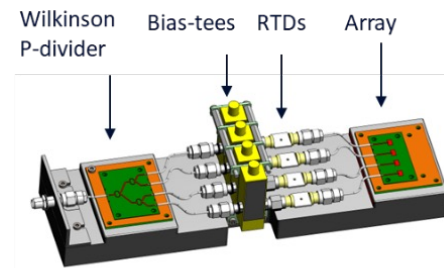
3. Phase-noise limited performance & asymmetrical LO



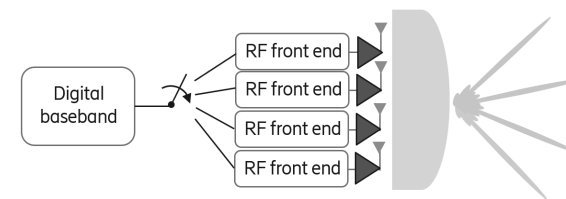
2. Models for main HW non-idealities



4. RTD-based architecture



5. Switched-beam antenna lenses

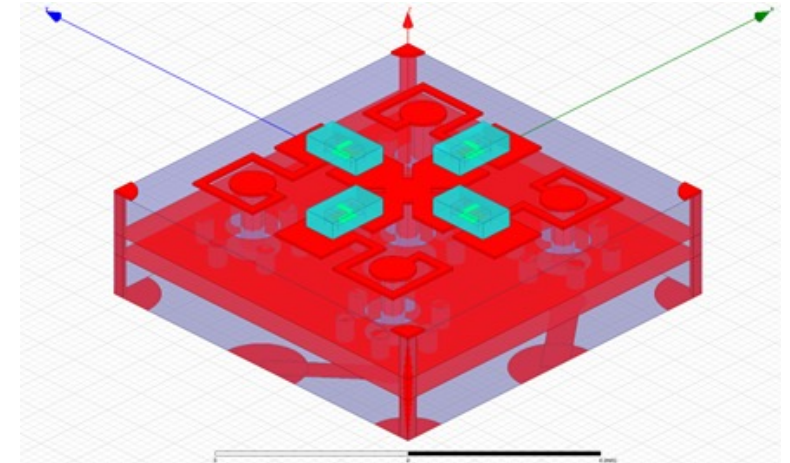
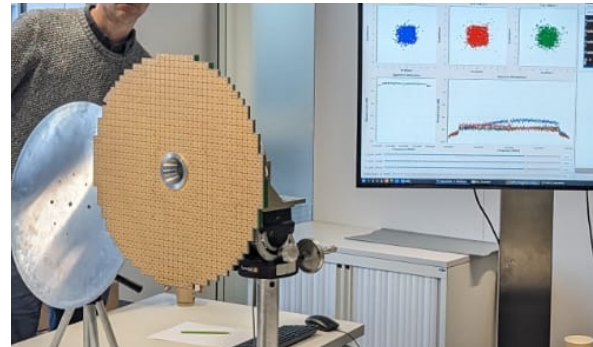
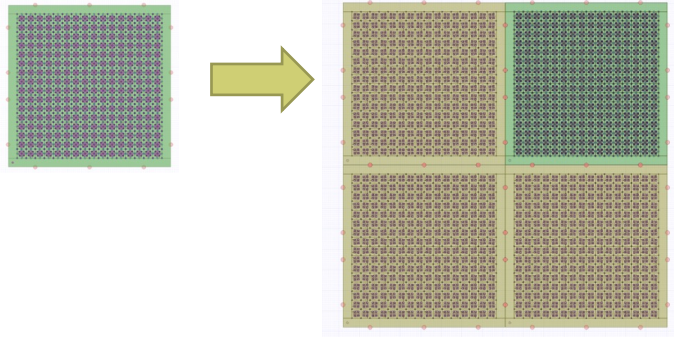


Reflective Intelligent Surface (RIS) design



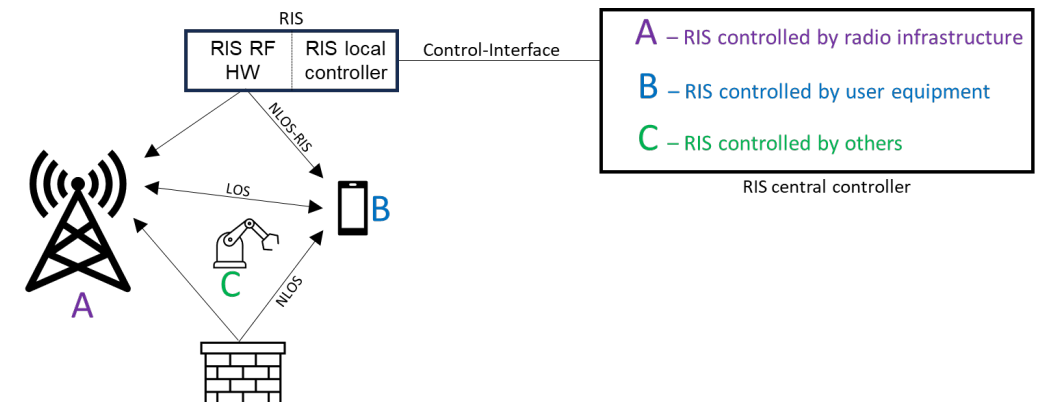
1. Reconfigurable RIS tiles

- Dual polarization unit cell at mmWave RF2 frequencies
- Continuous reflected phase control with at least 300°
- 16x16 unit cells tile prototype



2. RIS system integration

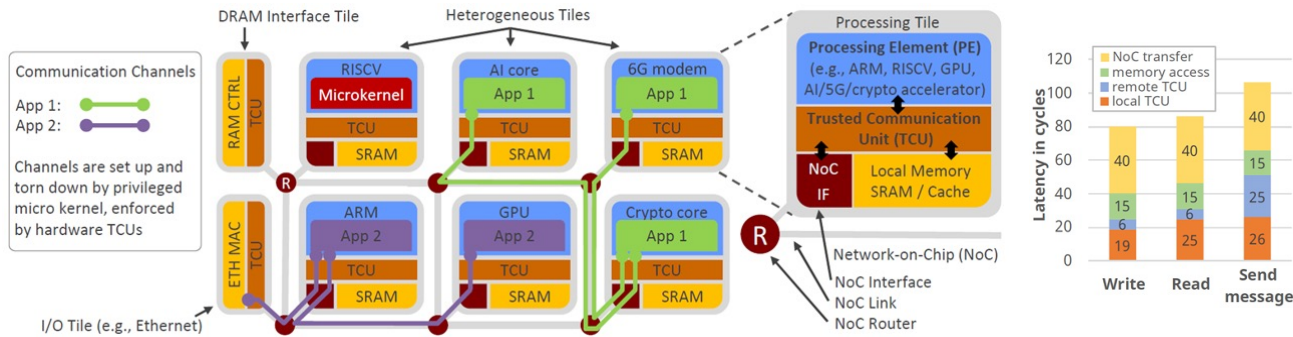
- Identifying key capabilities and limitations of RIS
- Local control functionality
- Control interface and protocol
- Multiple control architectures (network, UE, other)



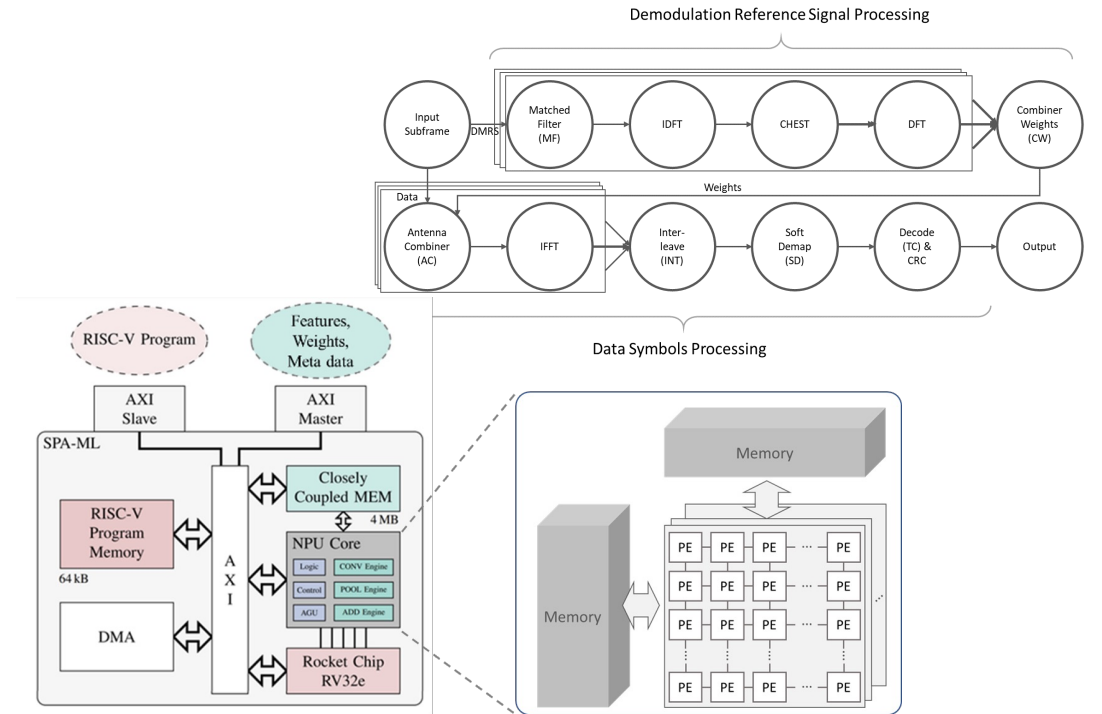


6G SoC design

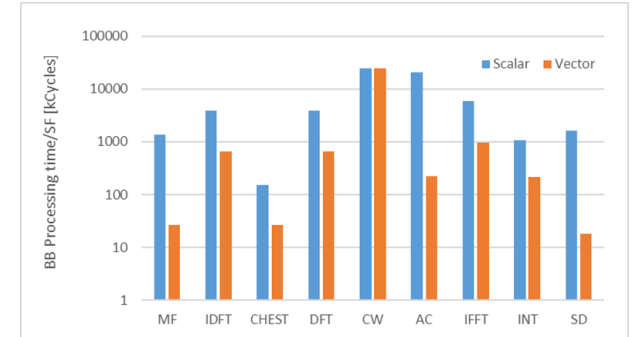
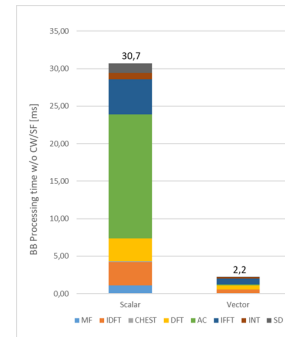
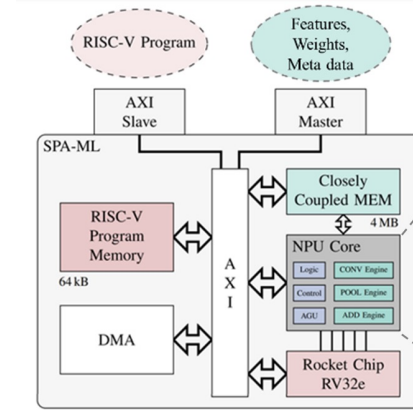
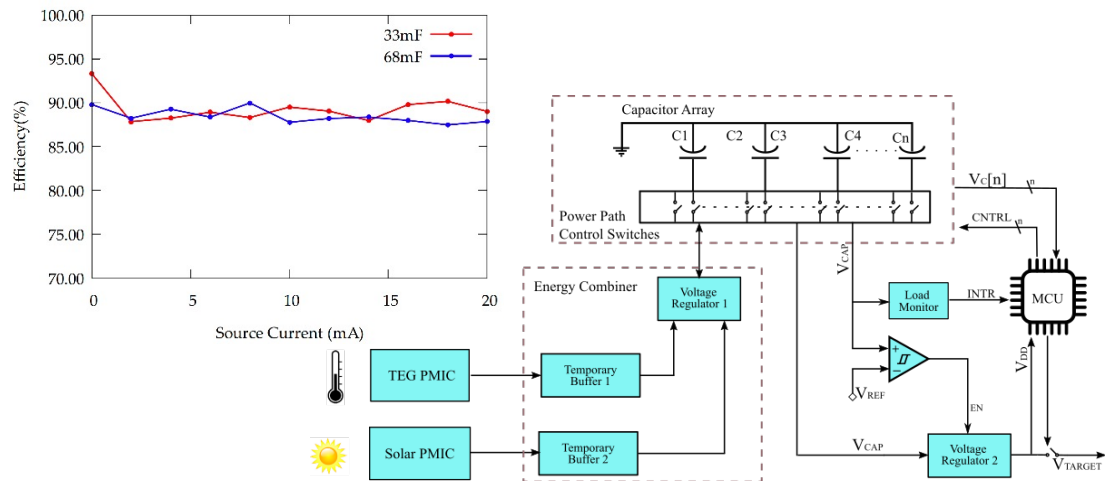
1. Secure and scalable SoC architecture tailored to a microkernel-based OS



2. DSP and AI capabilities of 6G SoC



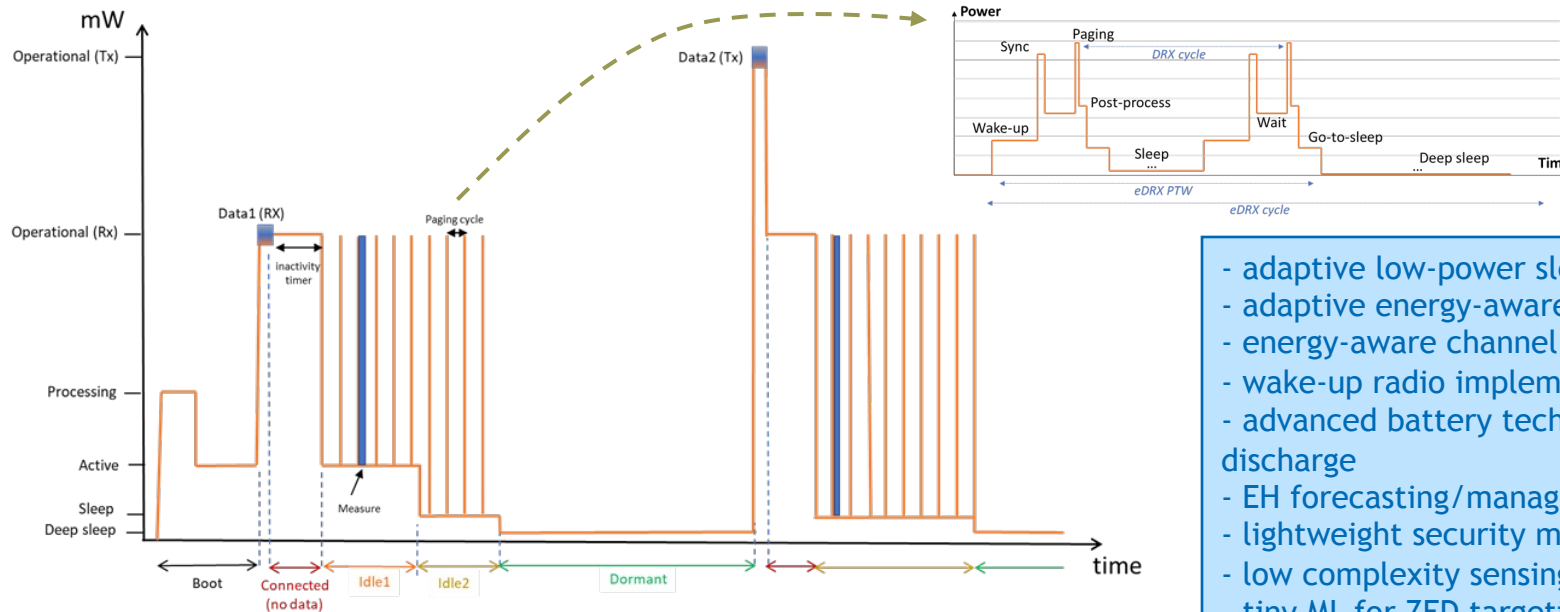
3. Multi-source energy harvesting and power management



Energy, cost, and performance trade-offs



- Power consumption analysis for 6G IoT modem
 - Obtain insight for evolution of power saving mechanisms
 - Enable battery lifetime KPI assessment (legacy and future modem)
 - Identify legacy and future potential features/mechanisms
 - Generalised parameterization for flexible analysis of future EmMTC devices or ZED



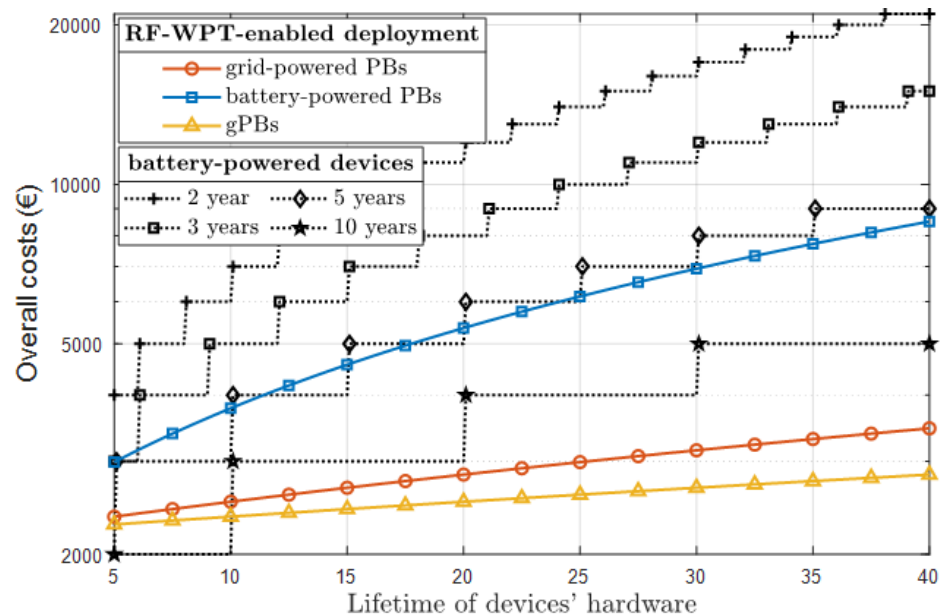
- adaptive low-power sleep modes and duty-cycling at both Tx and Rx
- adaptive energy-aware configuration for uplink and downlink transmission
- energy-aware channel access, synchronization, signaling, scheduling
- wake-up radio implementation
- advanced battery technologies, e.g., rechargeable battery storage of low self-discharge
- EH forecasting/management mechanisms
- lightweight security mechanisms
- low complexity sensing
- tiny ML for ZED targeting higher-end applications
- ...

Energy neutral device technologies



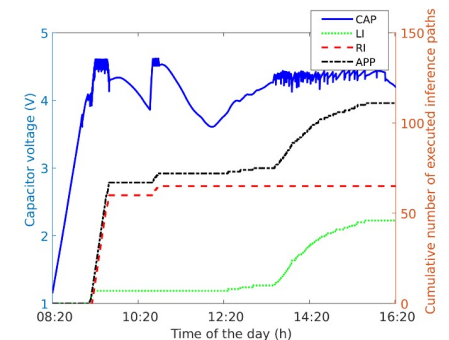
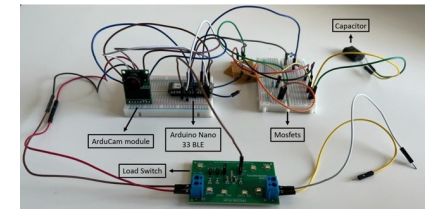
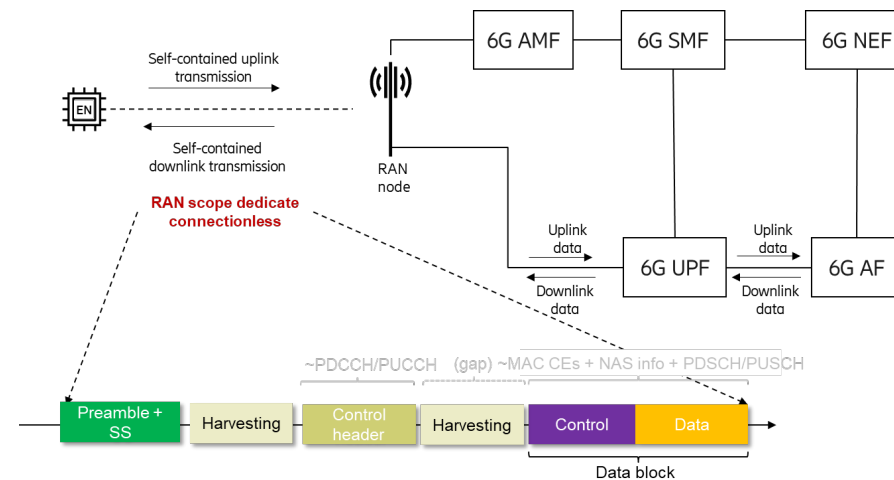
1. Trade-off analysis of RF Wireless Power Transfer (RF-WPT)

- Power beacons for RF-WPT can be cost-effective for massive IoT



2. Energy-aware protocols & applications

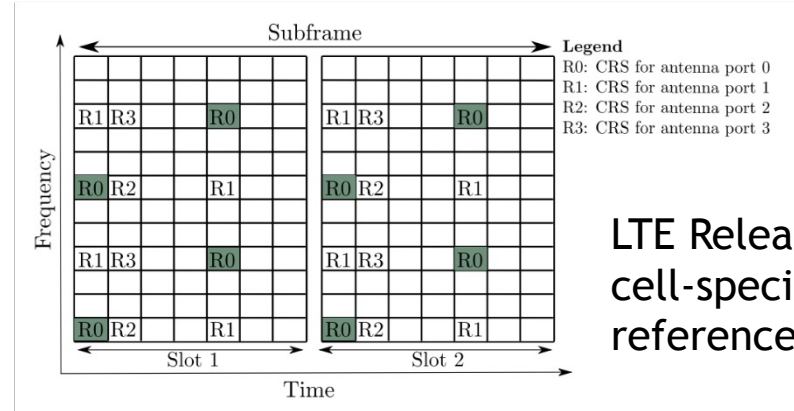
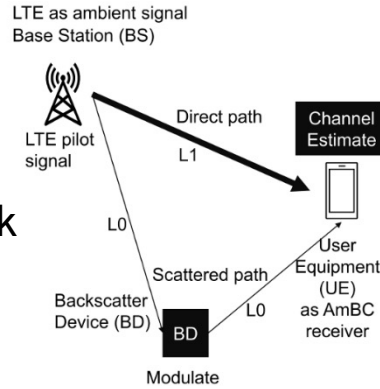
- Intelligent duty cycling and uplink/downlink scheduling
- Secure connection-less and self-contained protocols for ambient IoT
- Energy-aware tinyML applications that adapt ML inference to device energy



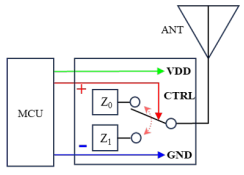
Zero Energy Device PoC



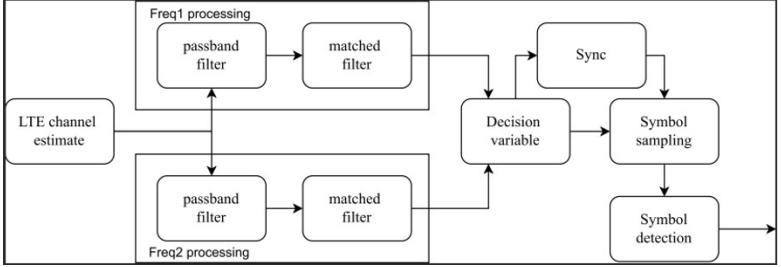
Downlink setup



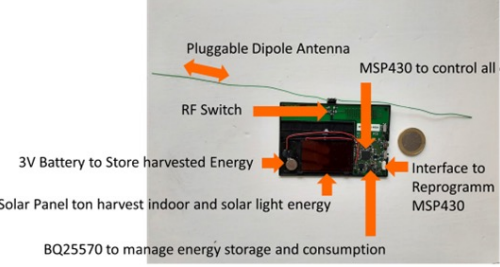
LTE Release 8 cell-specific reference signal



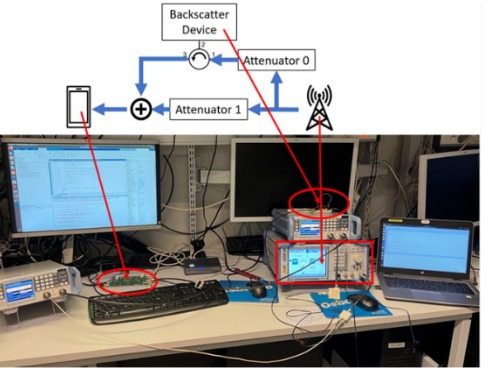
Prototype 1



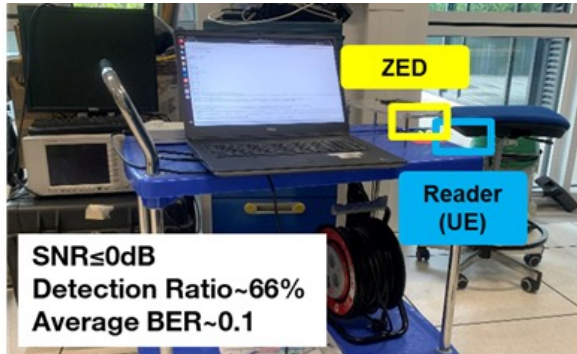
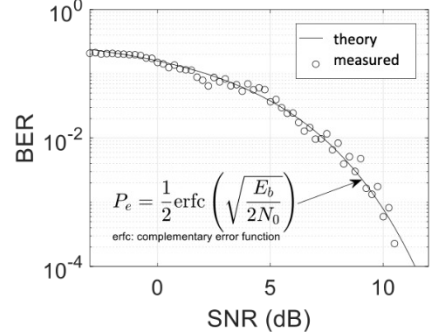
Flow chart of the proposed backscatter receiver



Prototype 2



Laboratory tests



SNR ≤ 0dB
Detection Ratio ~66%
Average BER ~0.1

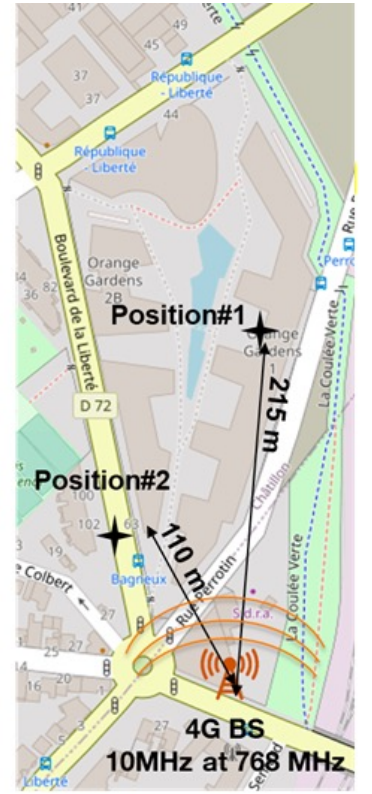
Position #1:
Non Line of Sight, Deep Indoor, Ground Floor,



SNR ≤ 4dB
Detection Ratio ~96%
Average BER ~0.04

Position #2:
Non Line of Sight, Deep Indoor, 4th Floor

Field trial



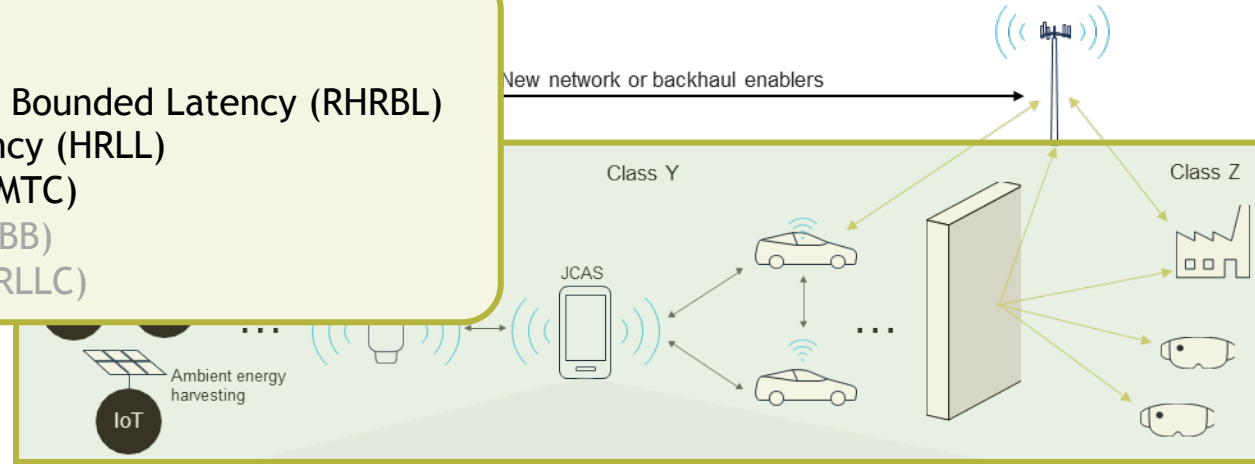


Summary



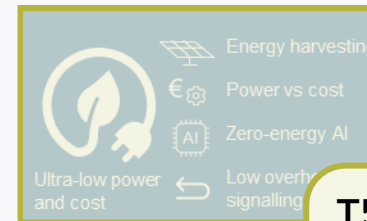
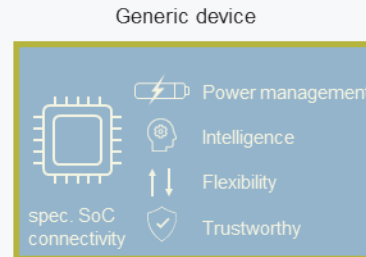
T5.1 - 6G device classes:

- Energy Neutral (EN)
- Reliable High Data Rate with Bounded Latency (RHRBL)
- High reliability and low latency (HRLL)
- Enhancements of mMTC (EmMTC)
- Enhancements of eMBB (EeMBB)
- Enhancements of URLLC (EURLLC)



T5.2 - 6G HW and RF transceivers

- Sub-THz radio (dimensioning, HW non-idealities, phase noise, RTDs, antenna lenses)
- RIS design (reconfigurable tiles, system integration)



T5.3 - Specialized 6G SoC connectivity

- Trustworthy SoC architecture
- DSP and AI accelerators for 6G
- Multi-source energy harvesting

T5.4 - Ultra-low power devices

- Power consumption (IoTmodem model, cost/power trade-offs)
- RF-WPT (analysis, ambient backscatter, PoC)
- Energy-aware protocols (duty cycle, signaling overhead, tinyML)

Want to learn more about Hexa-X-II WP5?



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



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



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

Available on
Hexa-X-II
website

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



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



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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

Available in
March 2024

<https://hexa-x-ii.eu/deliverables/>



HEXA-X-II.EU //   



Co-funded by
the European Union

6GSNS

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