Hexa-X | WP2 | D2.4

Enabling Radio Technologies and Roadmap towards 6G

30.06.2023

Introduction

Scope

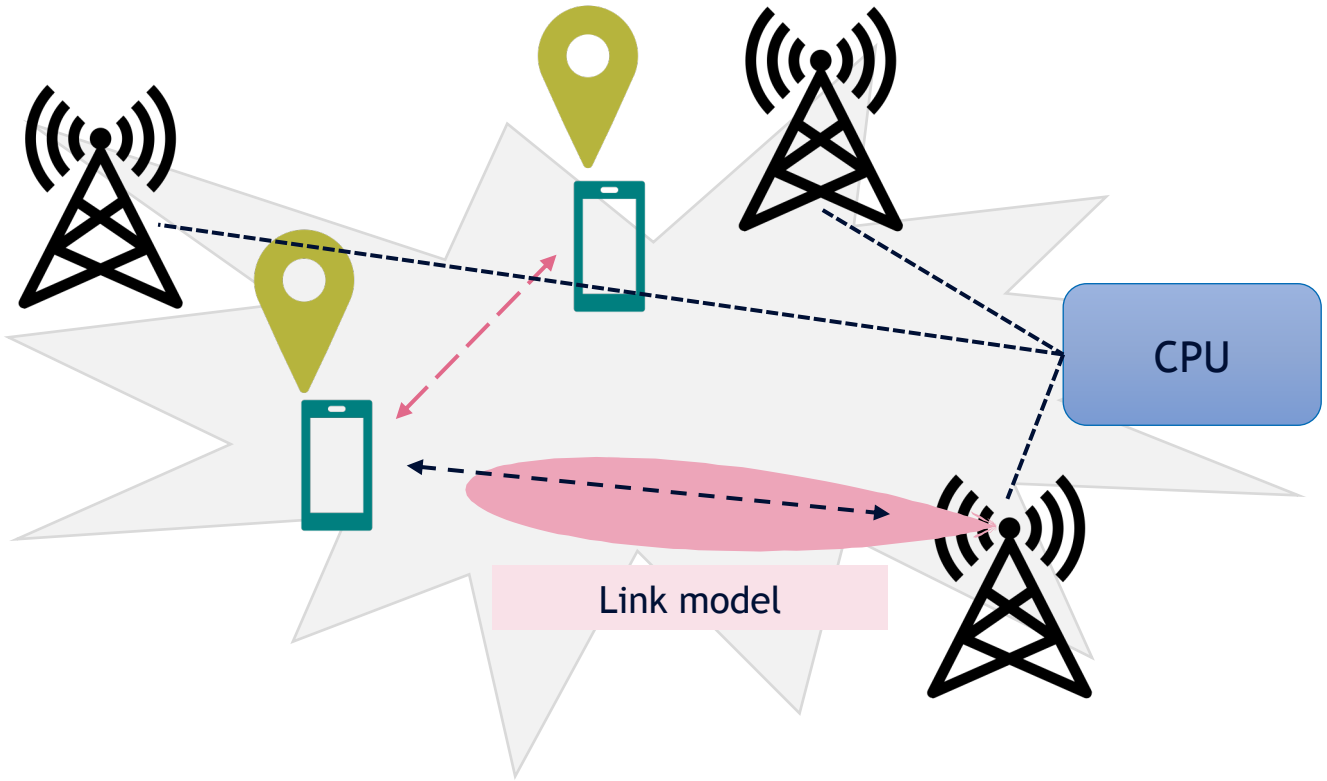
This report provides an evaluation of enabling radio technologies along with measurements from testbeds. It describes current research trends, attempts an economic forecast and a technology roadmap towards 6G.

It aims to benefit a wide range of stakeholders, including companies and researchers, society, policymakers, government agencies.

Outline

- Enabling radio technologies (current state of research)
- Measurements from proof-of-concepts
- Research trends (areas for future research)
- 6G markets evolution
- Radio technologies roadmap

Enabling Radio Technologies



An extended discussion of the findings can be found in D2.3 and D3.3 (available at https://hexa-x.eu/deliverables/).

Channel models

Material parameters for 2-260 GHz, and ***stored channel model*** at 140 GHz based on measurements

Radio architecture and models

RF transceiver architecture for the frequency range (100 – 300 GHz), description and evaluation of the ***hardware models***, and ***D-MIMO*** architectures

Signal processing techniques

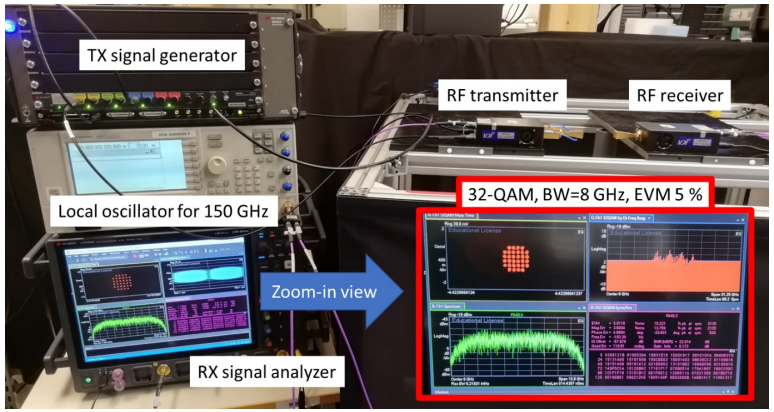
Guidelines for ***waveform*** and digital transceiver design, guidelines for ***beam management*** techniques in sub-THz system, ***studies of D-MIMO*** and integrated access and backhaul

Localization and sensing

Integration of localization, positioning, and sensing with communication in 6G systems can be at device-level, waveform-level, and resource-level. It will have significant implications in terms of ***new services and applications***, as well as ***improvements in the communication capabilities***.

Proof-of-Concepts

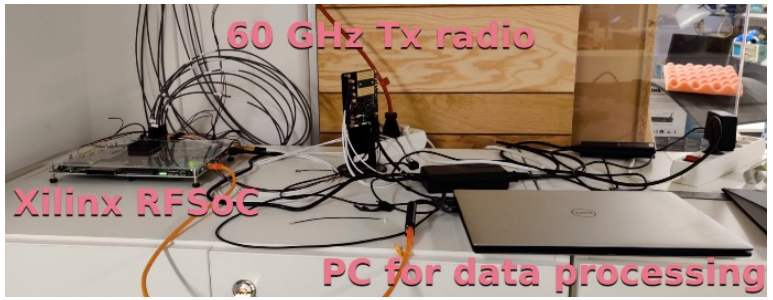
Sub-THz Communication



High data rate over-the-air radio link

$f_c = 150$ GHz
$B = \{2\text{ GHz}, 8\text{ GHz}, 10\text{ GHz}\}$
Single carrier
QPSK, 32-QAM

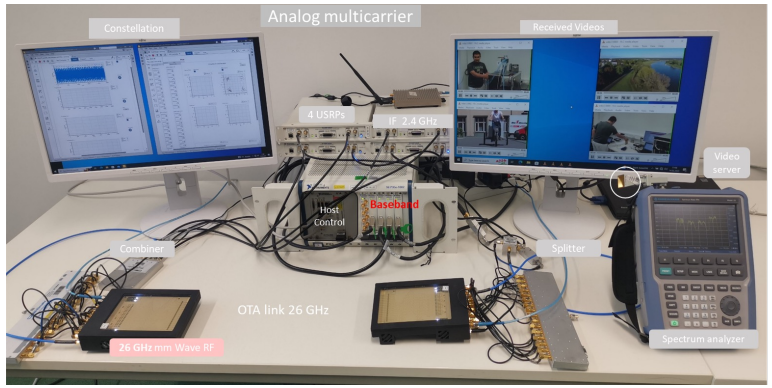
Joint Communications and Sensing



Same hardware and signal design can be used for communications and sensing

$f_c = 60$ GHz
$B = 800$ MHz
OFDM
MIMO

Flexible Base Band



Feasibility of exploiting ultra-wideband at different frequency bands using a unified IF transceiver

$f_c = \{2.4\text{ GHz}, 26\text{ GHz}\}$
$B = 640$ MHz
Analogue multi-carrier
4 channels

Research Trends

Channel Modelling

- Modelling near-field and wide bandwidth effects at (sub-)THz
- Small-scale fading over frequency and space due to the multi-paths created by rough surfaces

Radio Architecture and Models for D-MIMO

- Signal processing options
- Functional splits for different purposes
- Use of serialized and wireless fronthaul interfaces, RIS, and network-controlled repeaters
- Exploring the trade-offs between analogue and digital processing and centralized versus distributed processing

Localization and Sensing

- Algorithms for extra-large aperture arrays (in context of D-MIMO and near field localization)
- Reconfigurable intelligent surfaces as low-cost alternative to power-hungry base stations
- Techniques to use ML effectively with limited real-world data and to handle unknown channel models

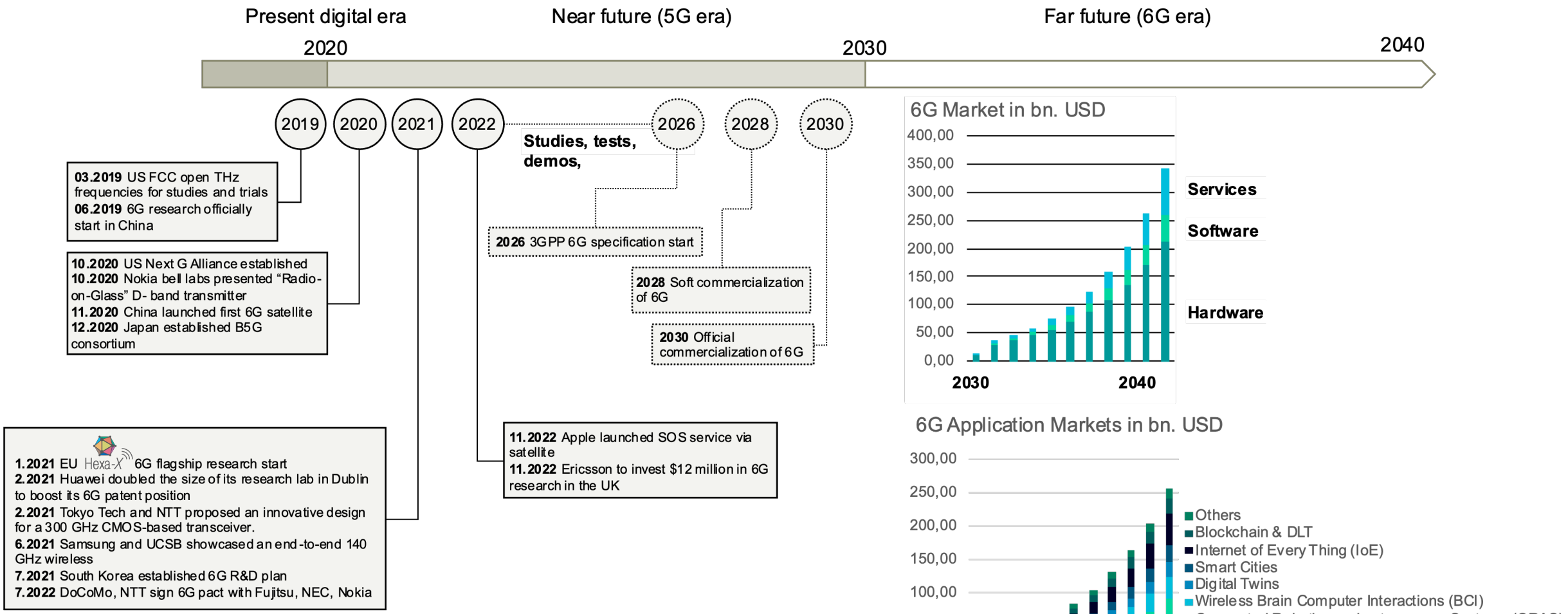
Signal processing techniques

- D-MIMO
  - Enhanced non-coherent techniques
  - Multi-band operations
  - Multi-antenna UEs
  - Heterogeneous nodes (w.r.t. capabilities and functionalities)
  - Role of reconfigurable intelligent surfaces and network-controlled repeaters for integrated access and backhaul
  - Context-aided communications
- Compensation of hardware impairments
  - Modelling of hardware impairments
  - TX vs. RX side compensation
  - Machine learning frameworks for data, training, monitoring, etc.

Optical Wireless Communications

- Methods for combining THz and OWC to enhance performance in terms of capacity, reliability, and latency

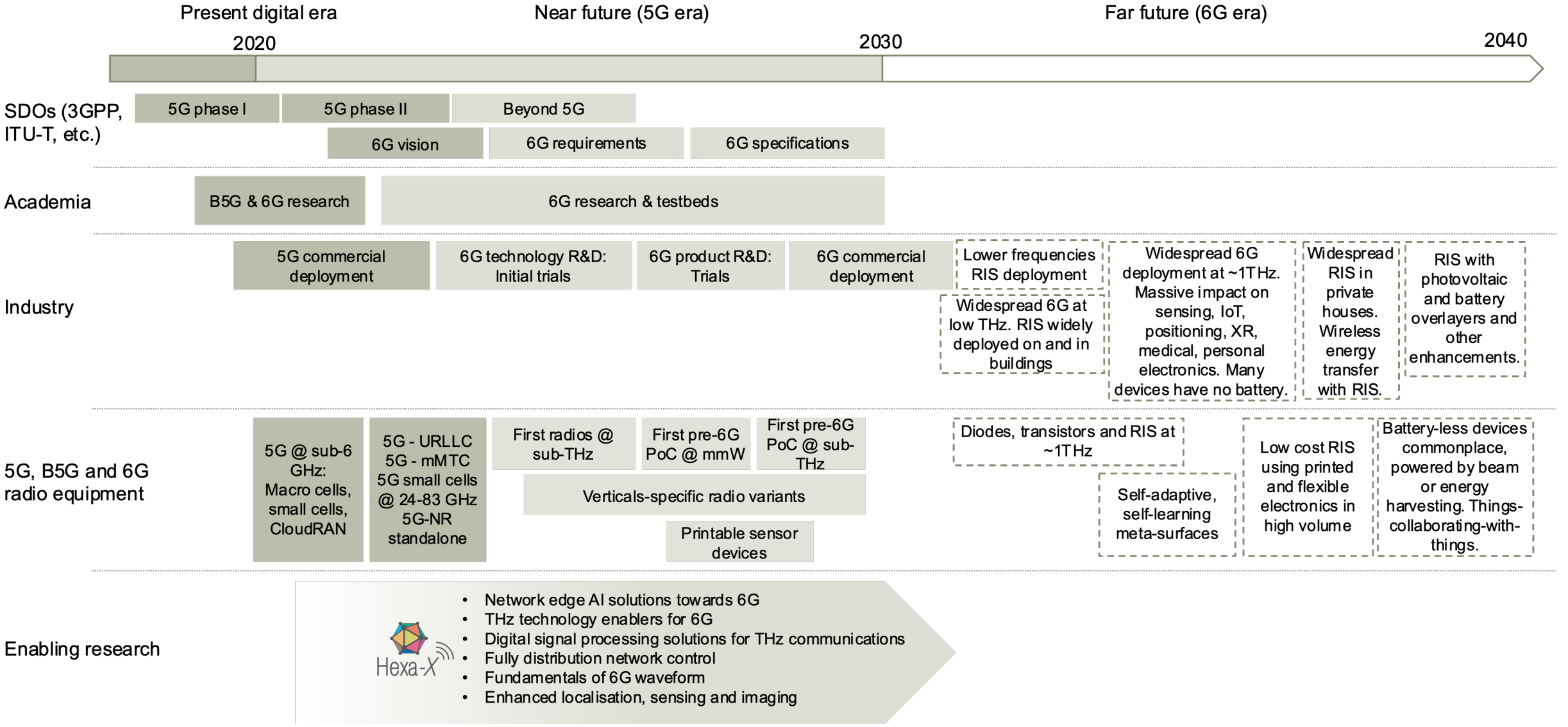
6G Markets Evolution



Based on: IDTechEx, „Where Are We at With 5G, and Where Are We Going With 6G?", 2022

Based on: Market Research Future, "6G Market Research Report", 2023

Estimated 6G Technology Roadmap



Based on: Liu et. al., “Federated learning for 6G communications: Challenges, methods, and future directions”, IEEE International Conference on Sustainable Computing and Data Communication Systems (ICSCDS), 2022

Based on: Pouttu et. al., “6G white paper on validation and trials for verticals towards 2030’s”, University of Oulu, 2020

Based on: IDTechEx, ”6G Communications WIET and RF Eliminating Batteries”, 2022

Summary

- New infrastructures are vital for socio-technical transformation.
- End users in various industries drive new value creation in 6G.
- Platform economy and ecosystems proliferate.

Europe needs a clear vision for infrastructure systems 2035 and an integrated approach for for information processing, communications and energy infrastructure that enables policy decisions, coordinated funding, and effective investments.

HEXA-X.EU

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