Partners: NFR, NFI, EAB, APP, ATO, CTT, EBY, ICC, NXW, NDK, NGE, OPT, OPL, ORA, VTT, TID, WIN, TUK, SIS

Hexa-X-II D2.1 Deliverable

D2.1 summary slides: Draft foundation for 6G system design

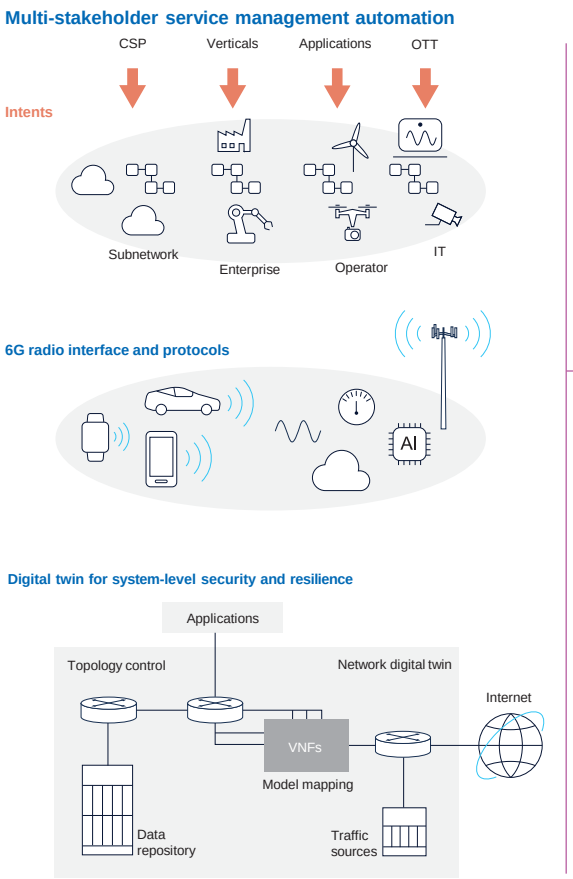
Hexa-X-II

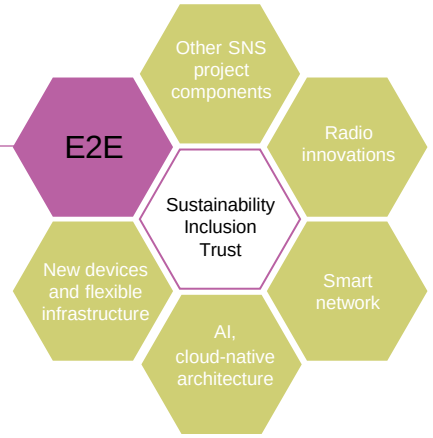
hexa-x-ii.eu

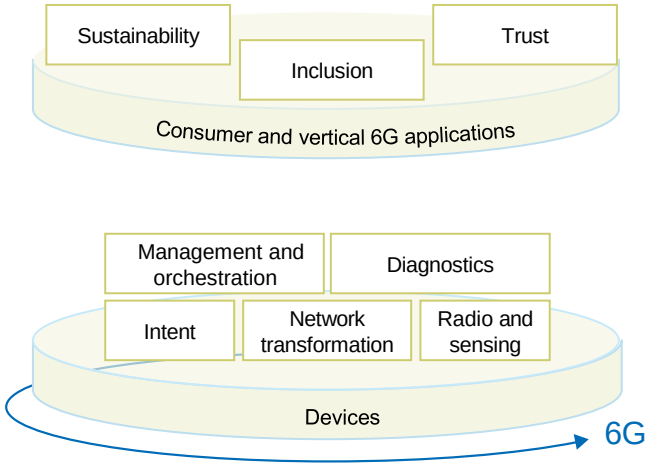
2023-06-29

WP2 objectives and technical concepts

Main objective of WP2 is to design a system blueprint aiming at the sustainable, inclusive, and trustworthy 6G platform, and to provide the E2E system validation.







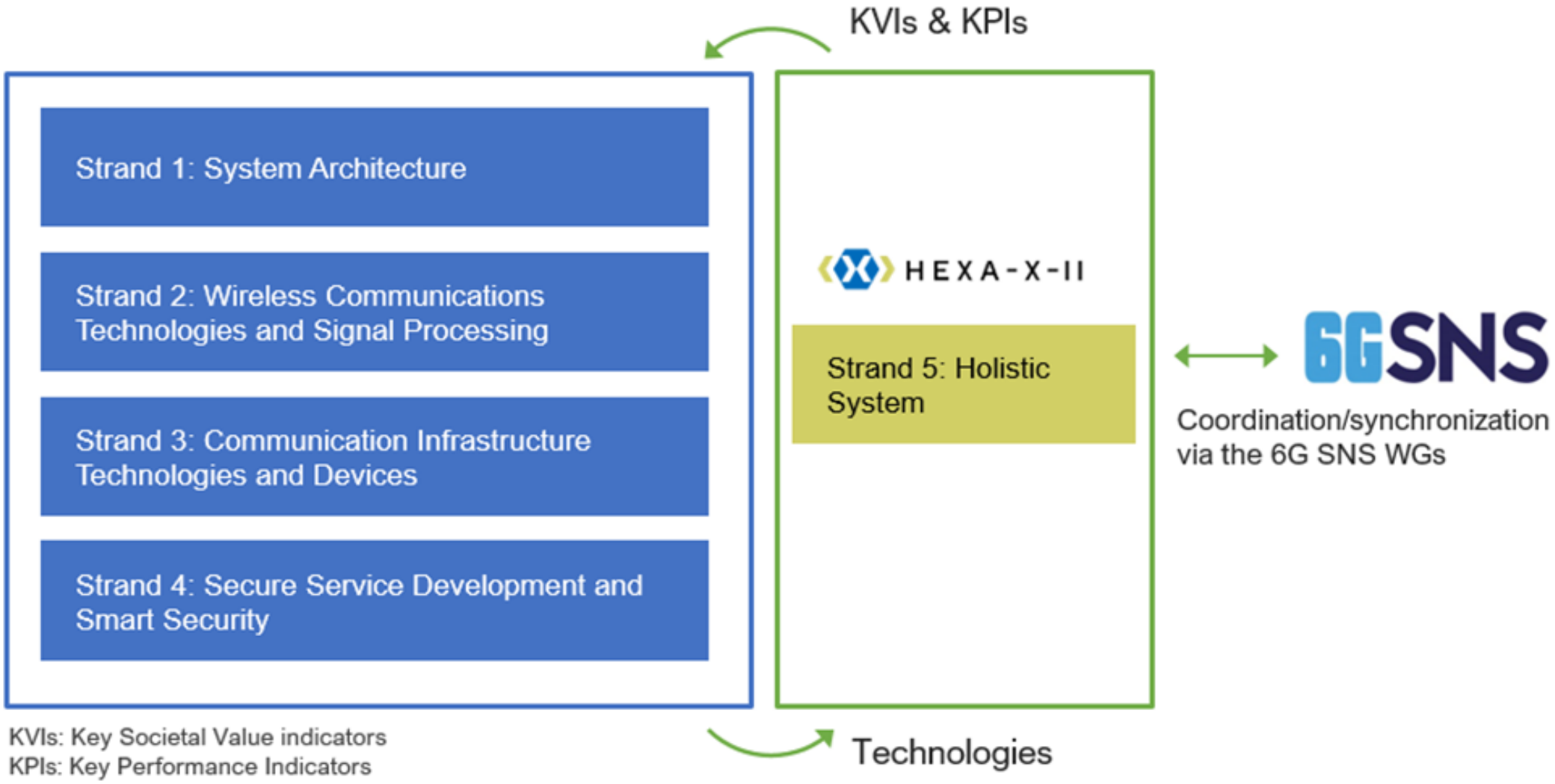
6G network platform blueprint → E2E system validation

Hexa-X-II WP2 technical concept on E2E system.

WP2 deliverables and timeline

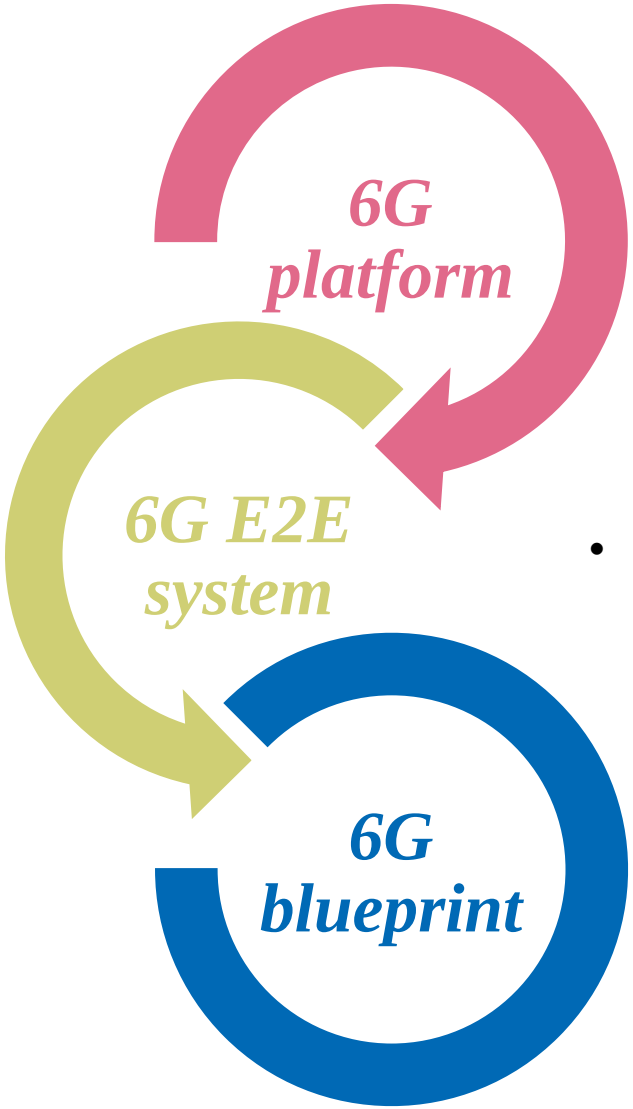
Deliverable Name	Purpose of deliverable
D2.1 Draft foundation for 6G system design (current deliverable) (Delivered by June 2023)	To provide the guidelines for the 6G system design and the methodology description for technology components selection and evaluation; To indicate the components considered for the first iteration of the System-PoC (A); To identify interworking with other SNS projects and WGs.
D2.2 Foundation of overall 6G system design and preliminary evaluation results (Delivered by December 2023)	To provide the foundation of the 6G platform blueprint, the early description of the components developed by WP2, and the preliminary evaluation results at the system level, including results from the first iteration of System-PoC (A).
D2.3 Interim overall 6G system design (Delivered by June 2024)	To provide an initial design of the overall 6G system; To discuss the synergies in terms of the technical enablers and components developed in other SNS Stream B projects; To provide initial description of components of WP2–WP6 relevant for the second iteration of System-PoC (B).
D2.4 E2E system evaluation results from the interim overall 6G system design (Delivered by September 2024)	To provide the evaluation results of the second iteration of the System-PoC (B).
D2.5 Final overall 6G system design (Delivered by April 2025)	To provide the final design of the overall 6G system; To discuss further synergies in terms of the technical enablers and components developed in other SNS Stream B projects; To provide the final description of components of WP2–WP6 relevant for the second iteration of System-PoC (C).
D2.6 Final E2E system evaluation results of the overall 6G system design (Delivered by June 2025)	To provide the final evaluation results of the System-PoC (C) based on the overall 6G system design.

Interaction and interworking with other SNS projects and WGs



Interaction with the strands in the SNS stream B

WP2 key terms



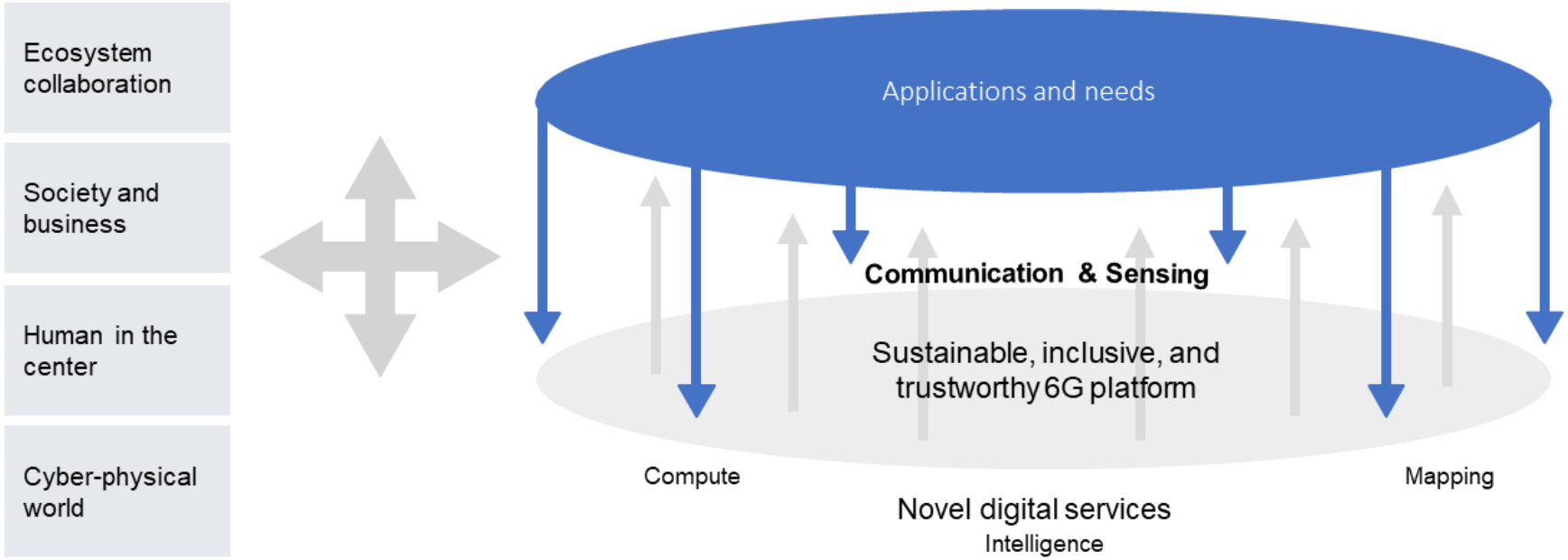
- The external view of a set of technologies and interfaces delivering 6G services to applications, ecosystems, verticals, users etc. enabling value.
- The technical realization of 6G platform which includes the technology enablers and their interaction.
- A reference architecture that meets the E2E system needs with respect to hardware, software and applications.

Table of Content (for main contribution)

Chapter 3
Principles/Foundation for 6G End-to-End System

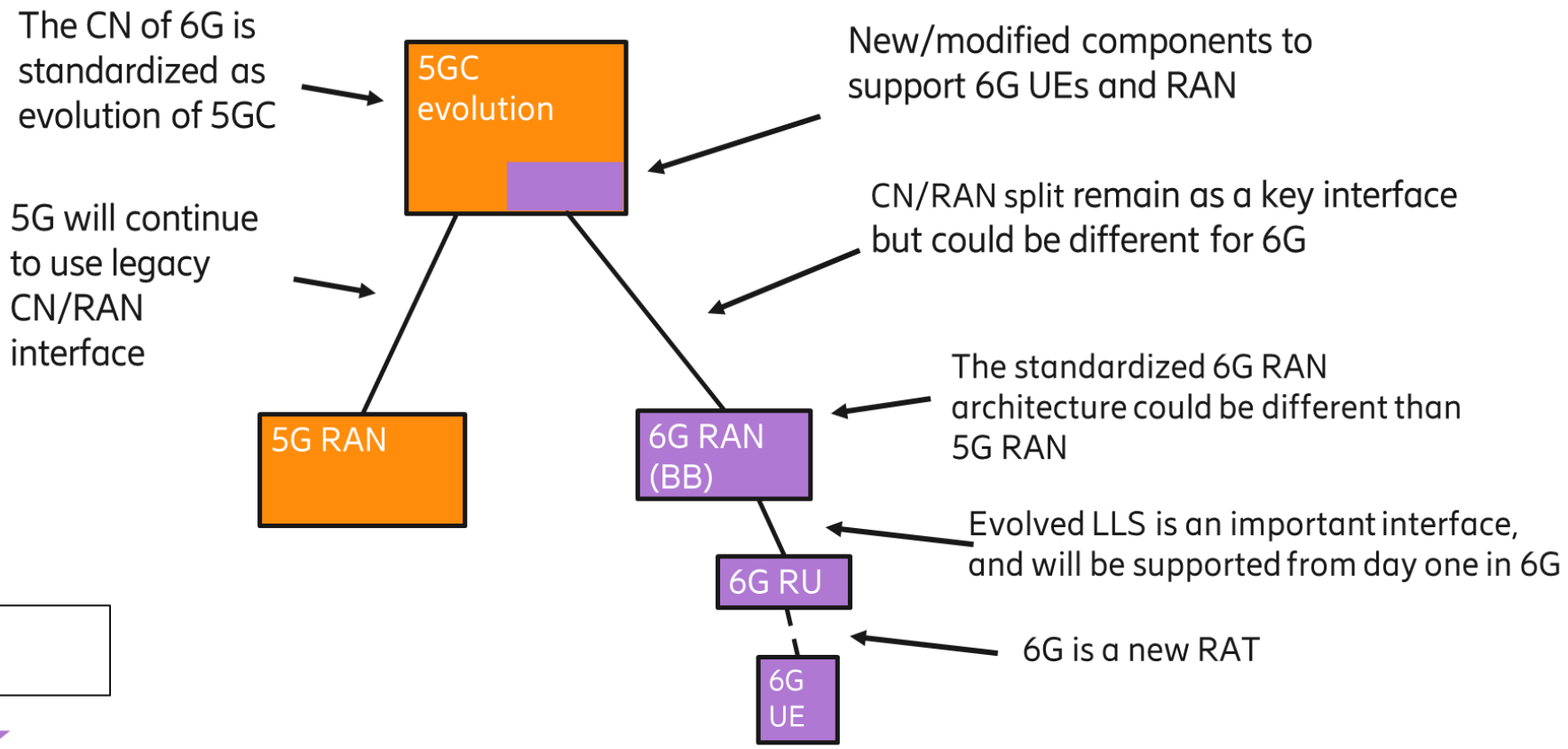
6G Vision

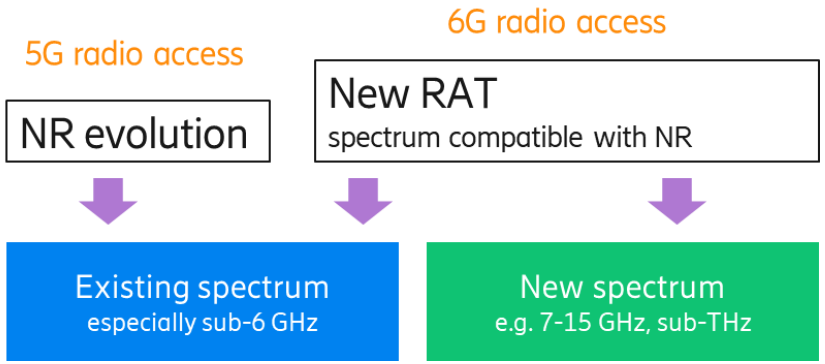
- 6G is about interactions in a cyber-physical world with humans at the center
- 6G is a sustainable, inclusive, and trustworthy platform meeting needs in society and business
- 6G enables ecosystem collaboration and delivers novel digital services



Evolution towards 6G

- A 6G RAT should support an extended spectrum range than 5G, provide open interfaces, and plug into an updated 5G CN

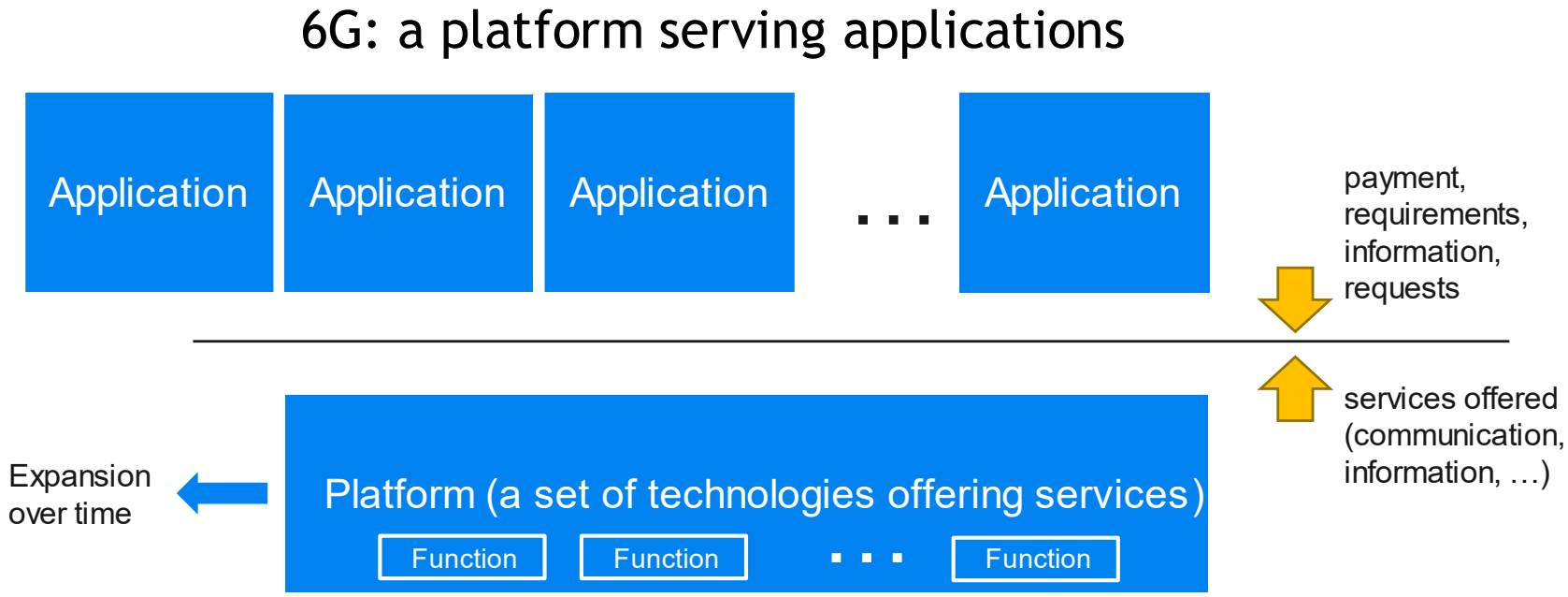




LLS = Lower layer split

6G Platform

- 6G networks should be platforms for a wide range of technologies towards a wide range of applications
- The networks should expose data through simple APIs and allow for interaction with applications



Architecture design principles for 6G End-to-End System

Principle 1
Support and exposure of 6G services and capabilities

Principle 2
Full automation and optimization

Principle 3
Flexibility to different network scenarios

Principle 4
Network Scalability

Principle 5
Resilience and availability

Principle 6
Persistent security and privacy

Principle 7
Internal interfaces are cloud optimized

Principle 8
Separation of concerns of network functions

Principle 9
Network simplification in comparison to previous generations

Principle 10
Minimizing environmental footprint and enabling sustainable networks

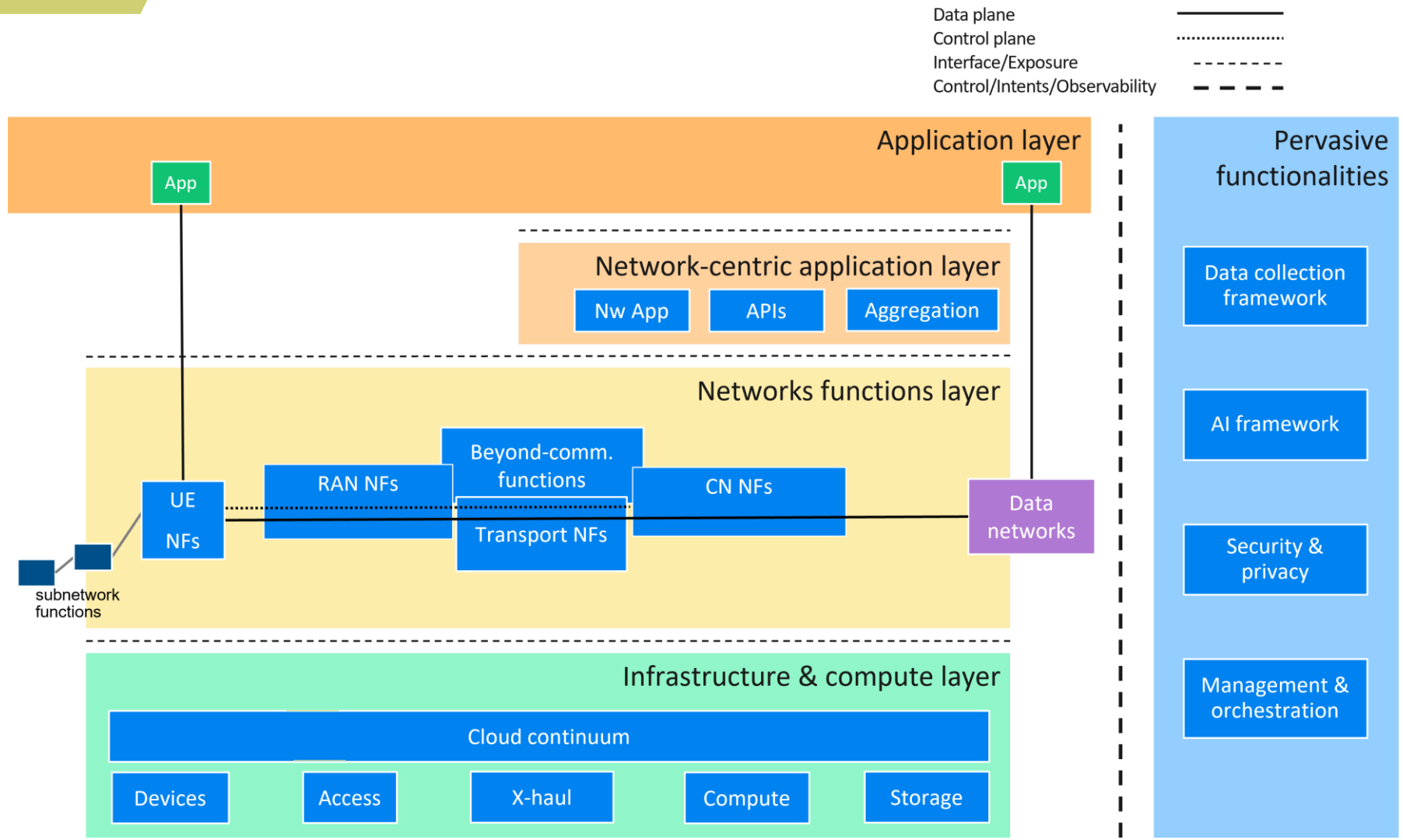
6G System Blueprint

Mapping of architectural principles on the 6G E2E system design

Architectural principle	E2E design impact	Related overarching values
1: Support and exposure of 6G services and capabilities	Generic and dynamic exposure functionality; Integration of beyond-communication network functions and HW; Pervasive AI; Compute infrastructure	Sustainability, Trustworthiness, Inclusiveness
2: Full automation and optimization	Pervasive data and analysis framework; Pervasive AI framework; Pervasive service management & orchestration	Sustainability, Trustworthiness
3: Flexibility to different topologies	Pervasive service management and orchestration; Exposure of infrastructure towards network layer to make accesses transparent; Gateway UEs; Programmable transport	Sustainability, Inclusiveness
4: Network Scalability	Pervasive service management and orchestration; Network-centric exposure layer; Transport network functions	Sustainability, Trustworthiness
5: Resilience and availability	Pervasive service management and orchestration; Pervasive data and analysis framework; Pervasive AI; RAN functions; Transport network functions; Core network functions; Subnetworks	Trustworthiness
6: Persistent security and privacy	Pervasive security and privacy framework	Trustworthiness
7: Internal interfaces are cloud optimized	Cloud native Virtual network functions; Exposure interfaces between layers	Sustainability, Trustworthiness
8: Separation of concerns of network functions	Optimized functionality in CN and RAN; Self-sustained NFs	Trustworthiness
9: Network simplification in comparison to previous generations	Avoid many standardized deployment options / protocol splits; 5GC evolution to support 6G RAN; Simplified protocol and reduced UE-NW signalling	Sustainability, Inclusiveness
10: Minimizing environmental footprint and enabling sustainable networks	E2E orchestration for energy-lean and cost-aware operation; Pervasive data and analysis framework; Modularization of network functions; Energy and cost-efficient infrastructure	Sustainability

6G System Blueprint

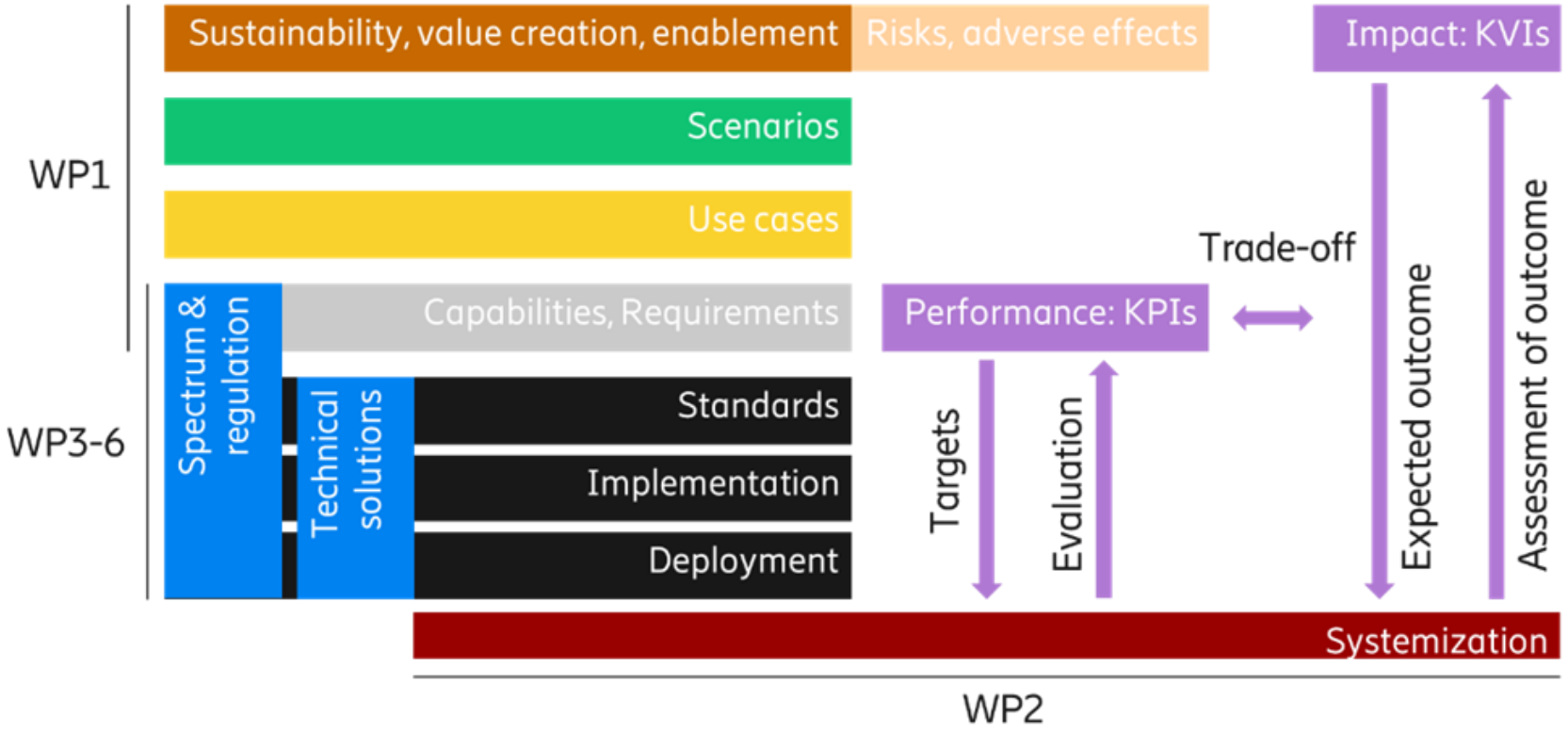
- The 6G system should provide data exposure to applications and have internal observability
- New functionalities should be incorporated into established network structures



Initial 6G E2E system blueprint

Interactive E2E system design process

- Systemization towards 6G involves studying technical components and assessing how they contribute to performance and impact
- Trade-off between targets can be important as well as managing conflicting technical solutions

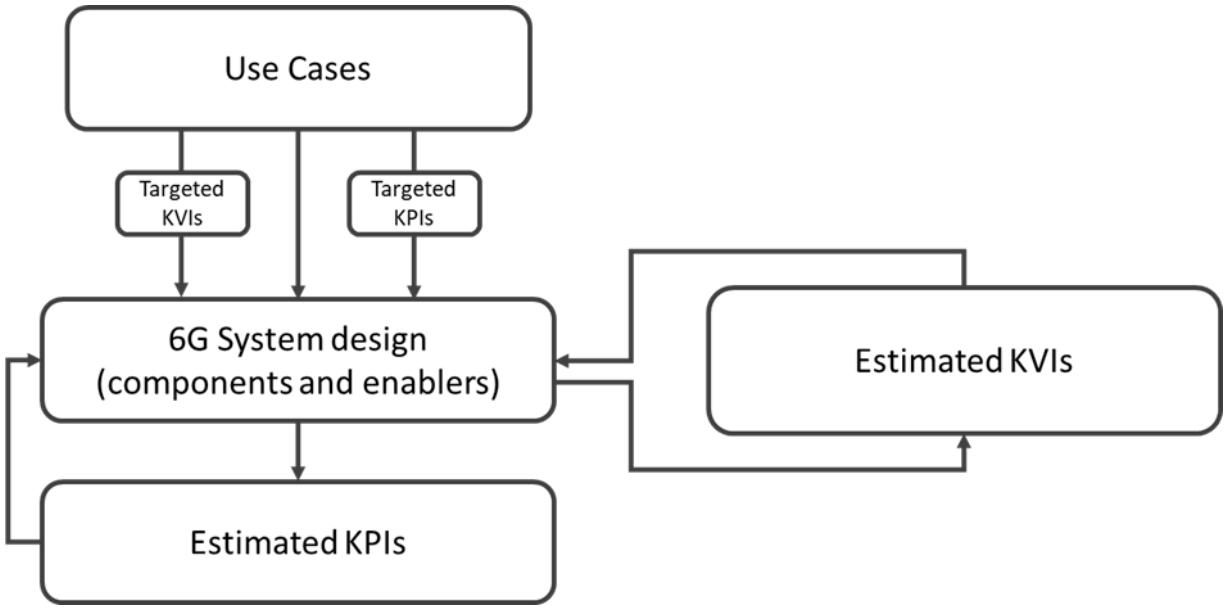


Hexa-X-II systemization process overview

E2E system design process

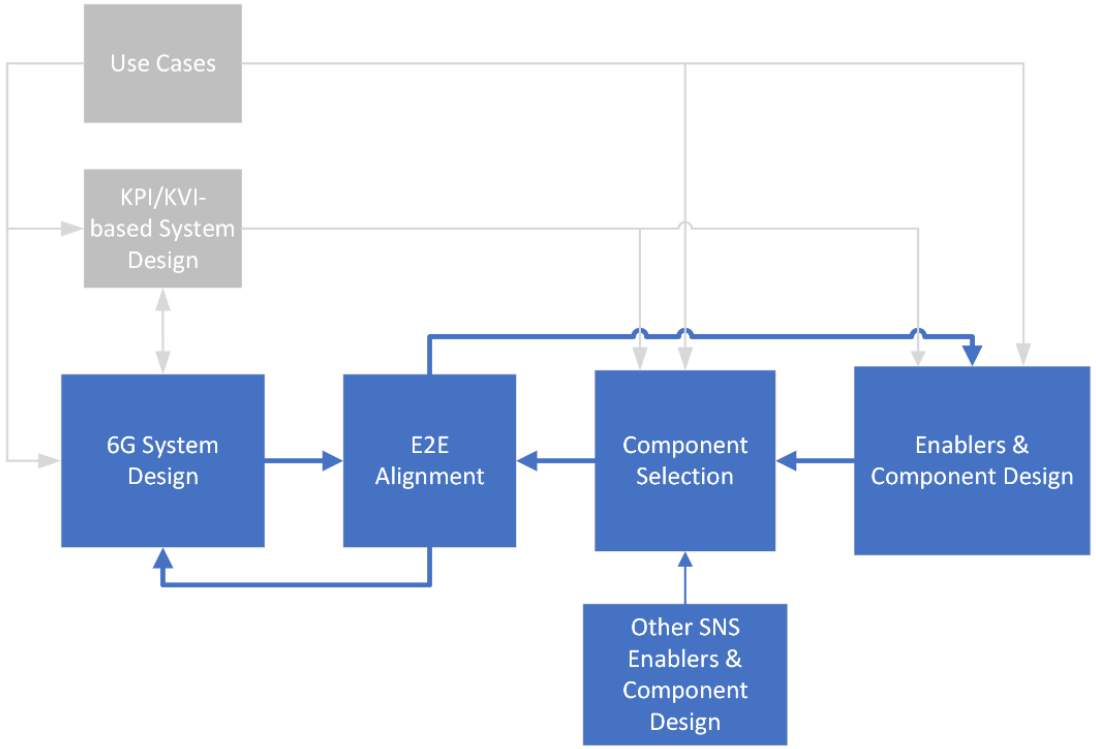
Iterative design process based on KPIs and KVIs

- Trade-offs as conformance to certain values can lead to degraded performance.



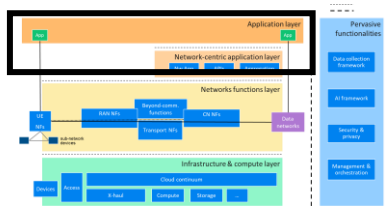
Top-down versus bottom-up alignment

- Pros and cons of each promising enabler/component/subsystem
- Aligning technical components/enablers with the E2E performance and operation targets/expectations



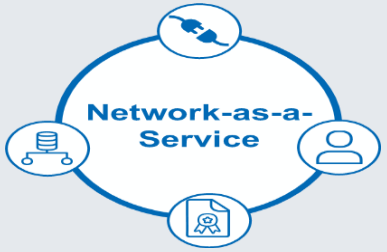
Chapter 4
Overview of 6G System Innovations

Application Layers



Impacts to and interaction with the network layer

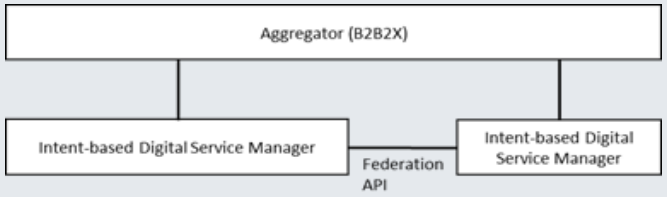
- Streamline the overall protocol stack (including network layer)
- Cross layer optimization; QoS/actionable QoE framework to include value indication; QoS for native AI services;



APIs for NaaS

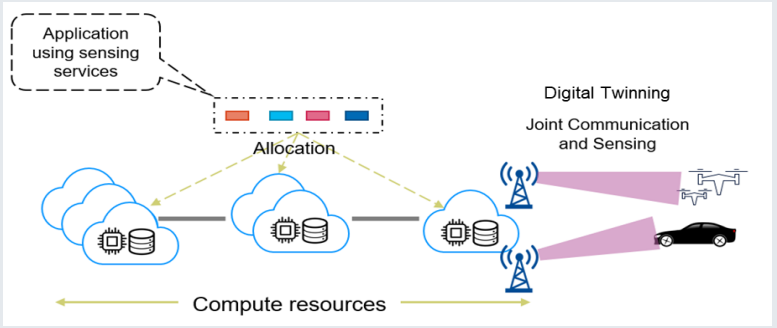
Controllable capability API exposure

- To allow transforming Hexa-X-II system into a programmable service platform for tenants (e.g., application developers, verticals, aggregators/hyperscalers) to develop new use cases and services.
- For external consumption (verticals, app developers), including monitoring (visibility) and control (configuration)



E2E service aggregation

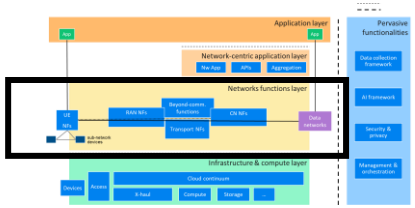
- To allow the management of 6G E2E services across multiple and different operator types and the involvement of other stakeholders such as service providers or hyperscalers.
- Federation of service providers, E2E SLAs

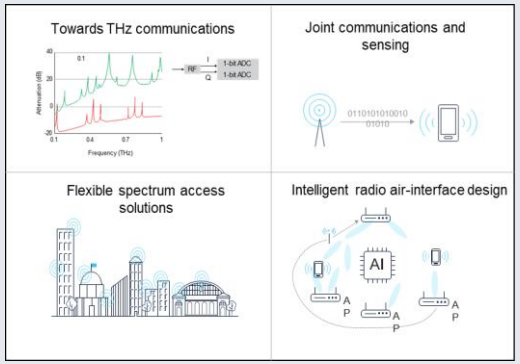


Beyond Communication Service Exposure

- Enabler for offering services leveraging sensing, synchronisation, localisation, computing (and storage)

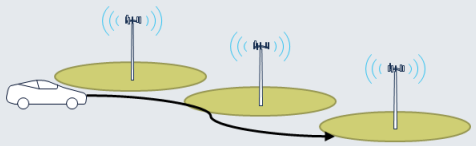
Network Function Layer





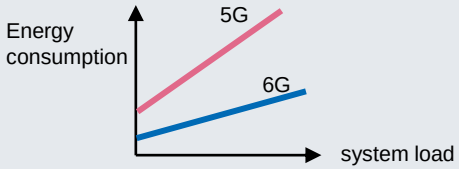
Flexible PHY radio interface and radio protocols

support & incorporate new technologies in radio (e.g, THz, sensing, D-MIMO)/cloud/AI, optimization based on learnings in previous generations



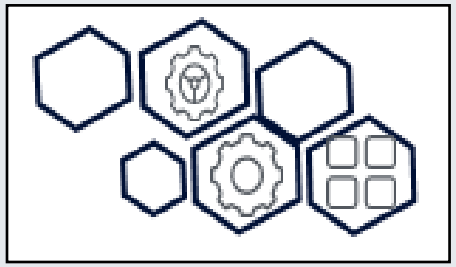
Optimized and harmonized mobility procedure

To consider below enablers: conditional handover, layer-1/layer-2 triggered mobility, beam managements in high frequency, D-MIMO, AI/ML



Energy efficient RAN design

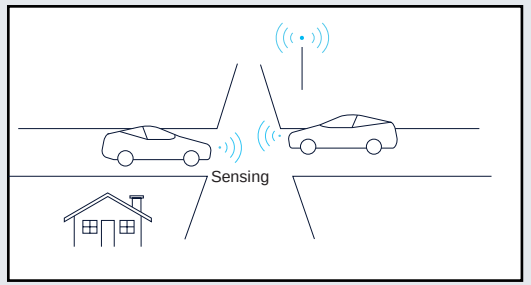
scale energy consumption with system load and reduce absolute energy consumption: component level design, solution design at RAN/UE, network deployment



Modularized network functions

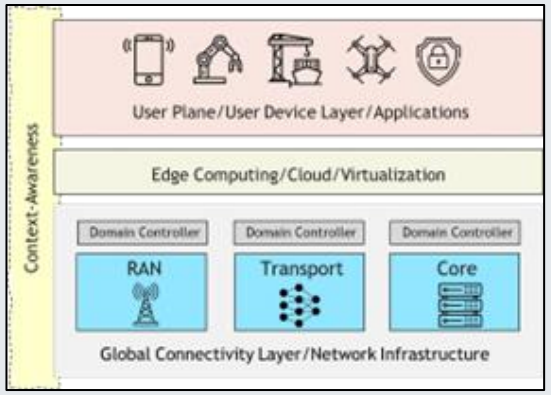
(RAN & Core)

- To add new modules to ensure operational effectiveness and interoperability



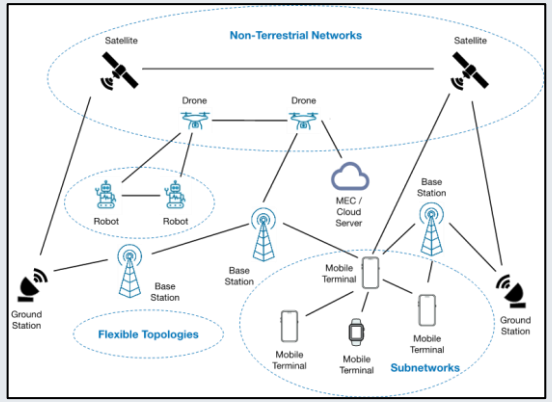
Beyond communication

interfaces, protocols & NF supporting sensing, computing, offloading



Context awareness management

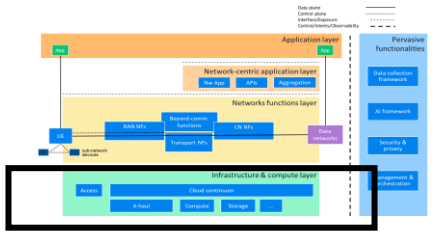
- To enable efficient support of the modular and flexible networks.
- To enable the network to optimize the E2E connection spanning over application, edge computing, RAN, CN, and Transport network

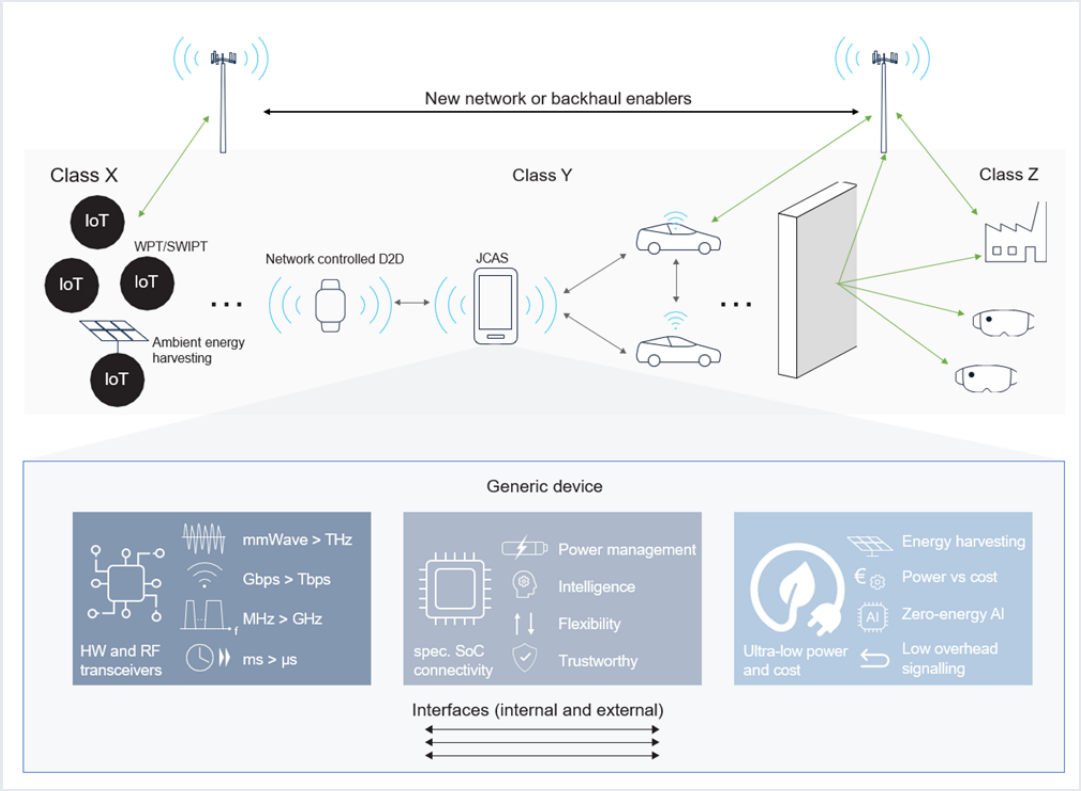


New access & topologies

(sub-networks, NTNs, mesh networks, D2D…)

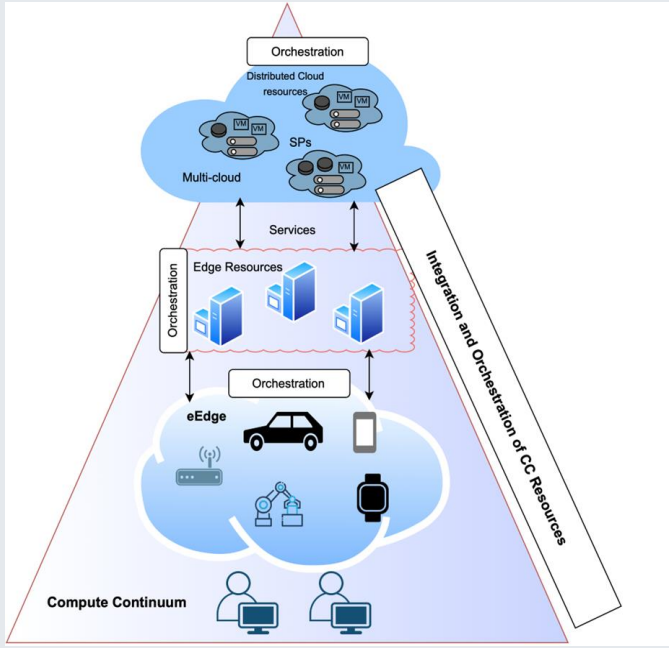
Infrastructure & Compute Layer





Future device & flexible infrastructure

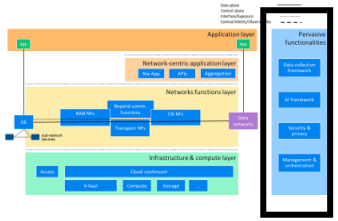
- New device types/classes identification
- Evolved hardware implementations of 6G transceivers
- Evolved specialized system-on-chip (SoC) connectivity for specific 6G applications
- Designing energy/material/cost-aware devices

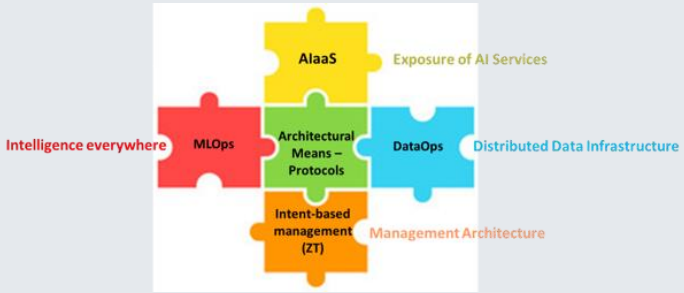


Integration and orchestration of computing continuum (CC) resources

Transformation of cloud to integrate edge and end-user devices into a compute continuum which is supported by a softwarized network contimuum.

Pervasive functionalities



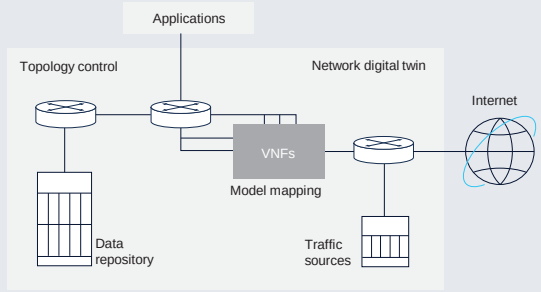


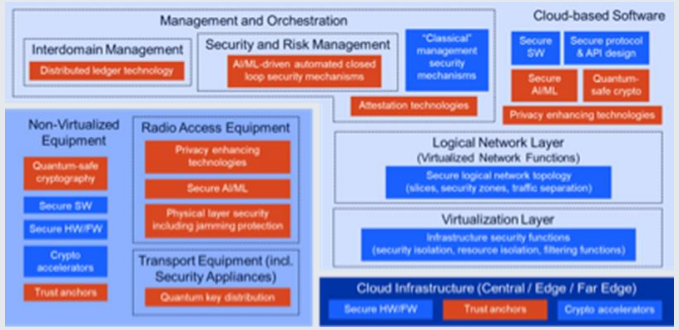
Data collection frameworks

- To effectively manage distributed applications and services that need transition from traditional monitoring tools to modern cloud-native observability tools.
- E.g., Network Tomography for network monitoring

AI frameworks

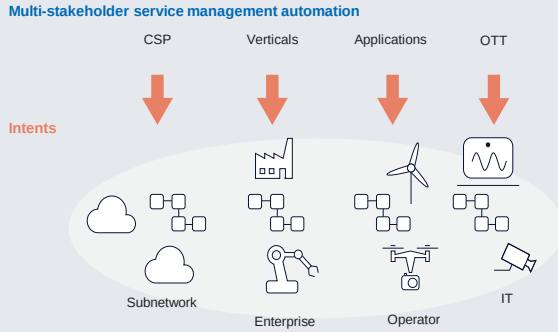
- To empower 6G with data-driven architecture that supports distributed intelligence and distributed AI platform.
- To allow AI for communication and beyond communication purposes

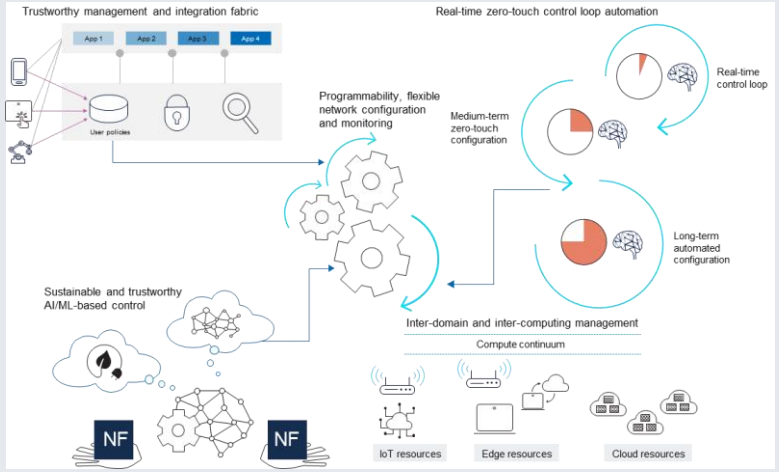




Security & privacy

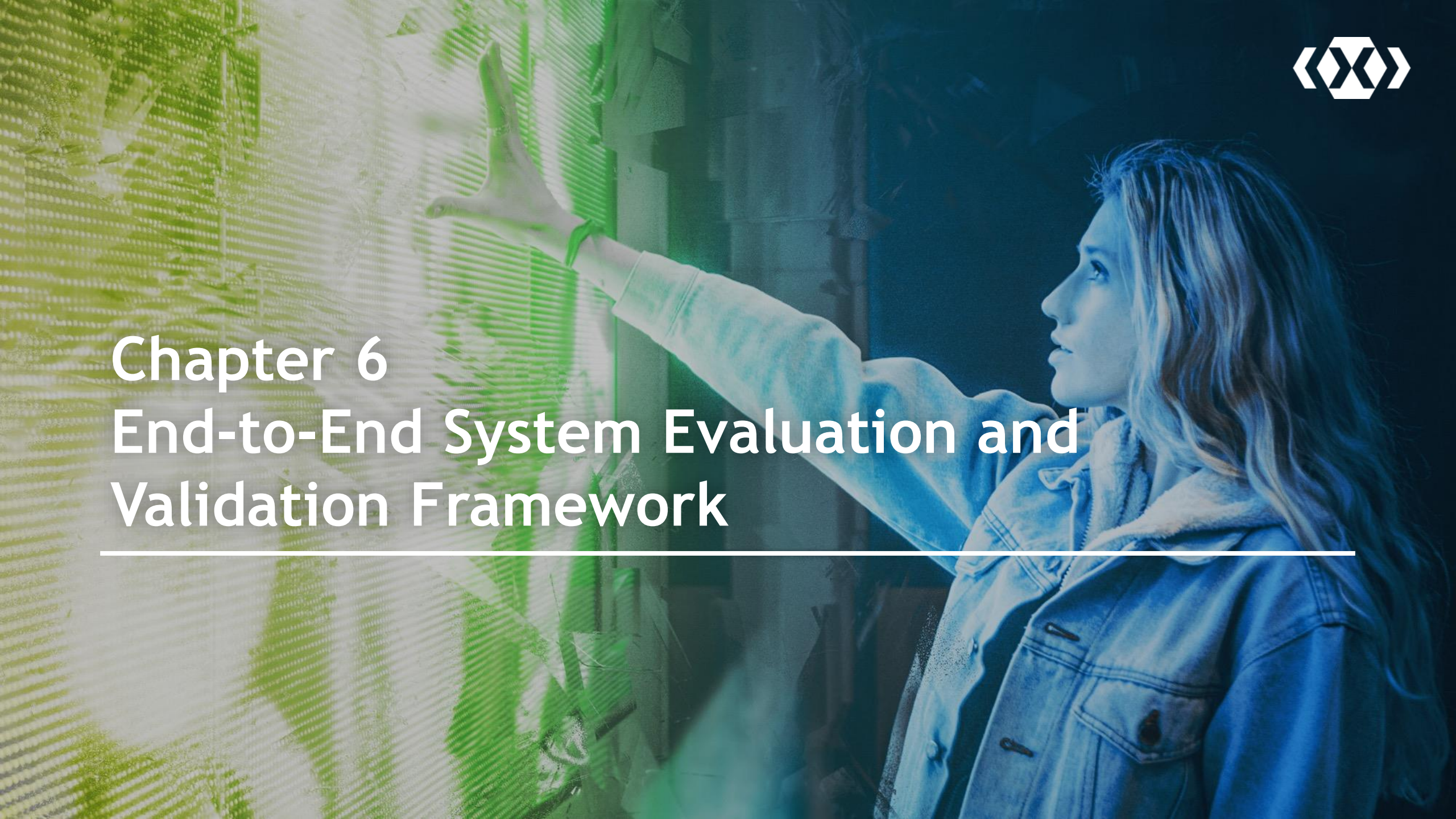
- To identify 6G threat landscape.
- To use Network Digital Twin framework for system-level for security, privacy and sytem resilience validation framework
- To leverage novel security/privacy technologies e.g., AI, quantum-safe crypto, DLT, attestation, context awareness





Management & orchestration

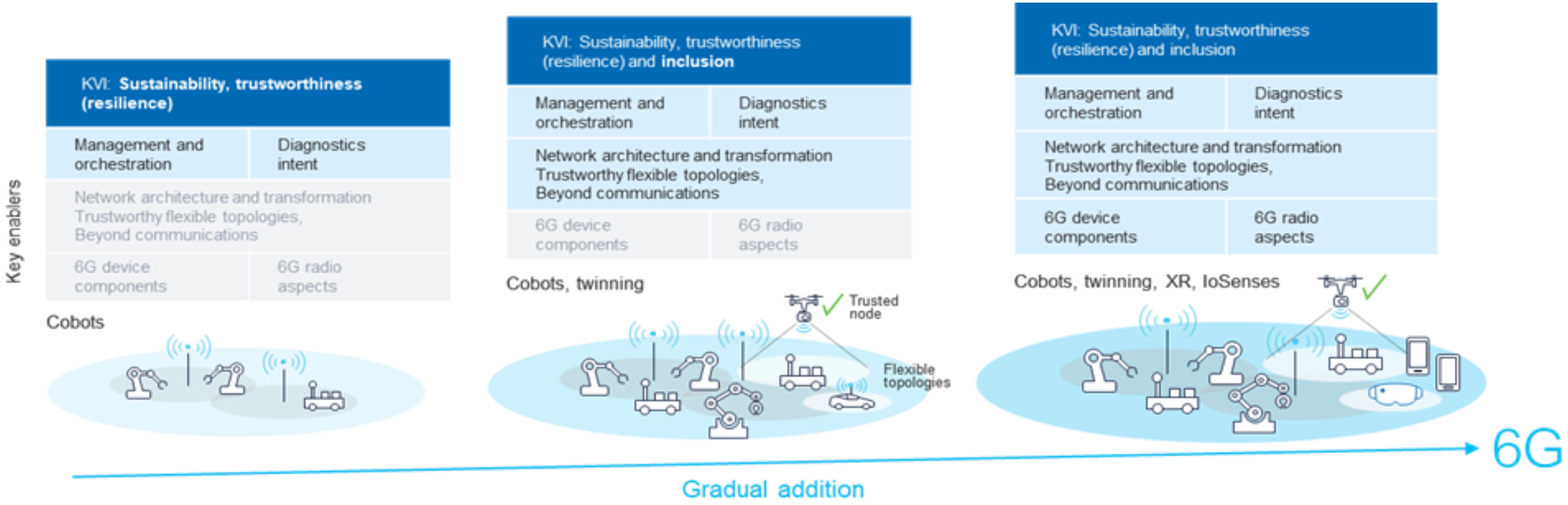
- To provide the appropriate levels of programmability, flexibility, scalability, and reliability in 6G networks.
- Innovations: M&O for 6G network automation, AI/ML for M&O, intent based management, inter-domain network management



Chapter 6
End-to-End System Evaluation and Validation Framework

Overview of the E2E system evaluation and validation framework

The project will develop 3 System PoCs which will evolve gradually as illustrated.



System PoC A focuses on aspects for demonstrating management mechanisms.

System PoC B focuses on network architecture elements and refinements of management.

System PoC C focuses on radio and devices aspects.

System-PoC A: Sustainability and trustworthy-oriented orchestration

Intent for NaaS delivery

Intents

Intent-based conflict resolution

Multi-platform resource orchestration

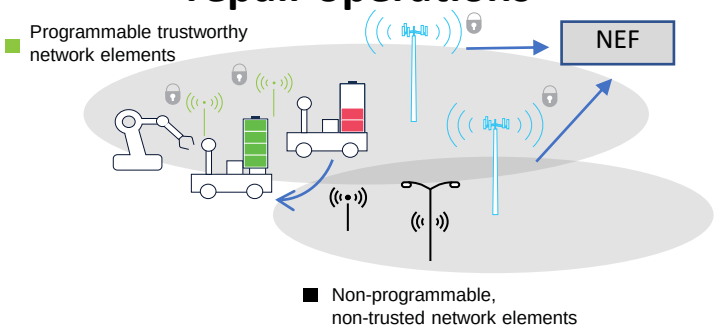
Heterogeneous platforms
(e.g., K8s, MicroK8s, K3s, OpenStack, etc.)

Extreme Edge | Edge | Cloud

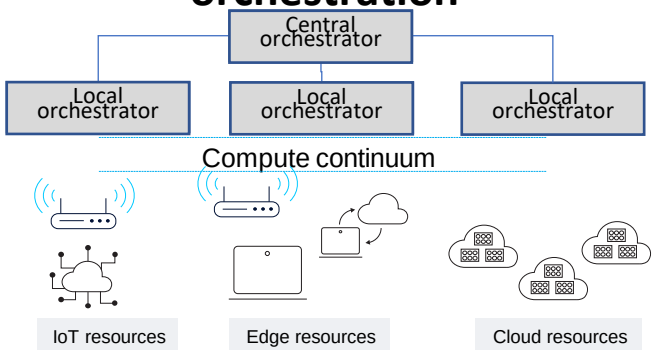
Compute Continuum

Monitoring

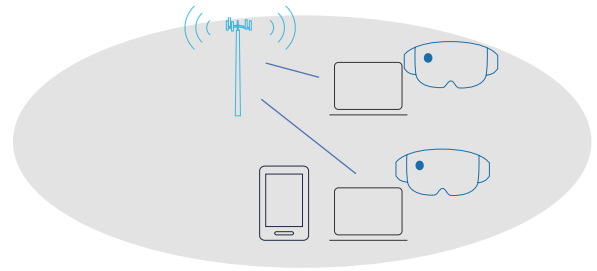
Resilience through autonomous repair operations



Repairs through multi-domain orchestration



Remote repairing through XR



System-PoC A: Functional components

Cobots:

Collaborative robots that can be deployed to maintain, inspect and repair various components of smart networks, themselves included.

XR

A range of technologies that enable users to experience a digitally enhanced version of reality. XR can be employed to manage and optimize the performance of a smart network, i.e., visualization, remote monitoring and control, training and simulation and collaboration.

Multi-platform Resource Orchestrator

Various management and orchestration frameworks will be considered including frameworks applicable to the various parts of the computing continuum, frameworks that focus on network services provision, 6G applications provision, as well as frameworks that tackle the interplay between network and application providers.

Intent Based Mechanisms

Intent will be used as a solution to deliver NaaS, enabling the integration of Hexa-X-II managed resources and 3rd party applications, with direct and open interactions between them. Intent-based conflict resolution will also be considered.

System-PoC A :KVIs & KPIs

KVIs

Sustainability

Trustworthiness

KPIs

Reliability
It refers to the percentage of time that the network is available and functioning correctly. High network reliability is required to minimize disruptions to service and prevent lost revenue.

Latency
It measures the time it takes for data to travel between two points in the network. In the context of 6G, low latency is crucial for applications that require real-time interactions, such as virtual reality, telemedicine, and autonomous vehicles.

Provisioning Time
It measures the time taken to enforce a provisioning request of a managed entity to the underlying infrastructure.

Termination Time
Time to terminate a managed entity from the termination request up to the release of its assigned resources.

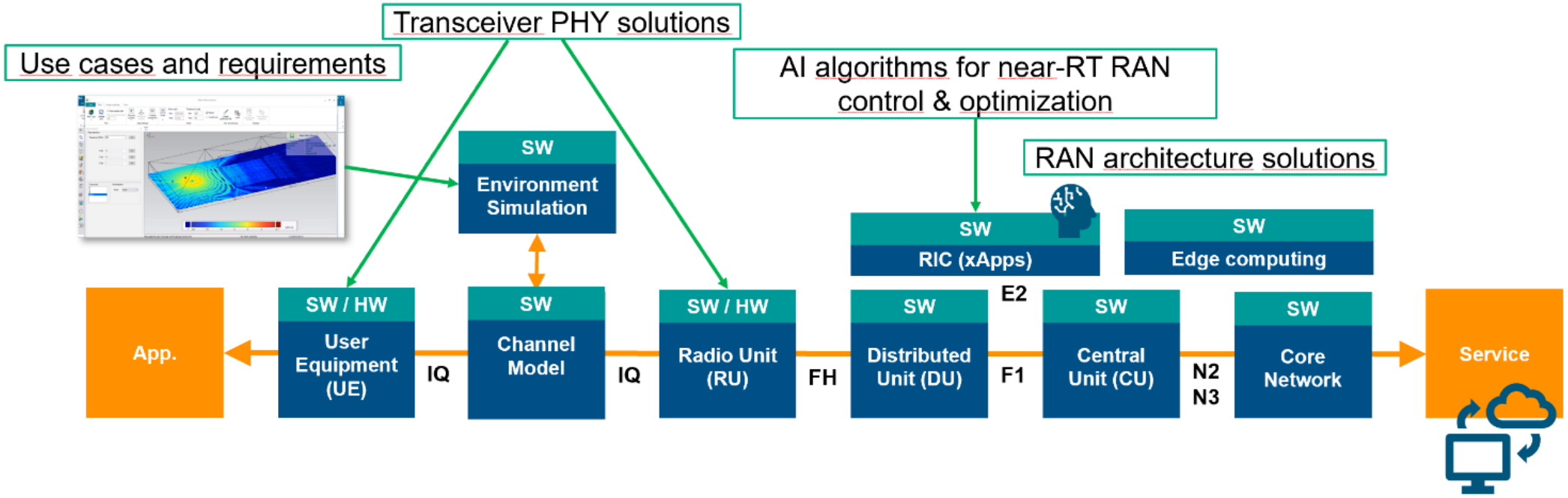
Recovery Time
It provides a measure of the reactiveness of the network in minimizing service downtime.

Intent Deployment Latency
Time to have a complete E2E intent-based service request properly deployed and available to be used by for the final user.

Simulation based approach with network digital twin

Network Digital Twin-oriented approach for connectivity:

- Digital twinning will be used to evaluate the communication performance in selected use case(s) to support the validation performed by implemented PoCs.



HEXA-X-II.EU //

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.