6G series workshop from Hexa-X-II

Hexa-X-II Foundation of overall 6G system design

13 February 2023

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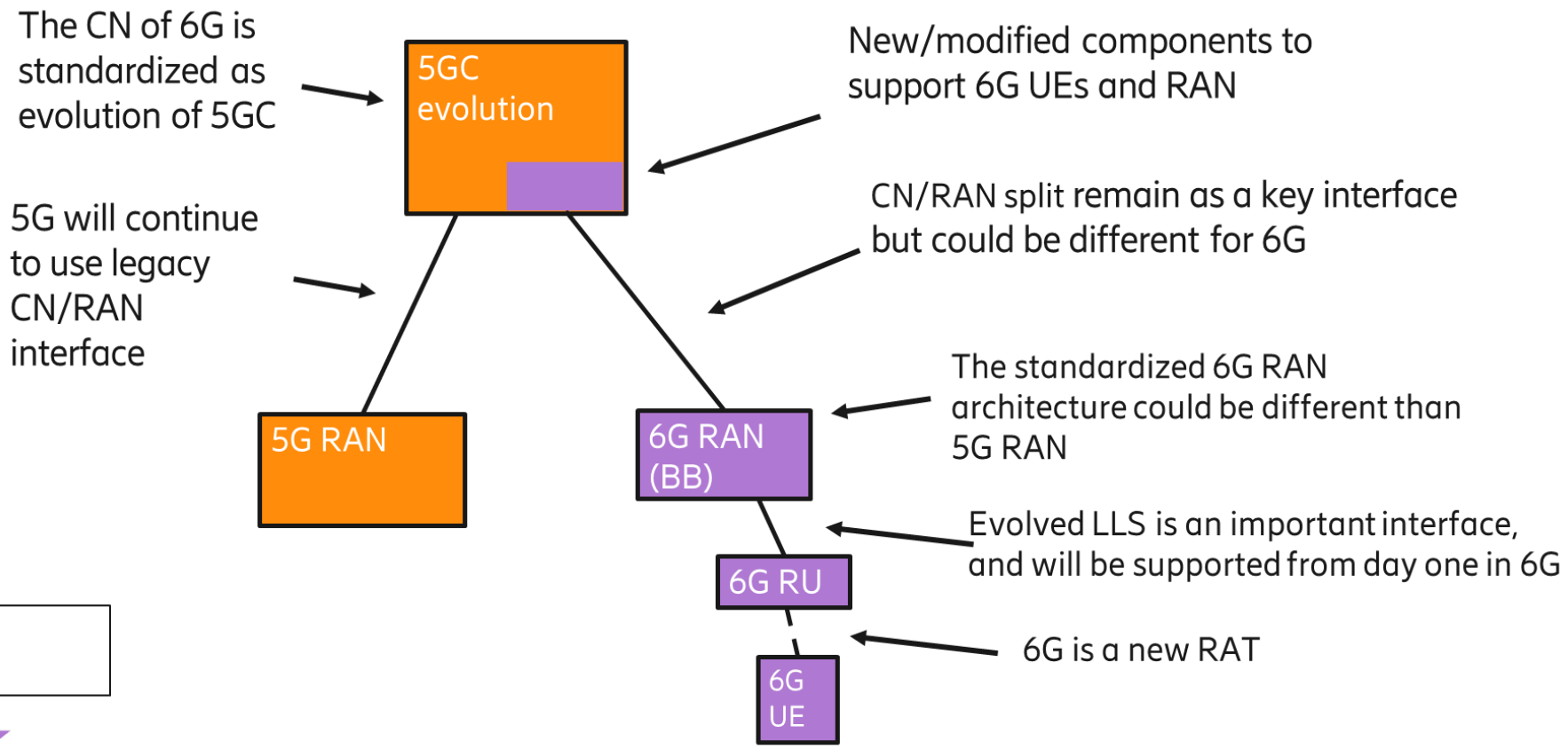
Hexa-X-II

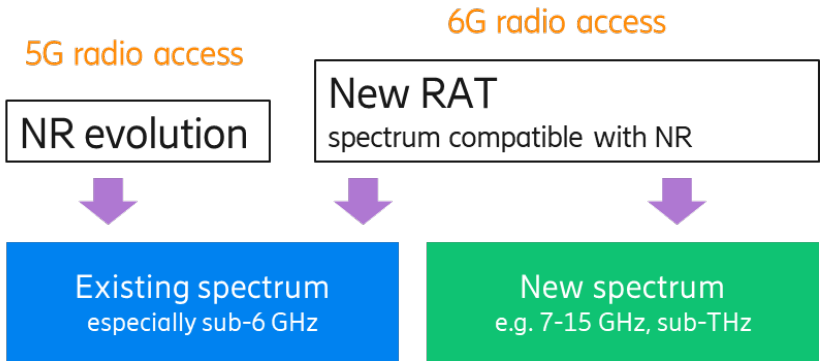
hexa-x-ii.eu

Evolution to 6G E2E system

Evolution towards 6G

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

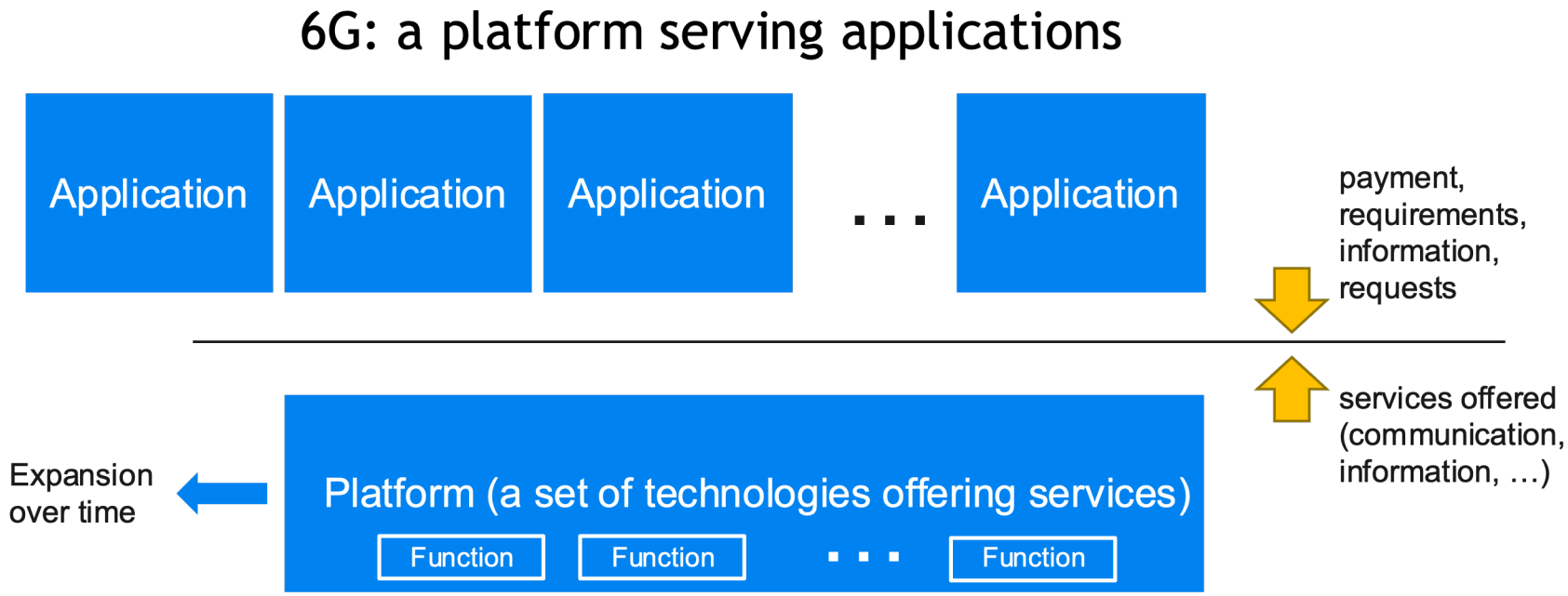




LLS = Lower layer split

6G: A platform serving applications

- 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



6G Design Principles & system requirements

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

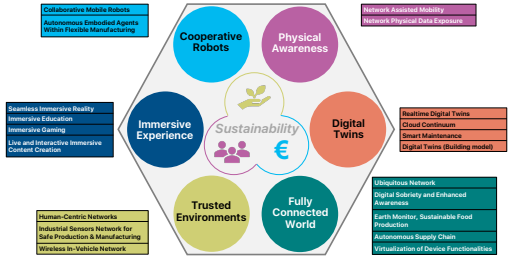
Principle 1 Support and exposure of 6G services and capabilities	Principle 2 Full automation and optimization	Principle 3 Flexibility to different network scenarios	Principle 4 Network Scalability
Principle 5 Resilience and availability	Principle 6 Persistent security and privacy	Principle 7 Internal 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		

Ten 6G design principles

- Impacting 6G E2E system blueprint design
- Achieving the 6G key values realization of environmental, social and economical sustainability.

6G System Requirements (initial)

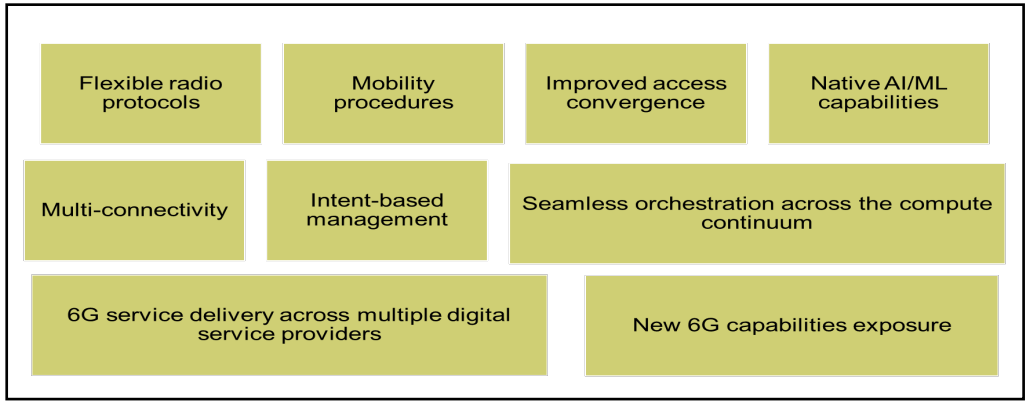
- ✓ Capabilities of the system in terms of what it should do and relevant to a selected list of 6G use cases.



Hexa-X-II 6G use-cases (source Hexa-X-II D1.2)

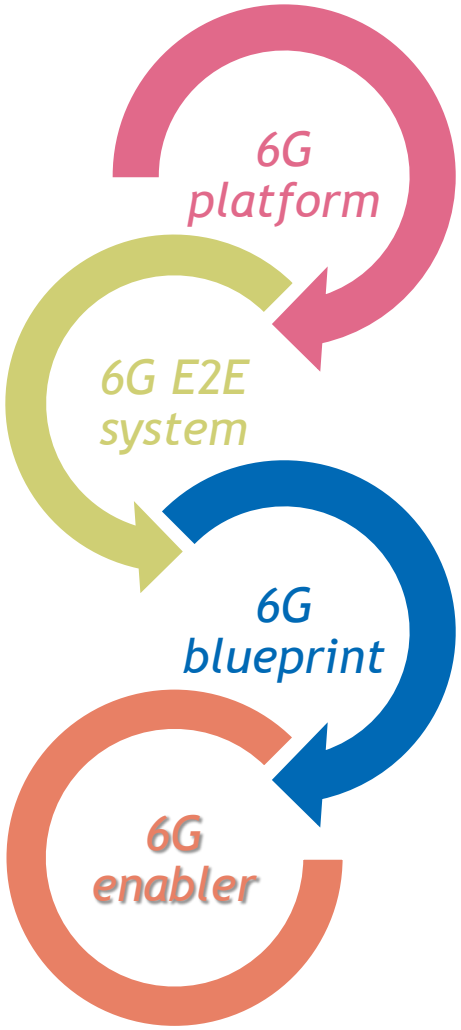
- ✓ A set of operational requirements which will not be directly visible to end-users, but provide functionality to efficiently fulfill use case requirements for operators

Requirements\Use case	Ubiquitous Network	Real-time digital twin	Seamless Immersive Reality	Cooperating mobile robots	Human centric services	Network assisted mobility
Ubiquitous connectivity	X	X		X	X	X
Indoor coverage	X	X	X	X	X	
Extreme connectivity (high bitrate)			X			
Mobility support	X		X	X	X	X
Pervasive AI/ML		X	X	X	X	X
Efficient sleep states	X		X		X	X
Compute as a Service		X	X	X		X
Intent-based interfaces		X		X		
Reliability		X		X	X	X
Positioning/sensing		X	X	X	X	X
Ultra-low-cost	X					
Energy neutral	X					
Predictable low-latency E2E communication		X	X	X		X
Security/Privacy	X	X	X	X	X	X
Resilience	X	X		X		X
Service continuity	X		X			X



E2E design

Hexa-X-II 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.
- Any technical asset that makes it possible to realize or enhance a 6G capability.

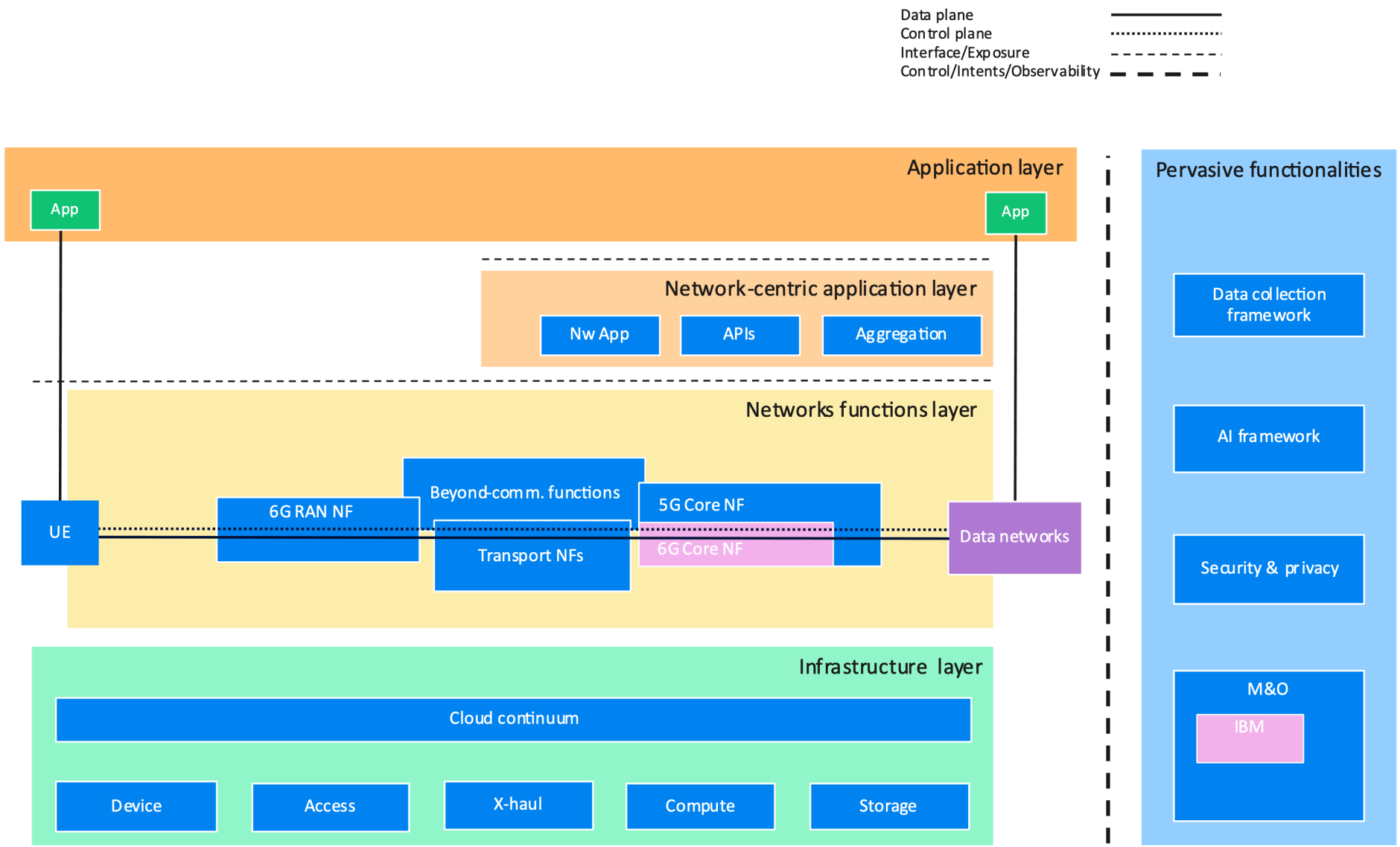
  A 6G enabler is recursive, e.g. 6G system enables new use cases, 6G radio is an enabler of 6G system to achieve system requirements. 6G enablers can be further classified into different types that are extensible, e.g. architecture, system component, process, algorithms, etc

6G E2E system – 6G blueprint

Foundation of the E2E 6G system architecture

- The 6G system should provide services and data exposure to E2E applications – covering new and existing capabilities
- New functionalities should be incorporated into established network structures

Completed with specific views to capture the holistic system, e.g. management and orchestration views, etc.



From 6G enablers to 6G system design?

AI enablers for data-driven architecture

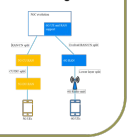
ML orchestration

Intent-based management

Network modularization

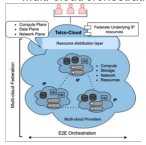
Streamlined NW function

Network migration



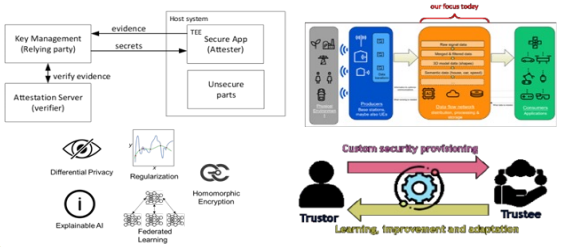
Virtualization and cloud transformation

Multi-cloud orchestration



Integration and orchestration of computing continuum resources

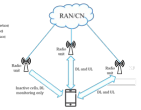
Security, privacy and E2E resilience



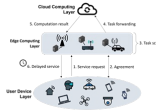
New access and flexible topologies

Network of networks

6G Multi-connectivity



Context aware transport

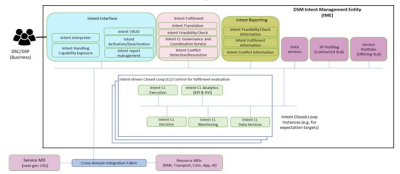


Networks beyond communications

JCAS

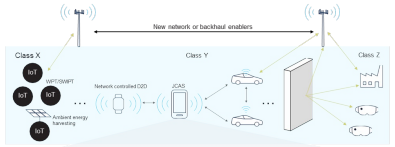
Dynamic device offloading

Intent-based service management automation enablers



Systemization towards 6G involves studying technical components and assessing how they contribute to performance and impact

Future devices and flexible infrastructure



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

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

Trustworthy SoC design, specialized AI/DSP accelerators

15.2.2024

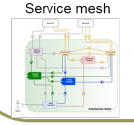
nable flexible network configuration

#1 Programmable flexible network configuration

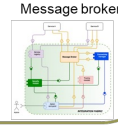
#2 Programmable network monitoring and telemetry

#3 Integration fabric

Service mesh



Message broker

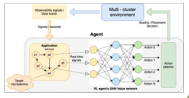


Management mechanisms

#4 Trustworthy 3rd party management

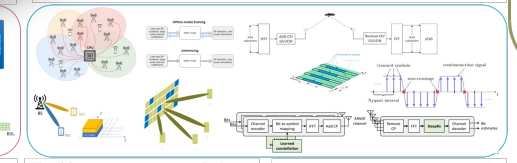
#5 Multi-cloud management mechanisms

#6 Orchestration mechanism for computing continuum

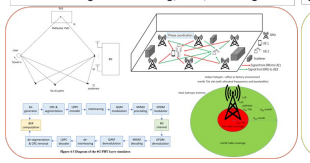


Architecture and deployment: Transceiver, MU-MIMO, D-MIMO, RIS, JCAS, TN/NTN

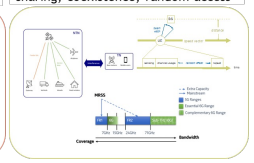
Signal processing and algorithms: Waveform, modulation, coding, radio resource allocation, AI-air interface for CSI prediction, precoding, PA post compensation, ...



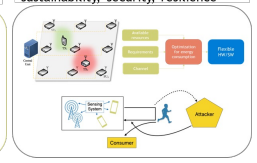
Radio link modelling: Channel modelling, Link-level signal modelling, EMF, coverage



Flexible spectrum access solutions: sharing, coexistence, random access

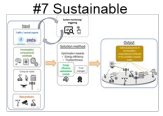


KVIs focused solutions: sustainability, security, resilience

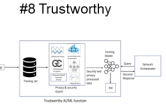


Sustainable AI/ML-based control

#7 Sustainable



#8 Trustworthy

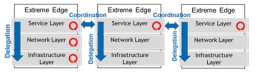


Zero-touch

#9 Network Digital Twin

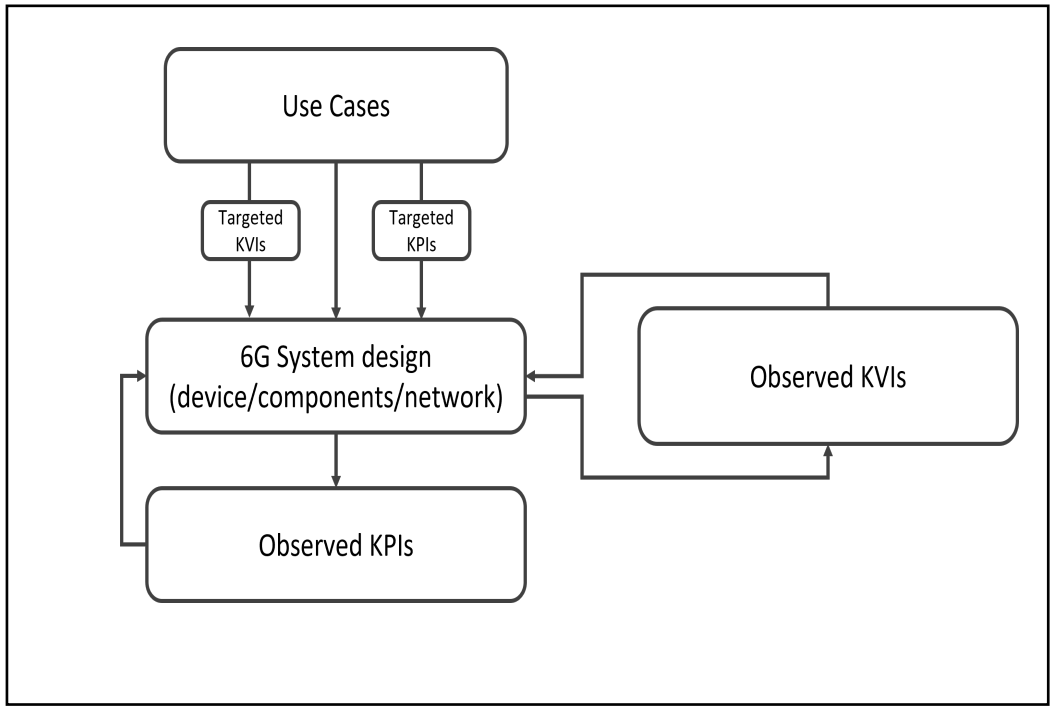
#10 Closed loop governance

#11 Coordination of multiple closed loops



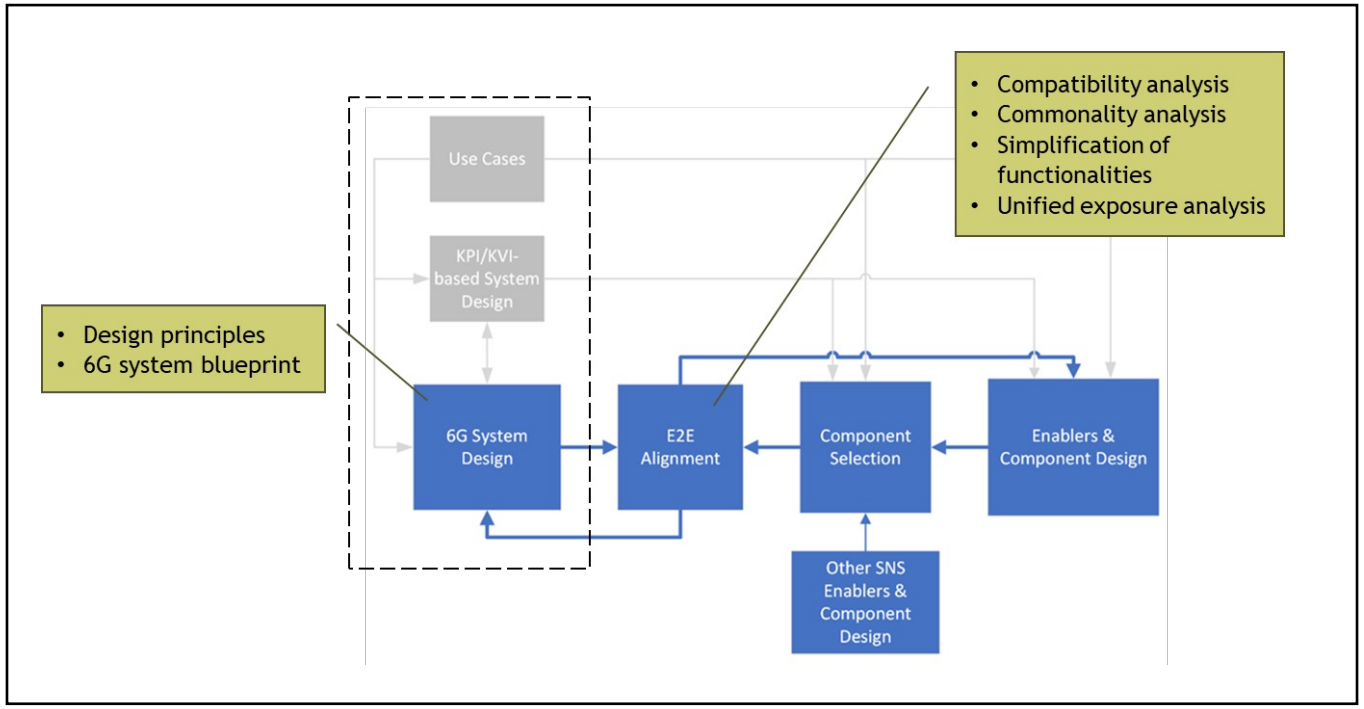
Iterative system design process

1 KPIs/KVIs-based design iterative sub-process



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

2 Top-down versus bottom-up alignment iterative sub-process



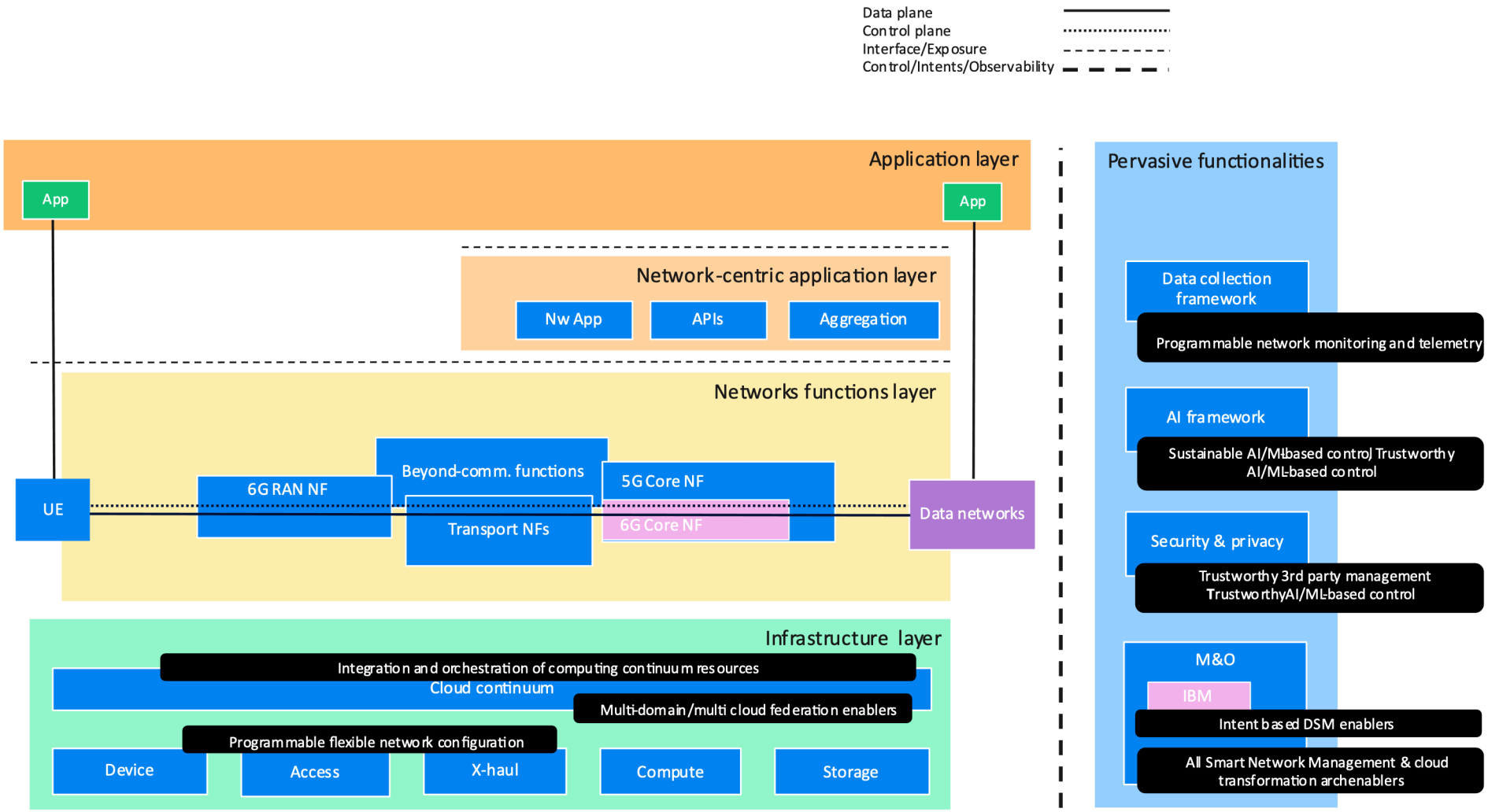
- Pros and cons of each promising enabler/component/subsystem
- Aligning technical components/enablers with the E2E performance and operation targets/expectations

Analysis of Hexa-X-II enablers for integration in E2E system

Key criteria for enabler integration in E2E system

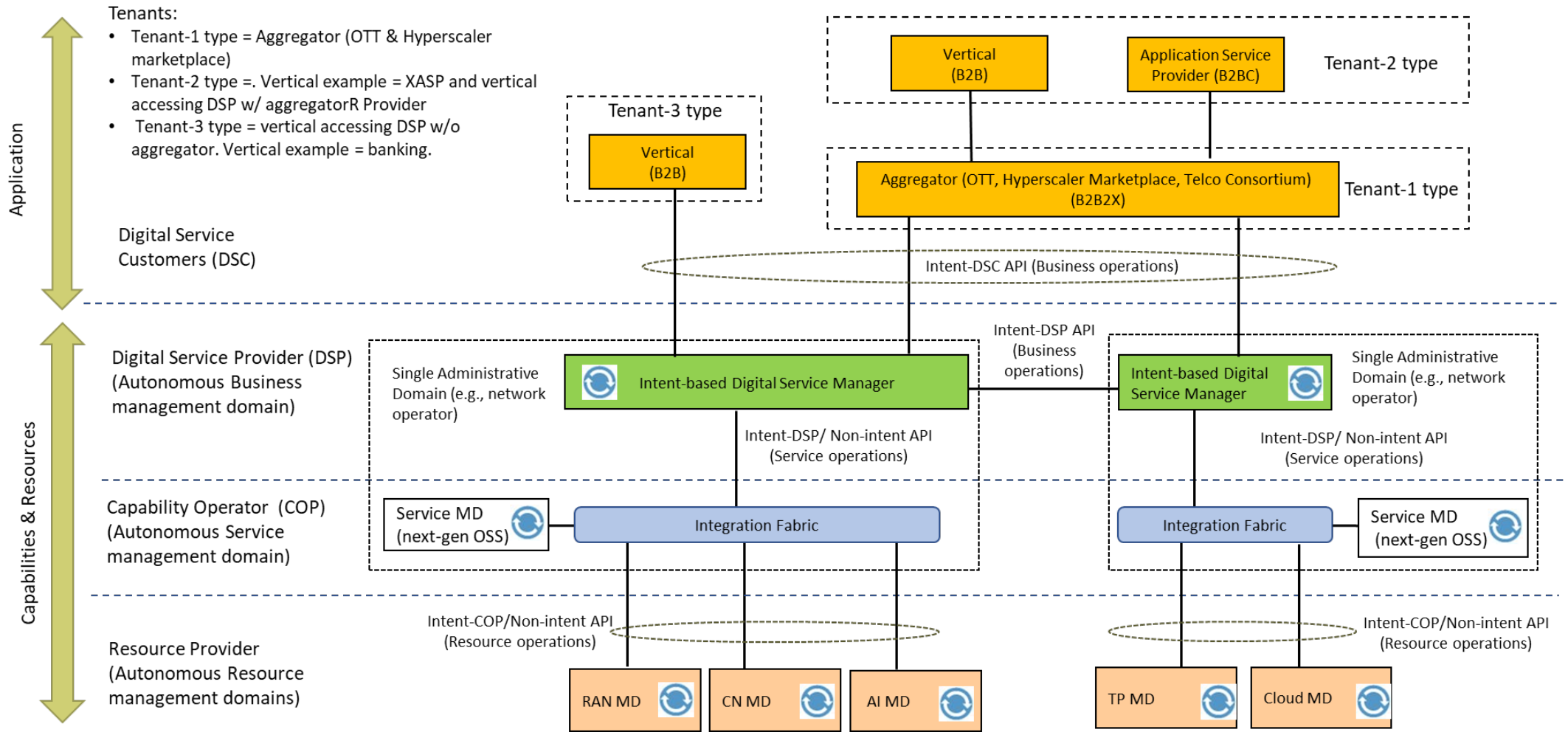
- ❑ Relevance and significance of enabler towards E2E system design
- ❑ Impact of the enabler on the E2E system design
- ❑ How the enabler fits with the system design principles
- ❑ Feasibility (estimation) of enabler vs migration options
- ❑ Dependency with other enablers
- ❑ Any proposed updates to E2E system design and architecture design principles
- ❑ Network performance, security/privacy, flexibility, resilience/robustness, and sustainability/energy efficiency

Mapping of management and orchestration enablers in E2E system blueprint



Representations the set of enablers analyzed in the first iteration that are part of the M&O view of the 6G E2E system blueprint.

Early M&O specific view



- A "TechCo" framework embraces new services beyond traditional connectivity, with a focus on digital and application-centric services resulting from an innovation ecosystem leveraging frictionless interactions between network and 3rd party application providers.

System Proof of Concepts

Three System-PoCs validating the system design and demonstrating the feasibility of achieving targeting 6G KPIs and KVIs.

Sustainability Aspects

Key enablers

Social	Environmental	Economic
Trustworthiness; Time related KPIs	Energy efficiency / Power consumption	Resilience / limited downtime; OPEX

Management and orchestration | Diagnostics intent

Network architecture and transformation
Trustworthy flexible topologies,
Beyond communications

6G device components | 6G radio aspects

Cobots

System PoC A

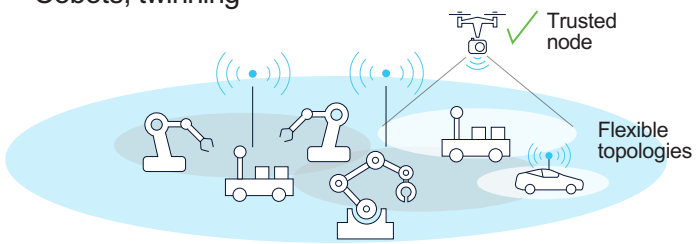
Social	Environmental	Economic
Trustworthiness; Exposure, security / privacy; Digital inclusion	Energy efficiency / Power consumption	Resilience / Limited downtime; OPEX; CAPEX

Management and orchestration | Diagnostics intent

Network architecture and transformation
Trustworthy flexible topologies,
Beyond communications

6G device components | 6G radio aspects

Cobots, twinning



System PoC B

Social	Environmental	Economic
Trustworthiness; Exposure, security / privacy; Digital inclusion	Energy efficient radio, zero-energy devices	Resilience / Limited downtime; OPEX; CAPEX

Management and orchestration | Diagnostics intent

Network architecture and transformation
Trustworthy flexible topologies,
Beyond communications

6G device components | 6G radio aspects

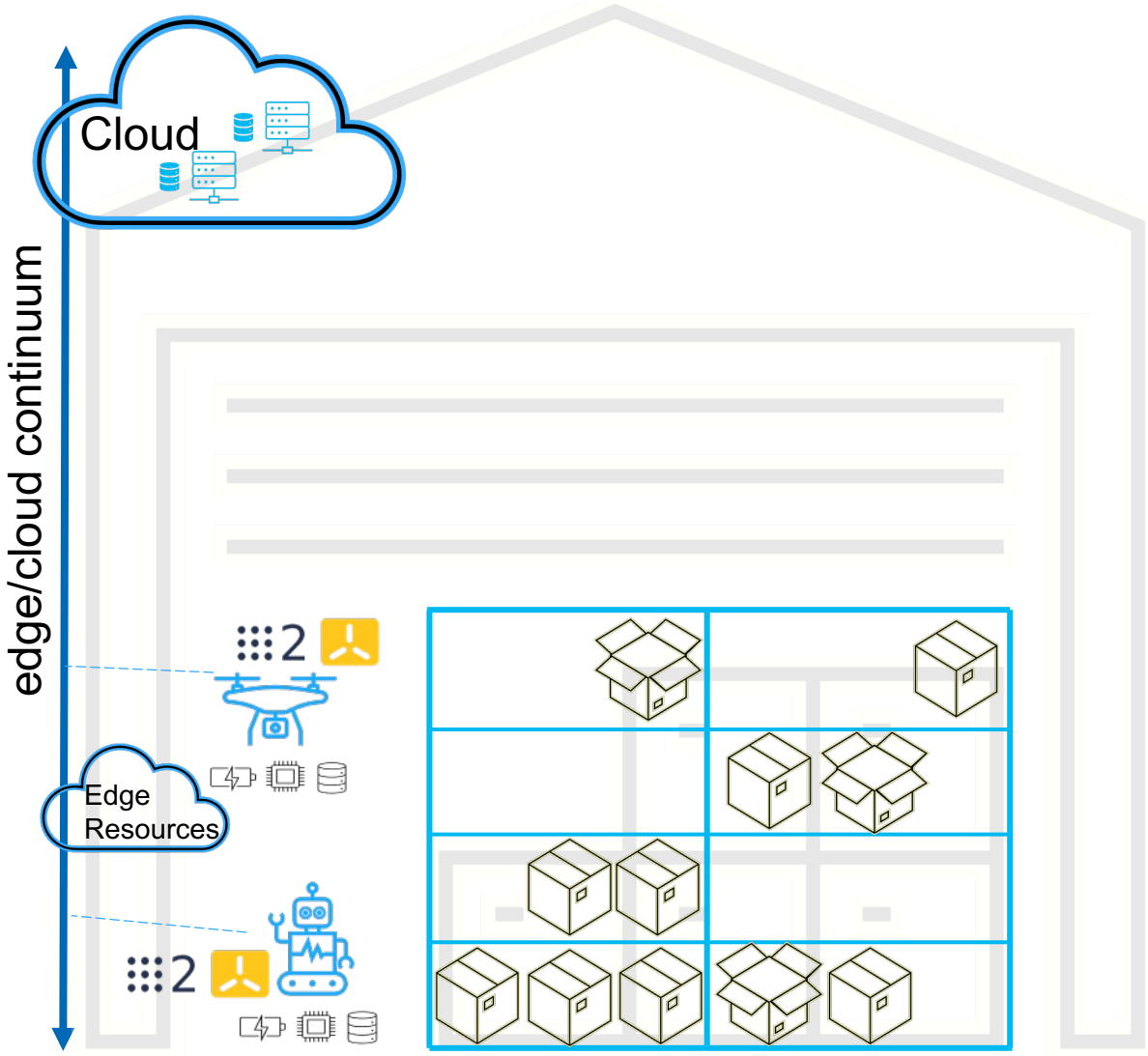
Cobots, twinning, XR, IoSenses

System PoC C

Gradual addition → 6G

Preliminary results of System-PoC A in D2.2

PoC A - Warehouse Inventory Management



Advanced Features for Applications:

- Cobots (autonomous robots, UAVs, human in the loo), Massive Twinning, XR

Social Considerations

- Sustainability (Environmental and other perspectives), Inclusion, Trustworthiness

Scenario

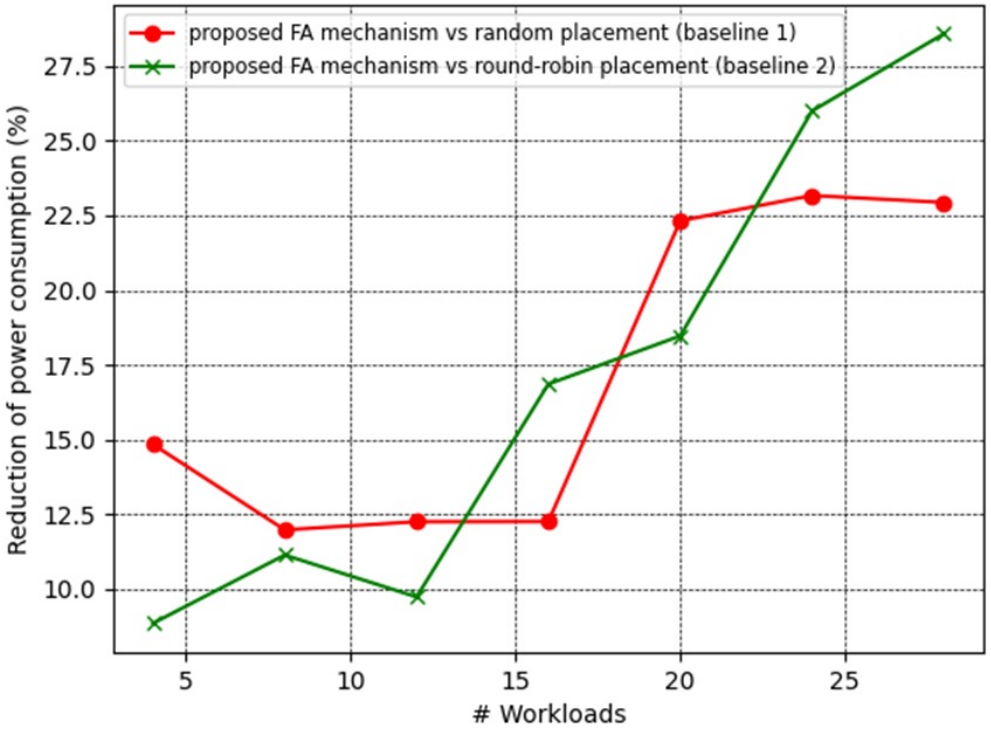
- Intent: area to be covered
- Task allocation: devices to sub-areas
- Functionality deployment
- Task realization through cooperation of devices and humans.

Requirements for next generation:

- Extreme connectivity: latency, bit rate
- Joint Communications and Sensing
- Flexible allocation of functionality & topology formulations

PoC A – Key findings*

- Functionality Allocation (FA) mechanism was developed for optimally placing functionality to the various compute nodes of the system.
- As power consumption is considered the power consumption for processing and the transmission power consumption.
- A metaheuristic algorithm is developed based on a Genetic Algorithm paradigm.
- The results are compared with two baseline algorithms, the feasible random placement and the SoTA round-robin placement.
  - The validation scenario comprised 7 compute nodes (3 robotic units, 2 edge servers, 2 cloud servers) and increasing number of compute workloads/ tasks
- The FA algorithm compared to the baselines can gain 8.8-28.6% reduction of power consumption
- Working on:
  - integrating the trust manager component to succeed maximum trustworthiness.
  - Develop an ML algorithm to possibly obtain better performance.

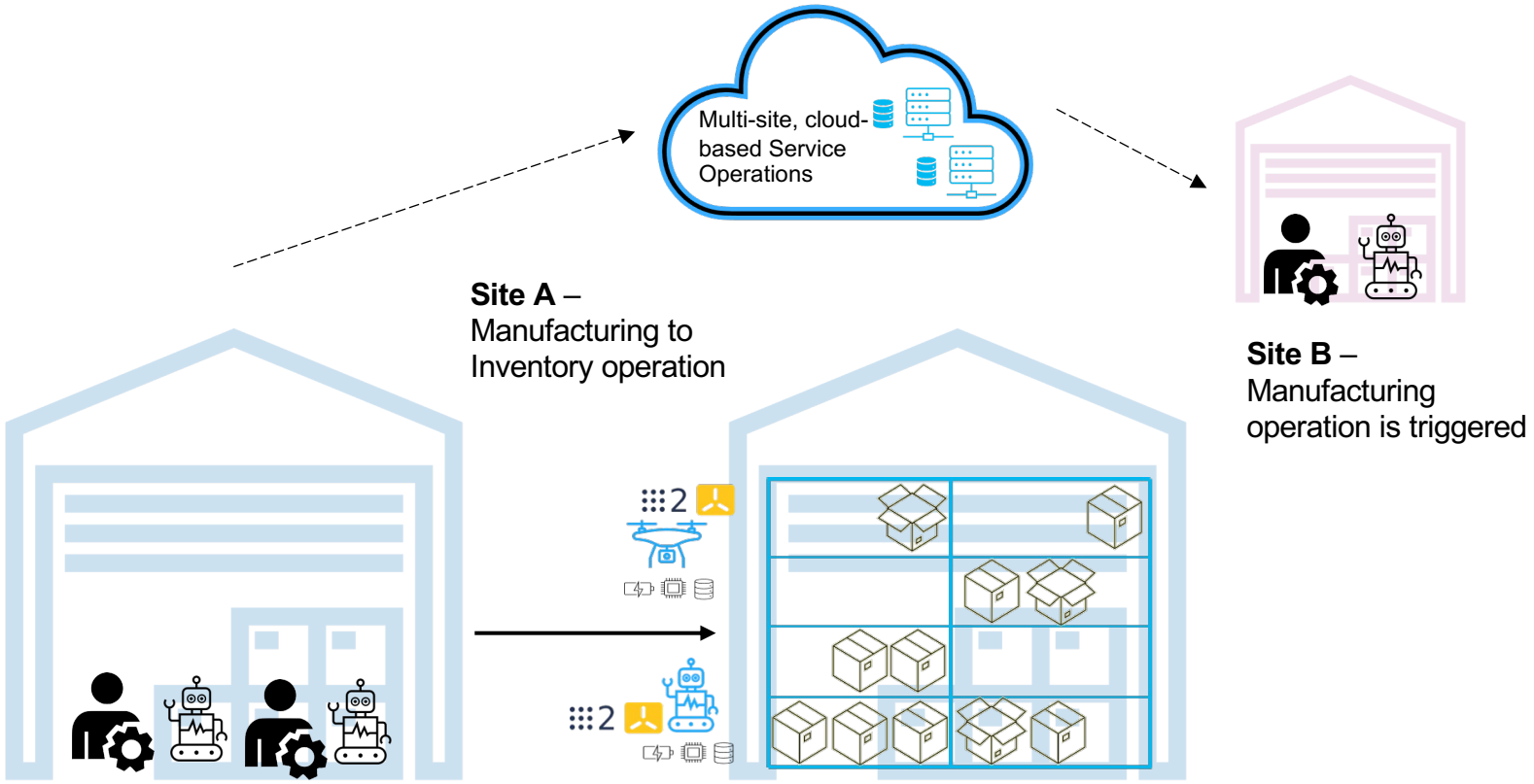


Reduction of power consumption with increasing number of workloads of our FA mechanism compared with two baseline algorithms.

* More key findings are reported in D2.2

System-PoC B

- Pre-condition: A manufacturing task is conducted in a certain site, e.g., site A
- In the particular site a role needs to be changed (e.g., from manufacturing to inventory)
- Manufacturing is transferred to another site, e.g., site B
  - Manufacturing in site B uses components from site A
  - Show case of multi-site, synergetic orchestration
  - requirements on connectivity
  - complementary use of software and hardware components (no duplication)



Multi-site, synergetic monitoring and orchestration

```
{
  "$schema": "http://json-schema.org/draft-07/schema#",
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    },
    {
      "metricName": "power_consumption_max",
      "metricValue": 260,
      "metricUnit": "Watts",
      "metricType": "Physical"
    },
    {
      "metricName": "cpu_utilization",
      "metricValue": 50, // Assuming 50% CPU utilization for this example
      "metricUnit": "Percent",
      "metricType": "Application"
    },
    {
      "metricName": "ram_utilization",
      "metricValue": 4, // Assuming 4 GB of RAM used for this example
      "metricUnit": "GB",
      "metricType": "Application"
    }
  ],
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        "name": "LinkToUUID2",
        "value": 1000 // Assuming a dummy value for maximum capacity link
      }
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    "power_consumption_idle": 70,
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}
```
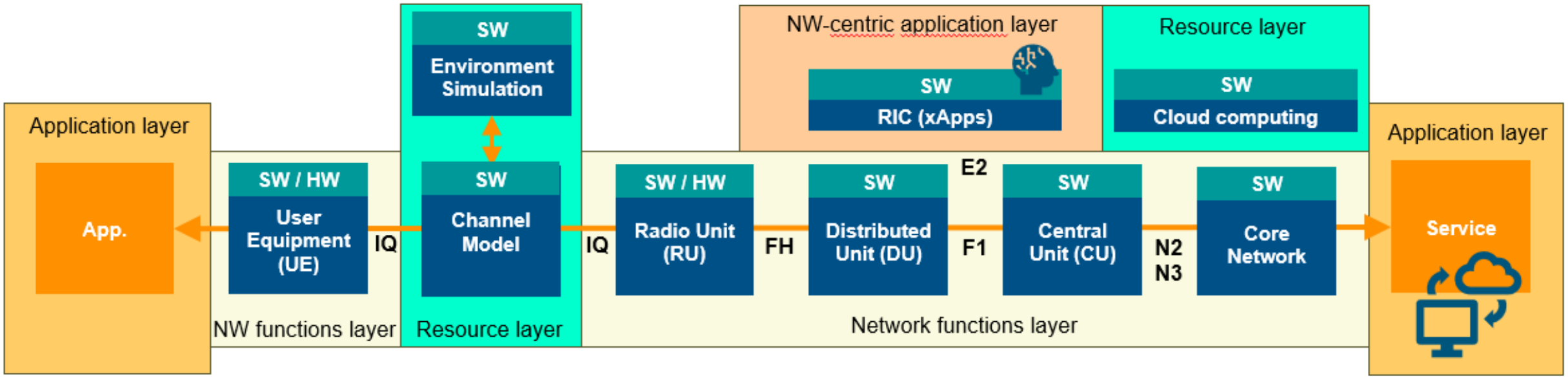

E2E simulation framework for connectivity

- E2E simulation framework is planned to be developed and used for selected 6G connectivity enablers performance evaluation



More details

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.

D2.1 Draft foundation for 6G system design

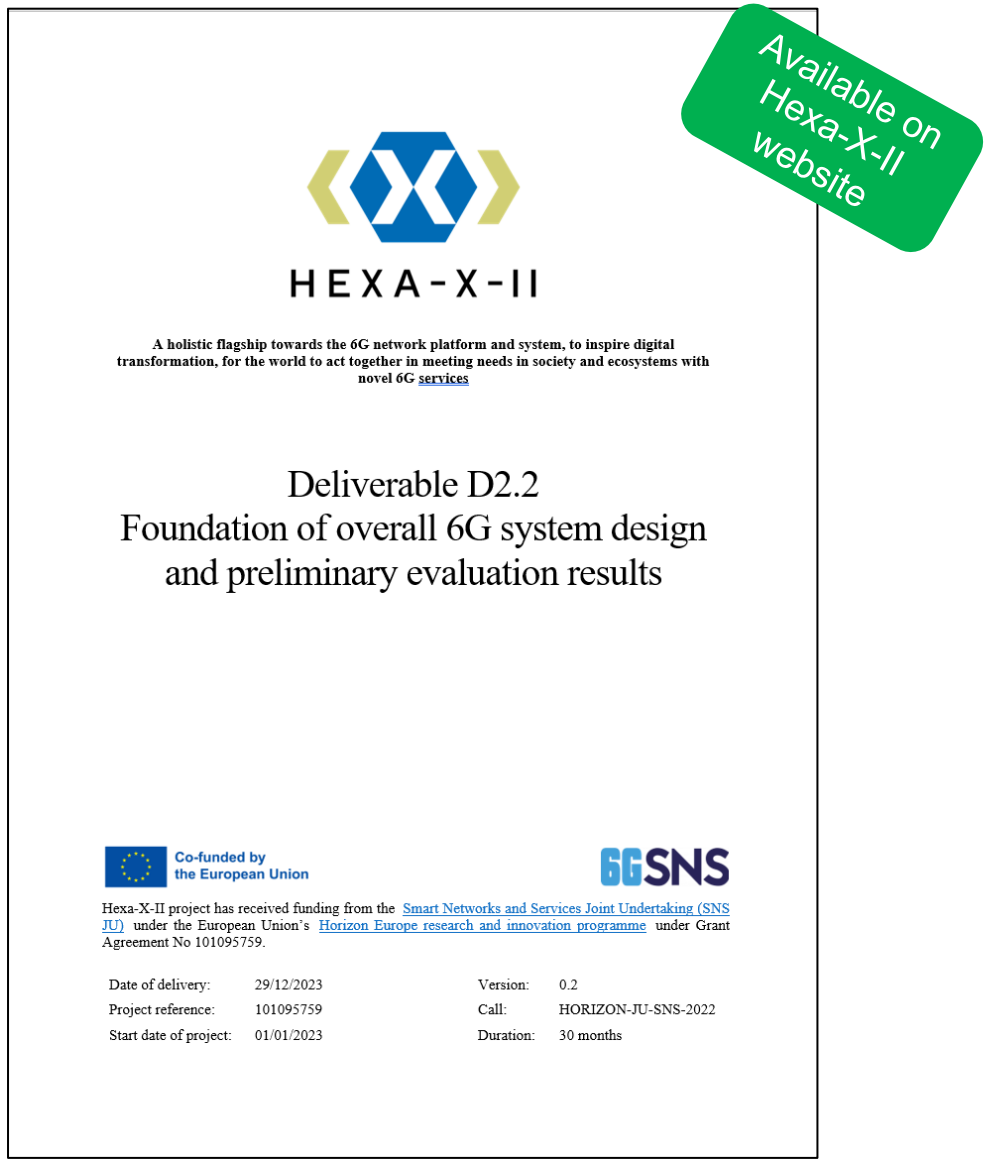
DISCLAIMER: Smart Networks and Services Joint Undertaking approval pending

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:	30/06/2023	Version:	1.0
Project reference:	101095759	Call:	HORIZON-JU-SNS-2022
Start date of project:	01/01/2023	Duration:	30 months



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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 D2.2
Foundation of overall 6G system design and preliminary evaluation results

Co-funded by the European Union

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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:	29/12/2023	Version:	0.2
Project reference:	101095759	Call:	HORIZON-JU-SNS-2022
Start date of project:	01/01/2023	Duration:	30 months

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