Hexa-X-II: Draft foundation for 6G system design

The 6G series workshop by Hexa-X and Hexa-X-II
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Hexa-X-II

hexa-x-ii.eu

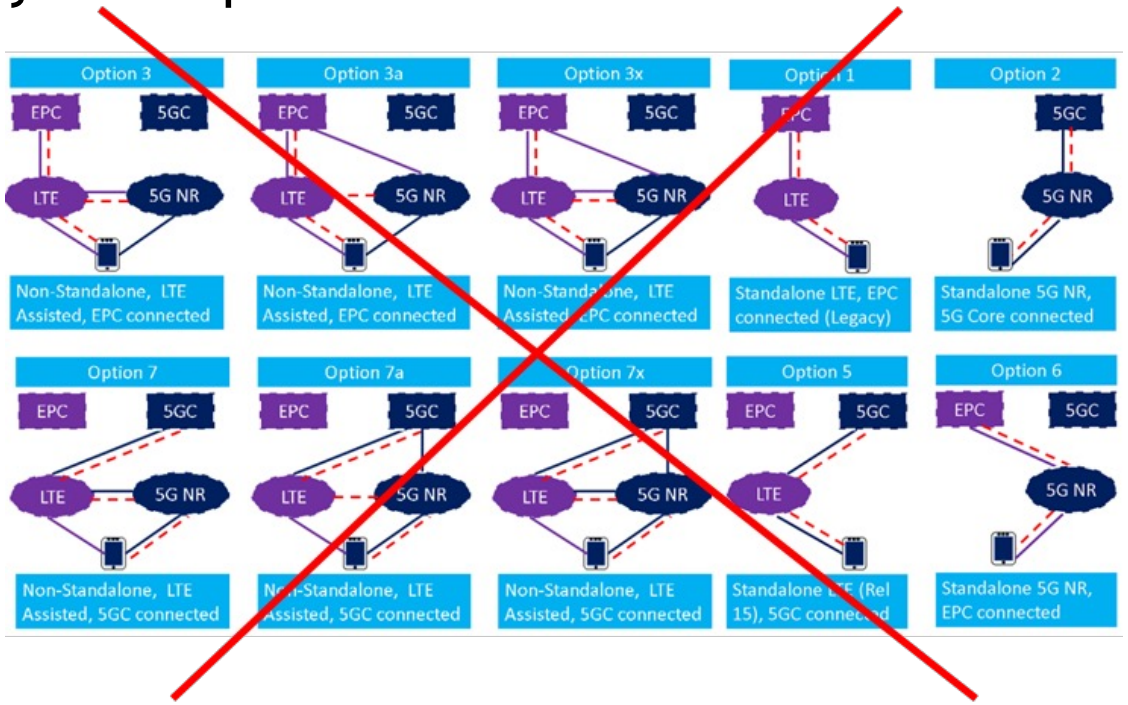
Outline

- Evolution towards 6G
- 6G design principles
- End-to-end design
- Iterative design process & system PoCs

Evolution towards 6G

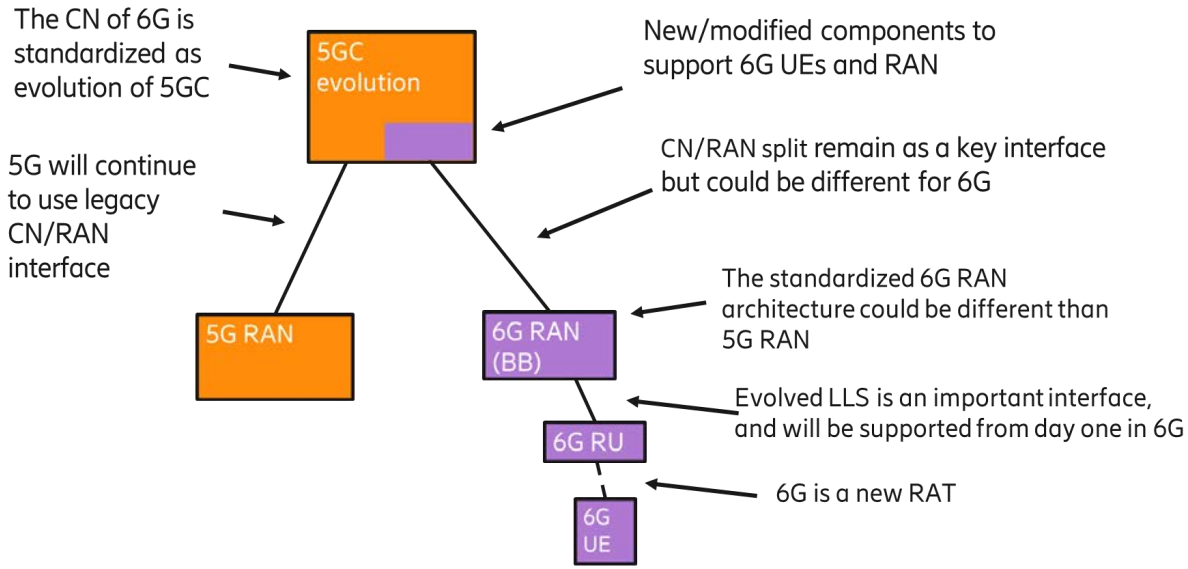
Evolution towards 6G

- Standardization of 5G was rushed to get an early drop
- Had to rely on 4G for non-standalone
- Opened up a wide variety of deployment options with 4G and 5G RAN and CN
- Each option had to be standardized and tested, but only very few were actually deployed
- In 6G we should avoid unnecessary deployment options



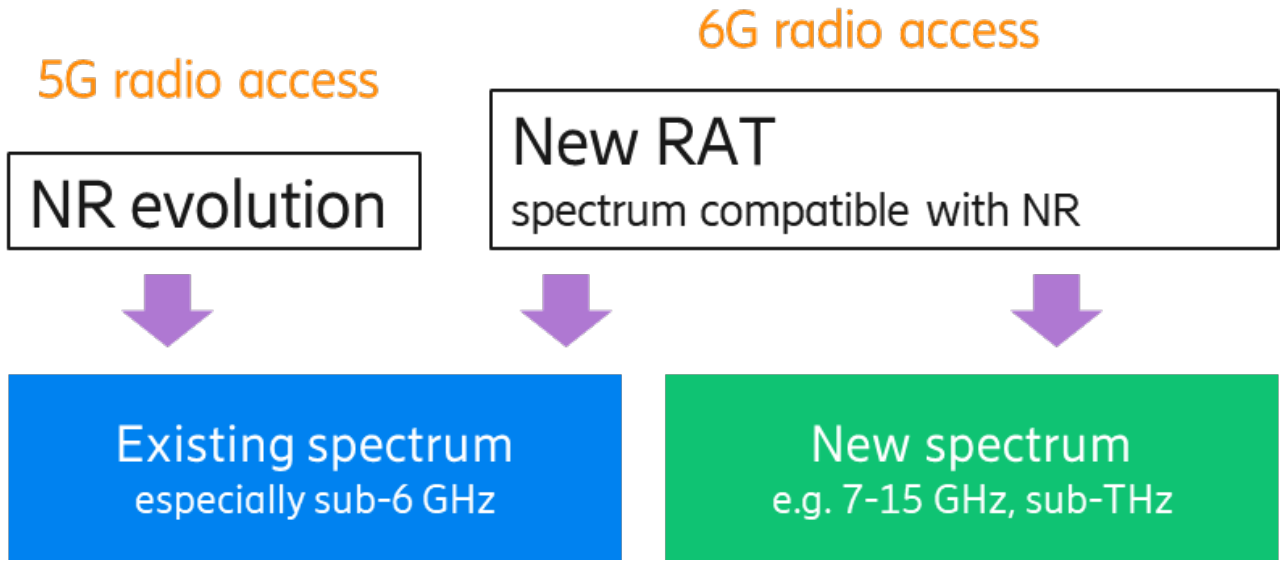
Evolution towards 6G

- To allow gradual migration o 6G, 5GC should be enhanced to support 6G RAN (instead of clean slate 6GC)
- The RAN/CN split and function placement could be revised (or even flexible)
- An evolved Lower Layer Split should be supported from the first release
- The 6G air interface will be non-backward compatible (new 6G RAT)



Evolution towards 6G

- Multi-RAT Spectrum Sharing (MRSS) will allow gradual refarming of existing spectrum to allow wide-area coverage
- New centimeter spectrum (7-15 GHz) can provide significant performance boost
- New high band spectrum (>100 GHz) can provide extreme performance in specific scenarios (e.g., short range or LoS)

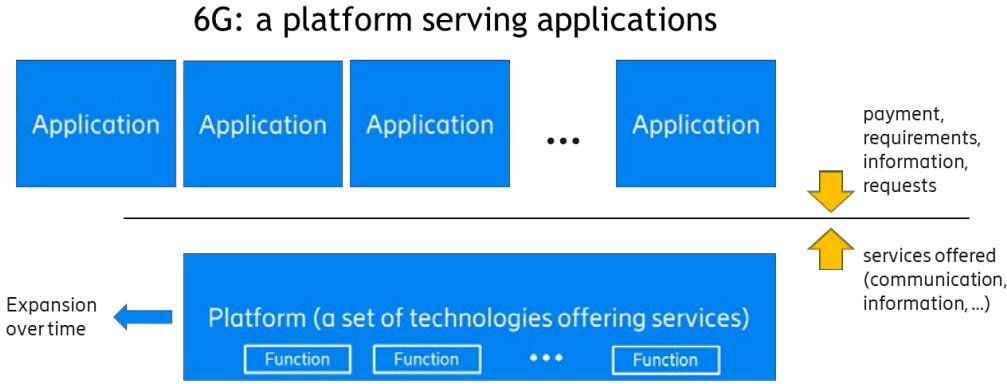


6G design prinicples

6G design principles

Intelligence and automation

- Principle 1 - Support and exposure of 6G services and capabilities
  - Support Communication / Beyond communication
  - Expose capabilities, both internally and externally



- Principle 2 - Full automation and optimization
  - Distributed AI/ML
  - Observability, analytics

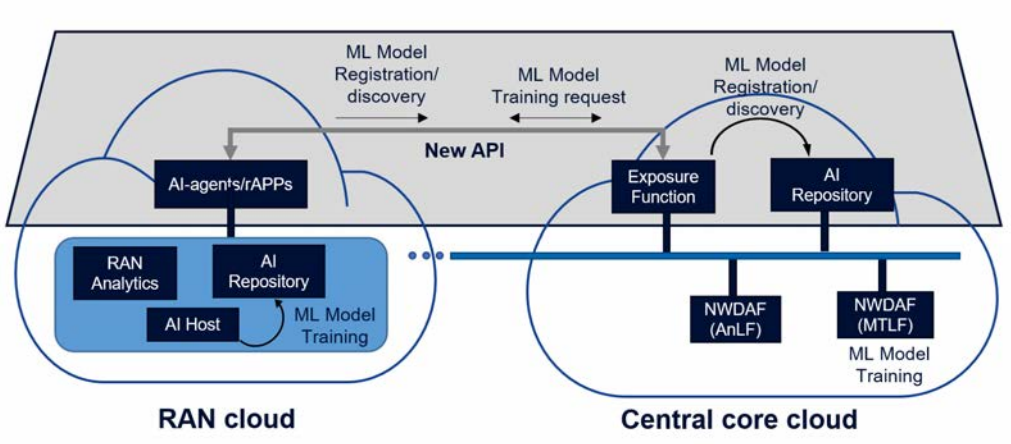
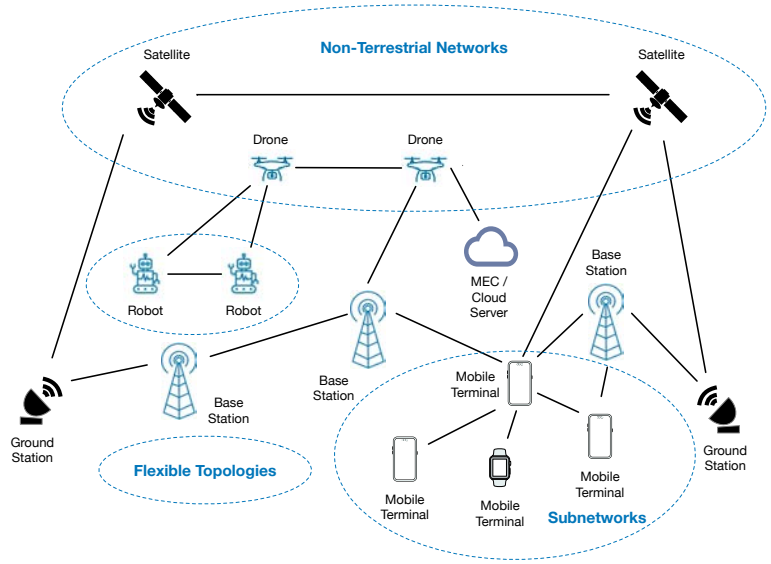


Image sources:
Top: Hexa-X-II
Bottom: Hexa-X D5.2 Analysis of 6G architectural enablers applicability and initial technological solutions

6G design principles

Flexibility

- Principle 3 - Flexibility to different network scenarios
  - Single standardization, multiple implementations
    - Macro, HetNet, mesh, D2D, NTN, NPN, sub-networks



- Principle 4 – Network Scalability
  - Very large to very small deployments
  - Turn off parts not in use
  - Real-time adaptation to needs

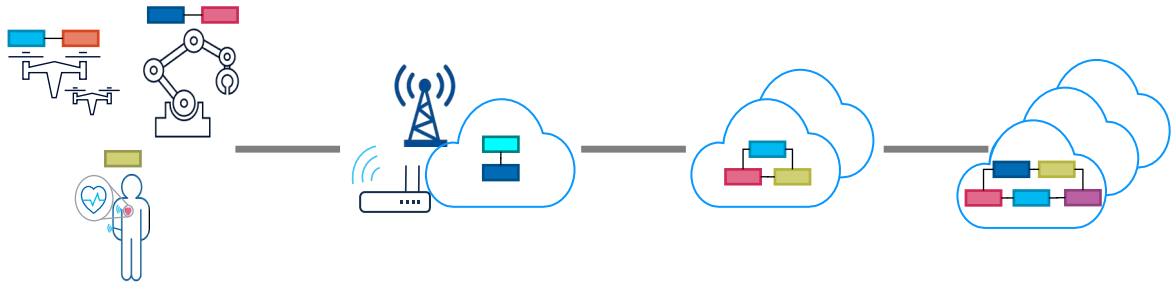
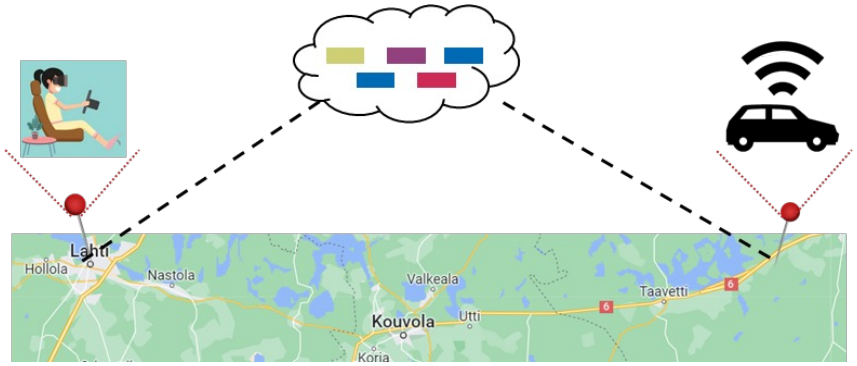


Image sources:
Hexa-X-II

6G design principles

Trustworthiness

- Principle 5 - Resilience and availability
  - Availability, coverage, disaster resilience, …



- Principle 6 - Persistent security and privacy
  - Integrity, privacy, encryption, zero-trust, …

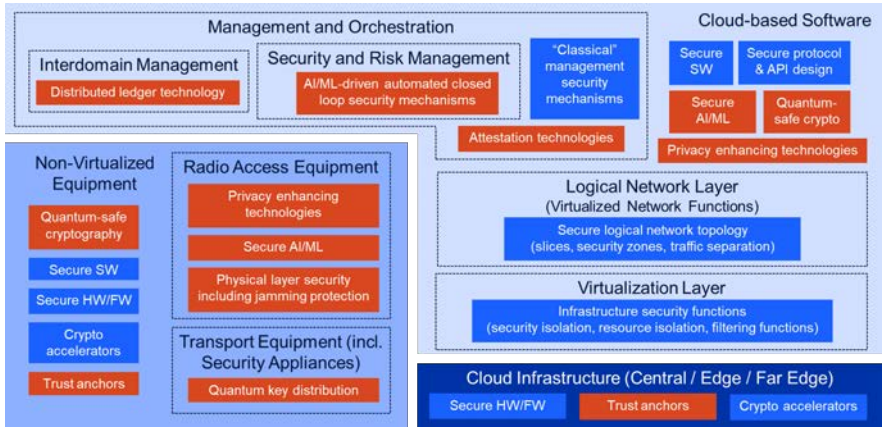


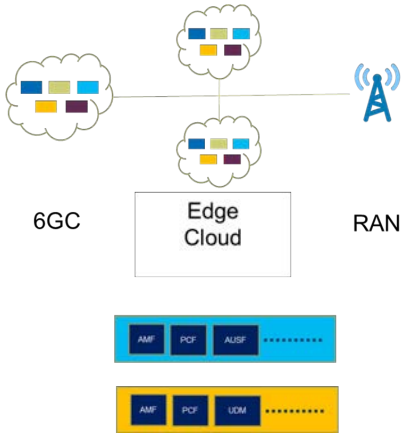
Image sources:
Top: Hexa-X-II
Bottom: Hexa-X D1.3 Targets and requirements for 6G – initial E2E architecture

6G design principles

Efficiency

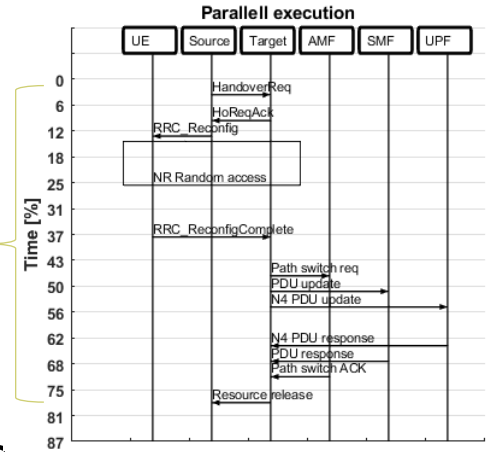
Principle 7 - Internal interfaces are cloud optimized

- Enhance SBA in CN
- Enable use of IT tools (e.g., DevOps) in CN



Principle 8 - Separation of concerns of network functions

- Reduce interdependencies, simplify deployment of new functions



Principle 9 - Network simplification in comparison to previous generations

- Simple migration, zero-touch, automation…

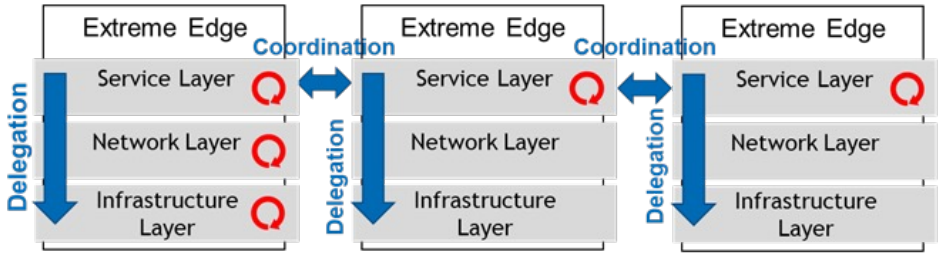


Image sources:
Hexa-X
Hexa-X-II

6G design principles

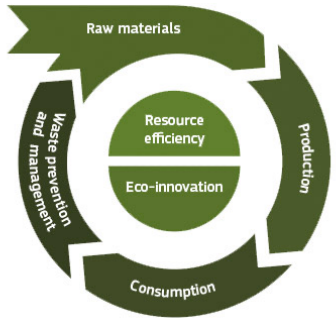
Sustainability

Principle 10 - Low footprint and enabling sustainable use cases

Sustainable 6G

GHG, Energy efficiency

Circularity



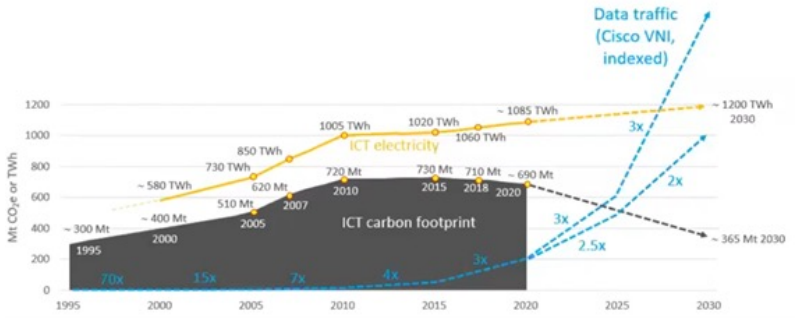


Image sources:
Top left: United Nations
Top right: European Union
Bottom: J. Malmodin, “The ICT sector’s carbon footprint,” Presentation at the techUK conference in London Tech Week on ‘Decarbonising Data’, 2020

6G for sustainability

Image source:
United Nations

6G design principles

Principle 1 – Support and exposure of 6G services and capabilities
Principle 2 – Full automation and optimization

Intelligence

Principle 3 – Flexibility to different network scenarios
Principle 4 – Network Scalability

Flexibility

Principle 5 – Resilience and availability
Principle 6 – Persistent security and privacy

Trustworthiness

Principle 7 – Internal interfaces are cloud optimized
Principle 8 – Separation of concerns of network functions
Principle 9 – Network simplification in comparison to previous generations

Efficiency

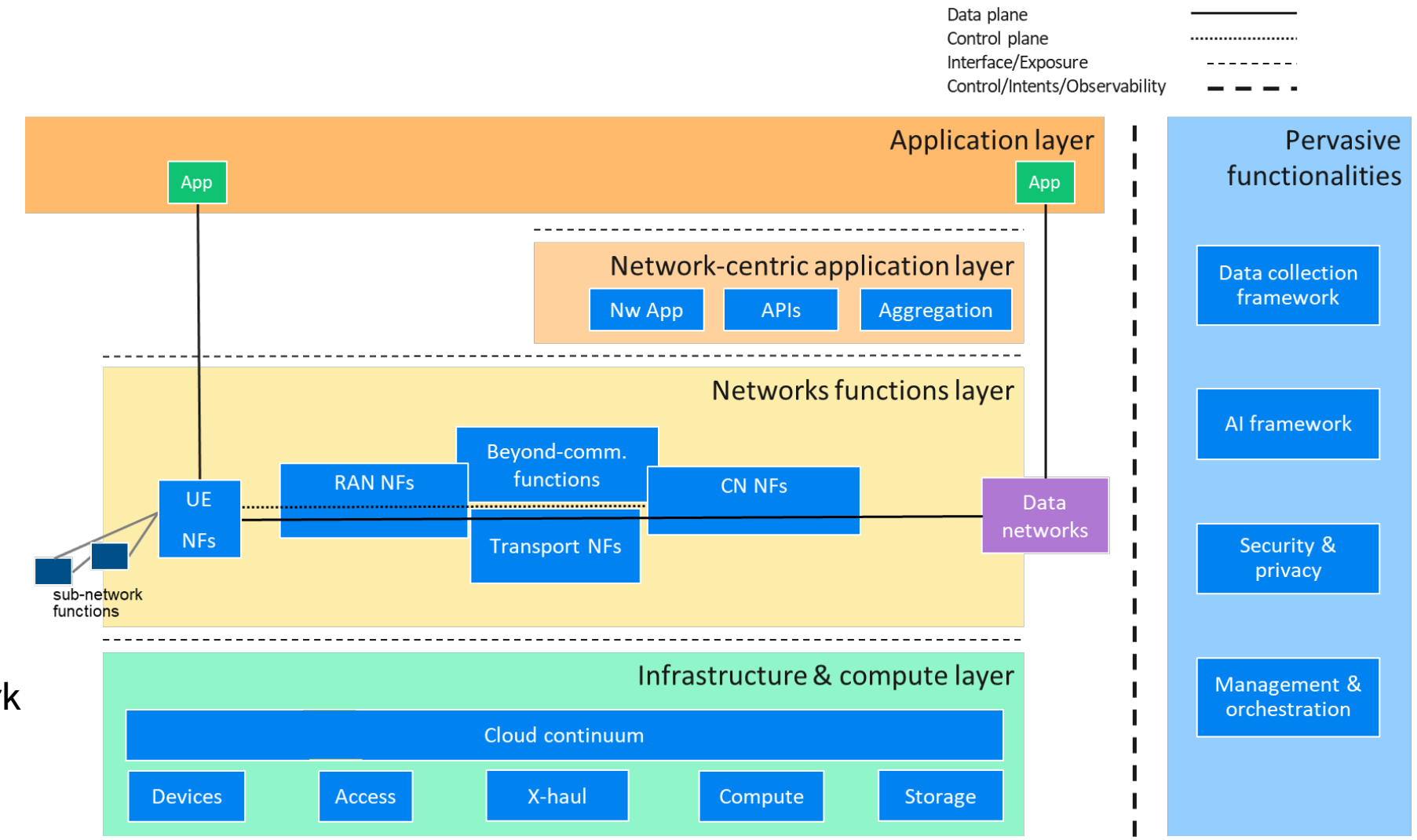
Principle 10 – Minimize environmental footprint and enabling sustainable use cases

Sustainability

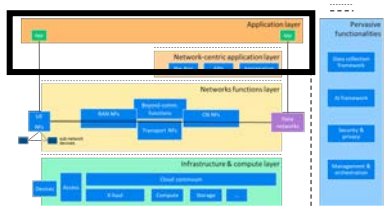
End-to-end design

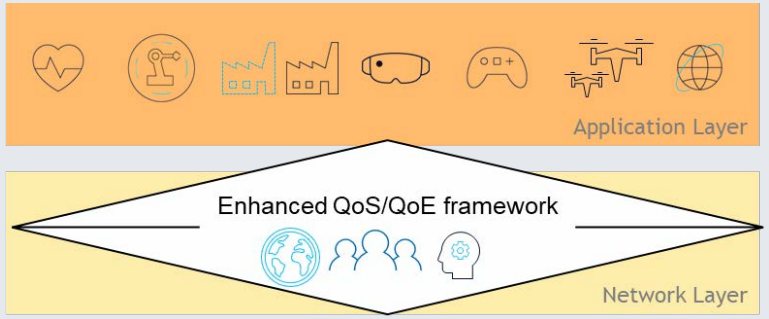
E2E design

- 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



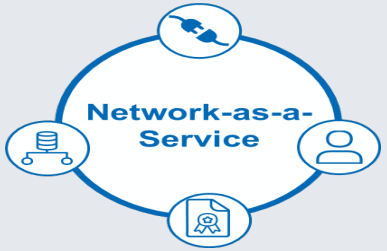
Application Layers





Impacts to and interaction with the network layer

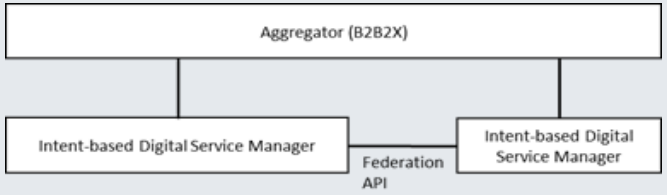
- Streamline the overall protocol stack (including network layer)
- Cross layer optimization; QoS/actionable QoE framework to include value indication; QoS for native AI services;



APIs for NaaS

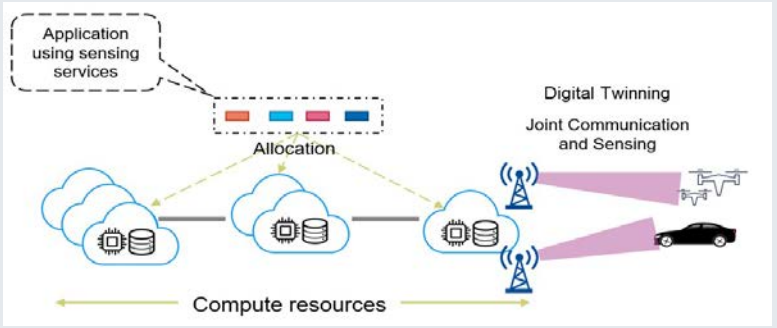
Controllable capability API exposure

- 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

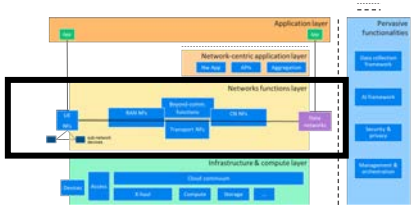
- To allow the management of 6G E2E services across multiple and different operator types and the involvement of other stakeholders such as service providers or hyperscalers.
- Federation of service providers, E2E SLAs

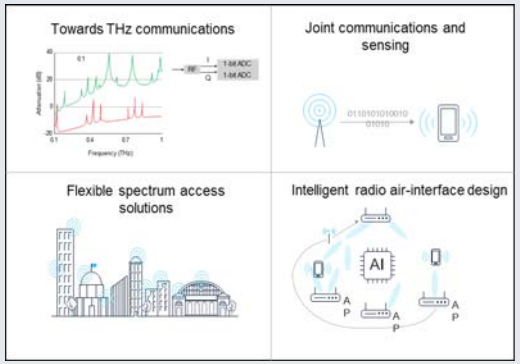


Beyond Communication Service Exposure

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

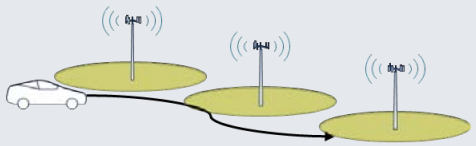
Network Function Layer





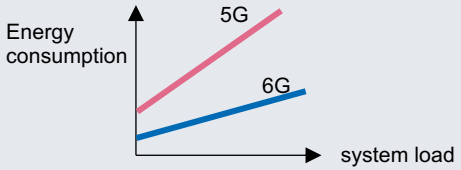
Flexible PHY radio interface and radio protocols

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



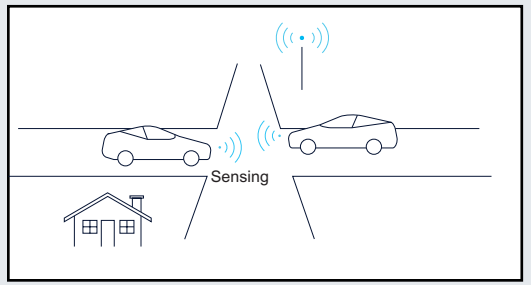
Sustainable RAN design

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

Modularized network functions

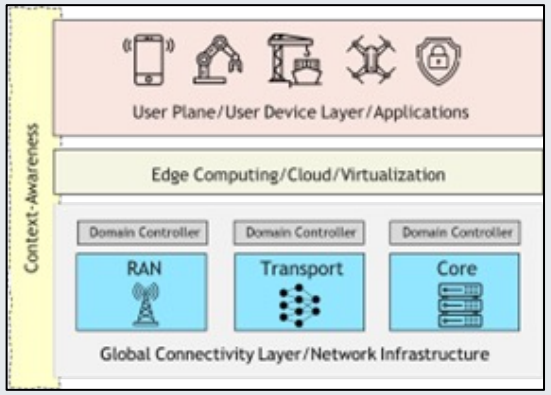
(RAN & Core)

- To add new modules to ensure operational effectiveness and interoperability



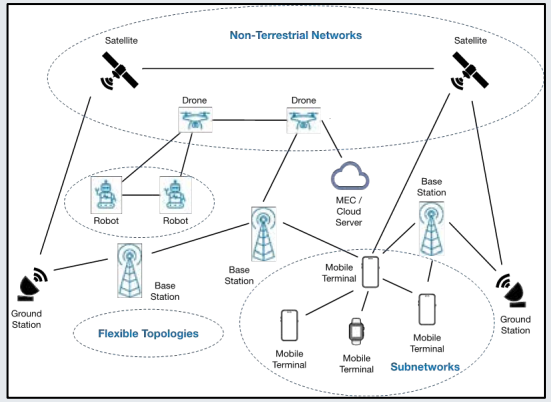
Beyond communication

interfaces, protocols & NF supporting sensing, computing, offloading



Context awareness management

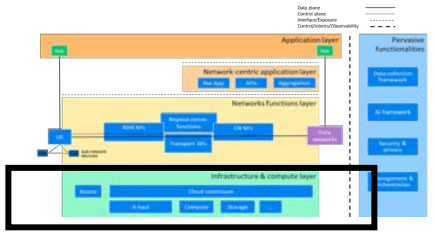
- To enable efficient support of the modular and flexible networks.
- To enable the network to optimize the E2E connection spanning over application, edge computing, RAN, CN, and Transport network

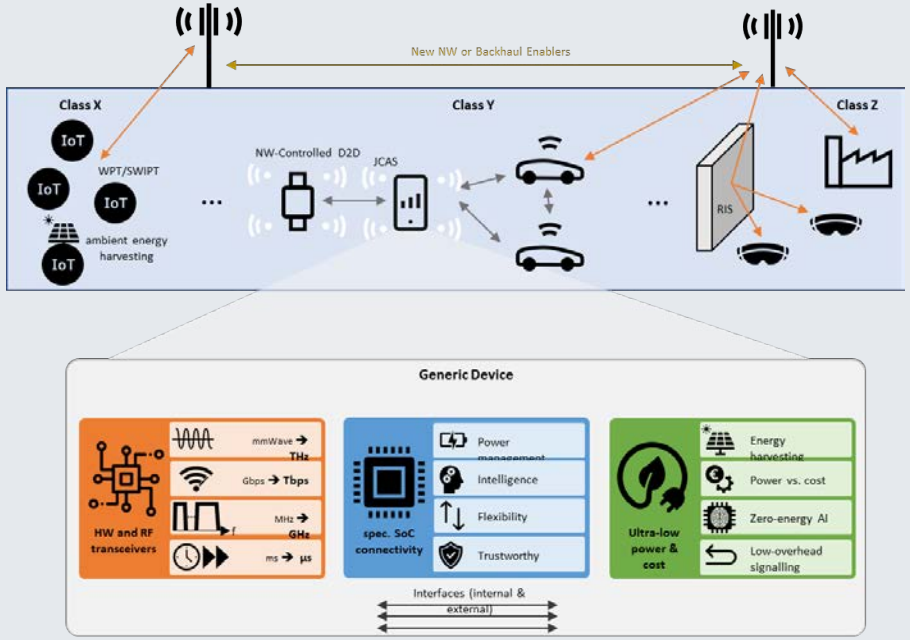


New access & flexible topologies

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

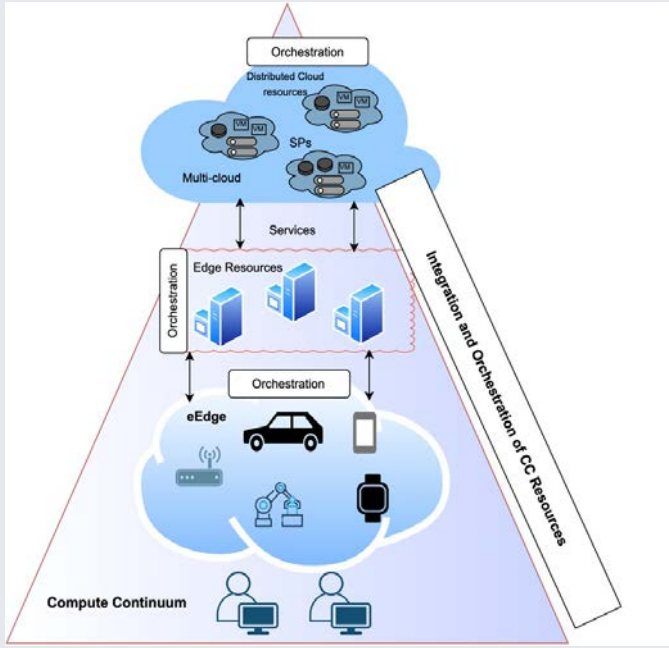
Infrastructure & Compute Layer





Future device & flexible infrastructure

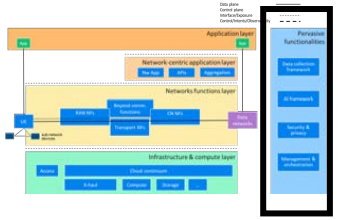
- New device types/classes identification
- Evolved hardware implementations of 6G transceivers
- Evolved specialized system-on-chip (SoC) connectivity for specific 6G applications
- Designing energy/material/cost-aware devices

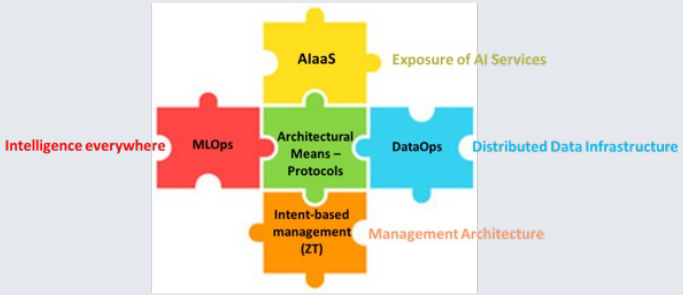


Integration and orchestration of computing continuum (CC) resources

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

Pervasive functionalities



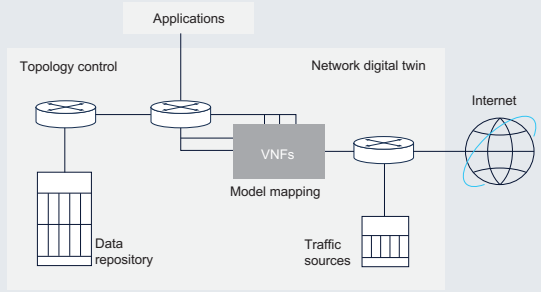


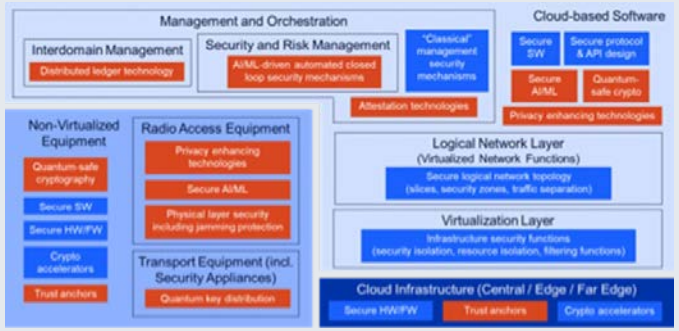
Data collection frameworks

- 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

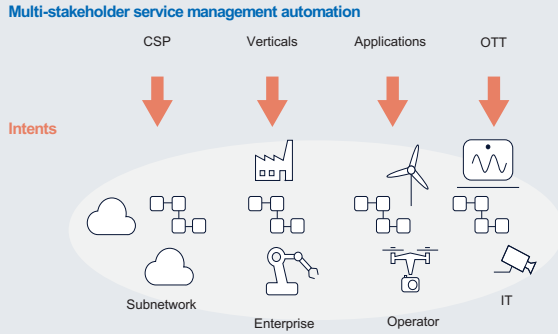
- To empower 6G with data-driven architecture that supports distributed intelligence and distributed AI platform.
- To allow AI for communication and beyond communication purposes

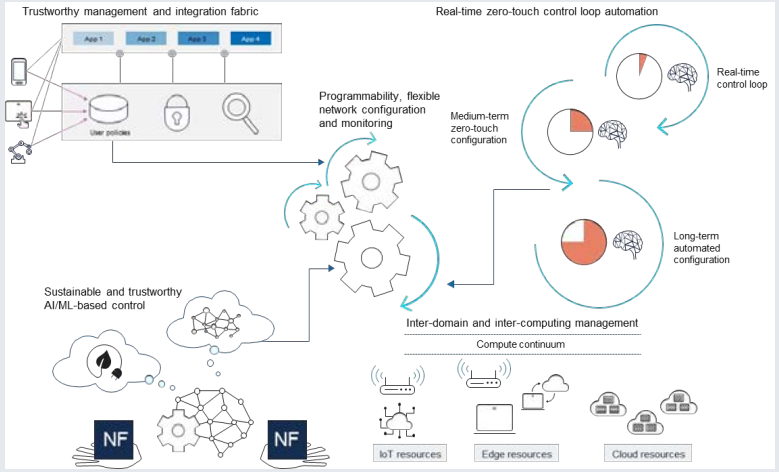




Security & privacy

- 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





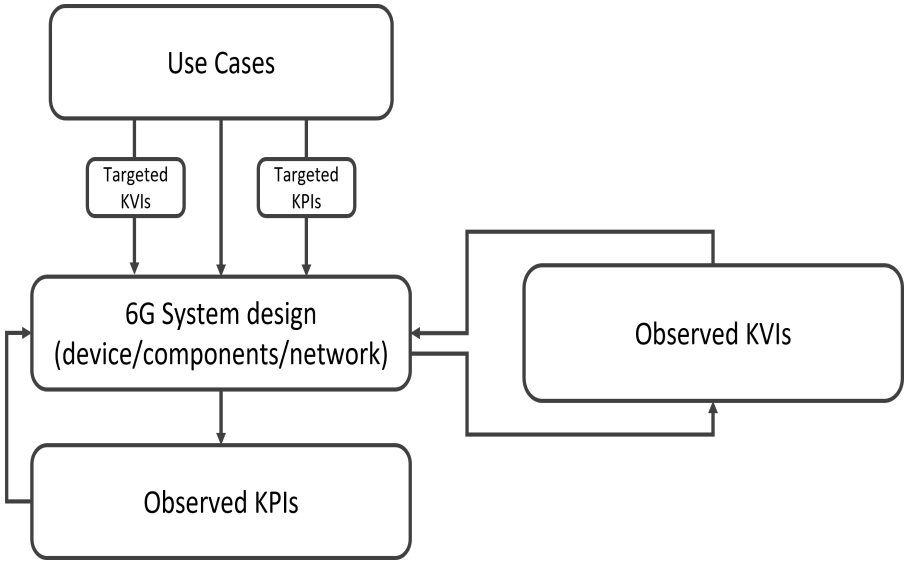
Management & orchestration

- 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

Iterative design process & system PoCs

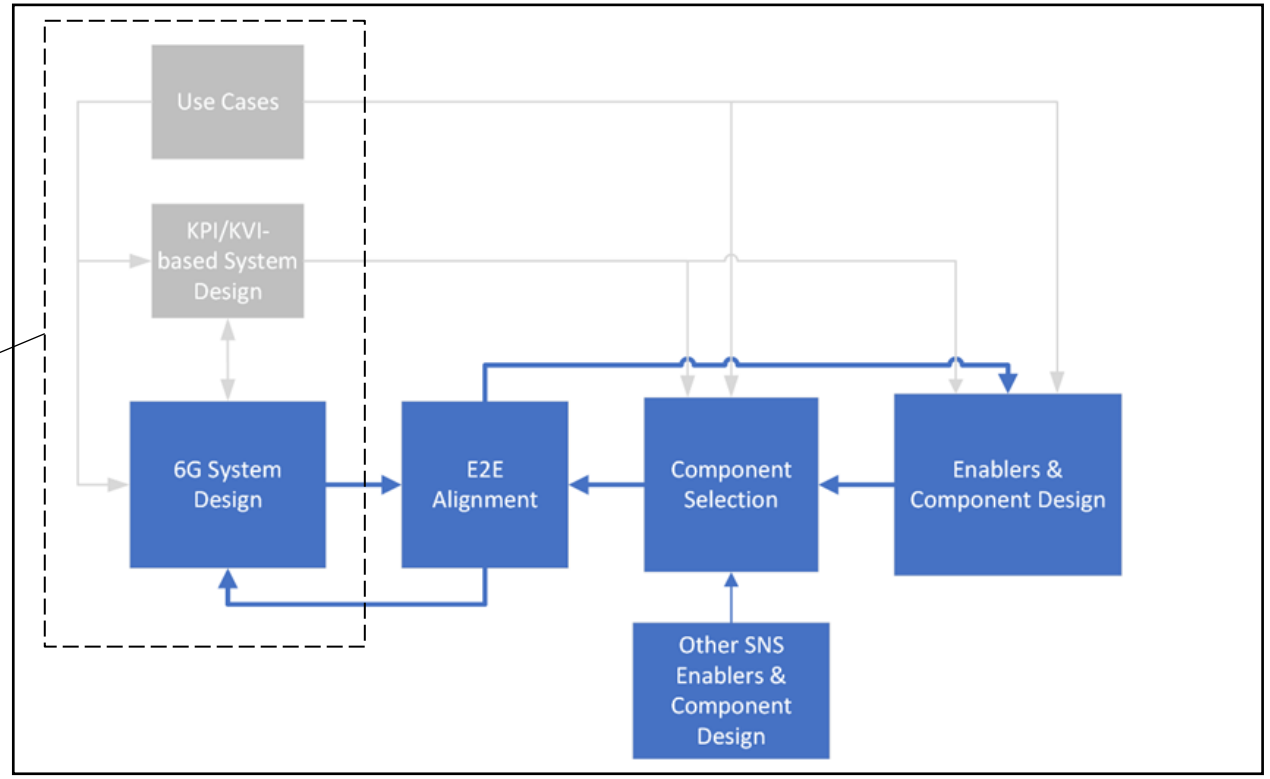
Iterative system design process

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

System Proof of Concepts

Three System-PoCs

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

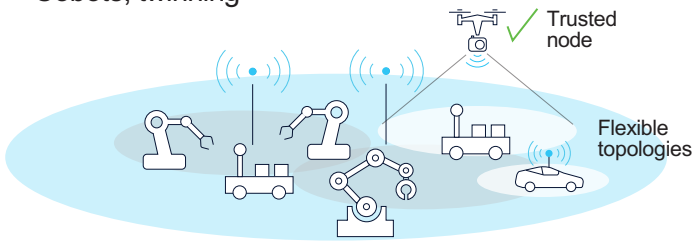
Key enablers

KVI: **Sustainability, trustworthiness (resilience)**	
Management and orchestration	Diagnostics intent
Network architecture and transformation Trustworthy flexible topologies, Beyond communications	
6G device components	6G radio aspects

Cobots

KVI: Sustainability, trustworthiness (resilience) and inclusion	
Management and orchestration	Diagnostics intent
Network architecture and transformation Trustworthy flexible topologies, Beyond communications	
6G device components	6G radio aspects

Cobots, twinning



KVI: Sustainability, trustworthiness (resilience) and inclusion	
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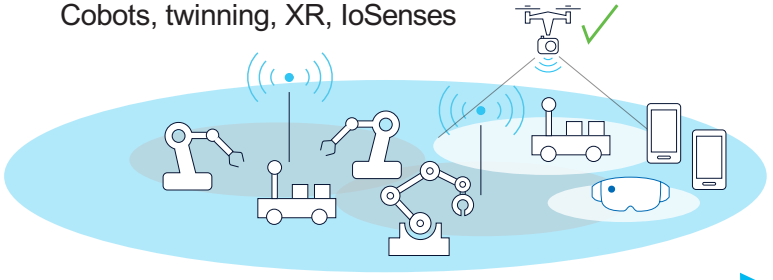
Cobots, twinning, XR, IoSenses



6G

Gradual addition

HEXA-X-II.EU //

This project has received funding from the European Union's Horizon Europe research and innovation programme and Smart Networks and Services Joint Undertaking (SNS JU) under grant agreement No 101095759.