Short-range in-X subnetworks for extreme communications

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with contribution of 6G-SHINE project partners

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Introduction

- High performance requirements (e.g., high determinism, 10^{-6}-10^{-8} reliability, multi-Gbps data rates) → go local!
  - Short-range high performance wireless networks

- Current 3GPP topologies and communication modes are not suited for localized communication since
  - Connecting and managing all devices within the short-range networks through the 3GPP infrastructure can be difficult
  - Losing connection to the 3GPP network could cause unacceptable outage to the system.
  - Directing sub-system traffic and management functions through the 3GPP network results in higher latency and network congestion.

- Existing ad-hoc networks may not support the most demanding requirements (e.g., in terms of latency, reliability).

In-X subnetworks as novel paradigm for short-range communication

- **Able to operate autonomously**
- **Leveraging connectivity with a 6G parent network**

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Introduction

In-X subnetworks

- **New use cases**
- **Architectural innovation**
- **PHY/MAC innovation**
- **Radio resource management innovation**

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Relevant in-X subnetworks use cases

Consumer

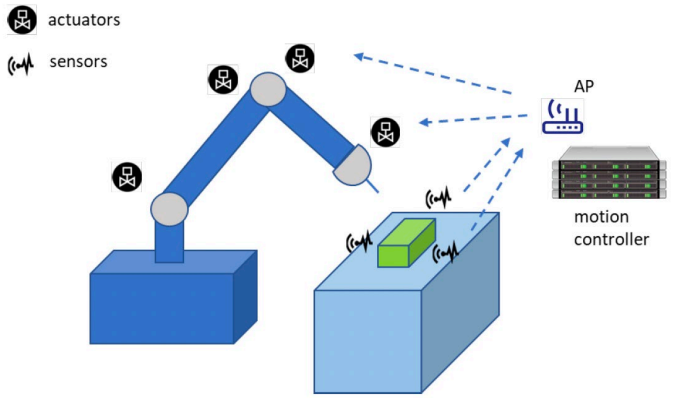
- Immersive education
- Indoor interactive games
- Virtual live production
- Augmented Reality (AR) navigation

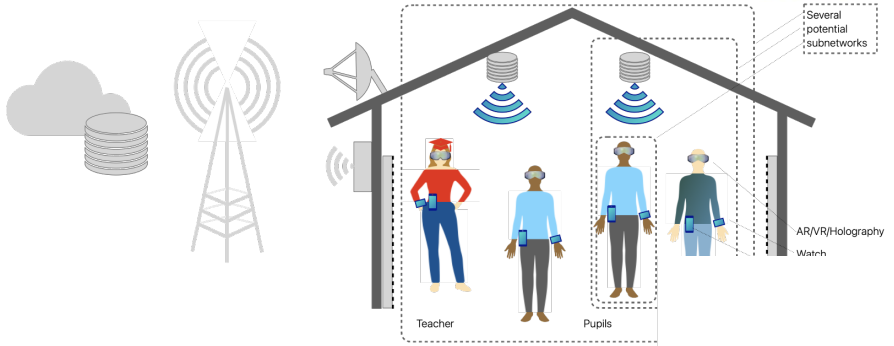
Invehicle

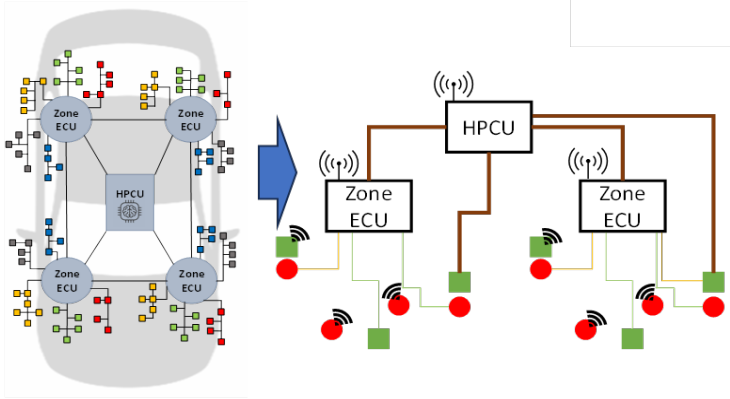
- Wireless zone Electronic Control Unit (ECU)
- Collaborative wireless zone ECU
- Inter-subnetwork coordination
- Virtual ECU

Industrial

- Robot control
- Unit test cell
- Visual inspection cell
- Subnetwork coexistence in the factory floor
- Subnetwork segmentation and management







Use cases and related requirements are described in our coming 6G-SHINE deliverable D2.2: https://6gshine.eu/deliverables-ii/

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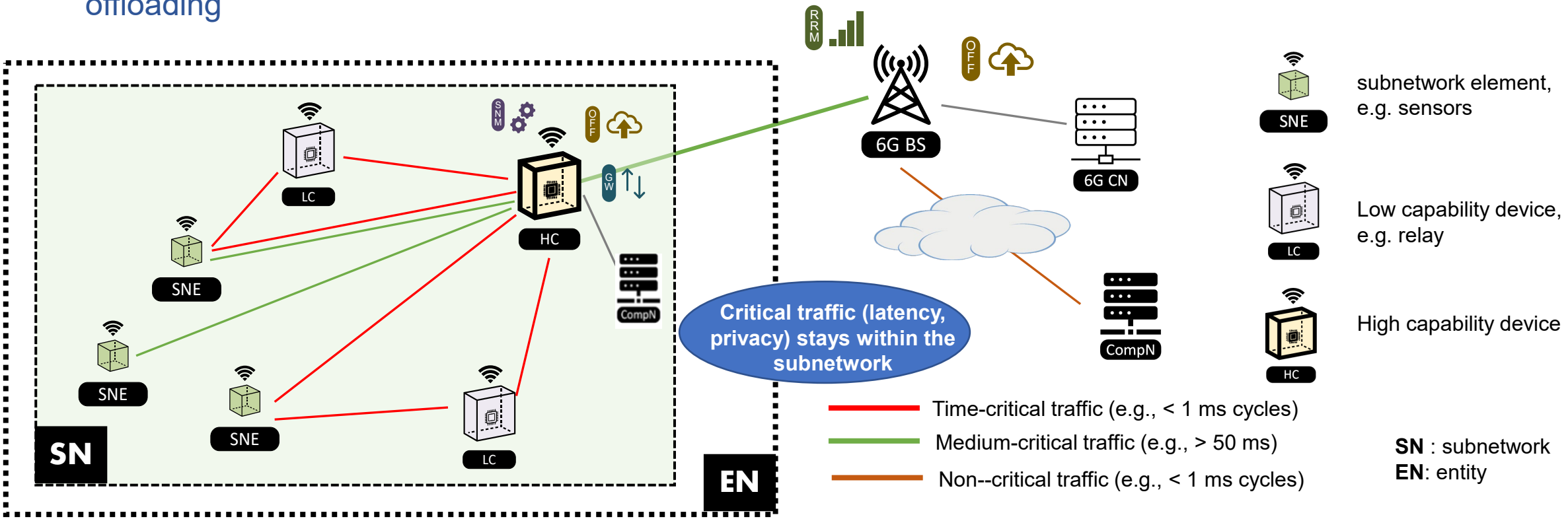
In-X subnetworks

- In-X subnetworks can be **task-specific, spatially confined, and time-bounded**
- In-X subnetworks should be able to operate autonomously (survivability), but are also part of a larger 6G ecosystem, benefiting from connection to a wide area/enterprise parent network
  - Improved interference coordination, traffic steering, service discovery and subscription, authentication / authorization, policy enforcement for traffic to/from devices in the subnetwork, traffic offloading



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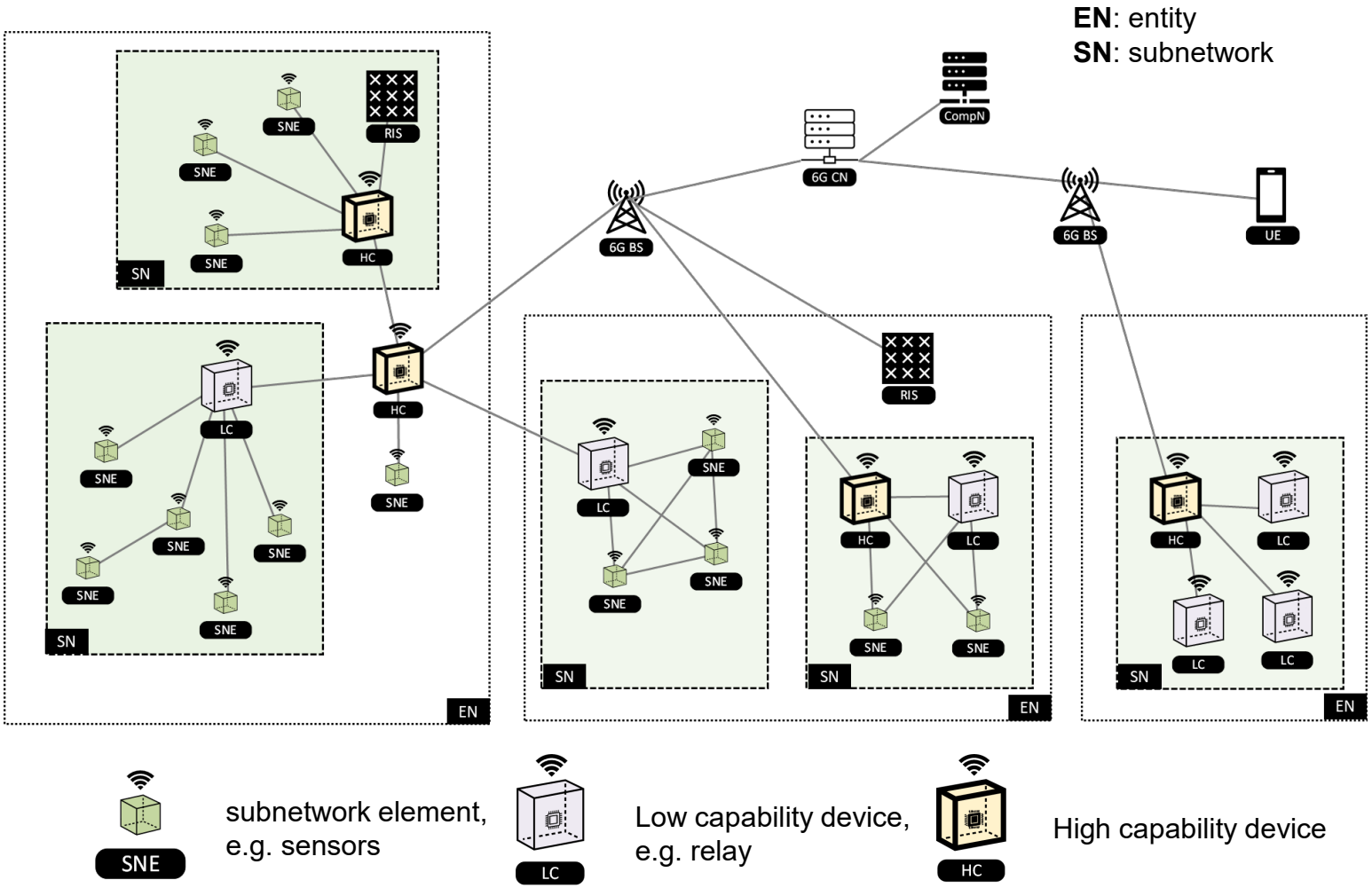
In-X subnetworks



SNE — subnetwork element, e.g. sensors

LC — Low capability device, e.g. relay

HC — High capability device

- Nodes in the subnetwork can have different and flexible roles in coordinating and combining the communication links
  - novel distribution of control and data plane functionalities
- Support of mobility
  - Devices entering and leaving a subnetwork
  - Subnetwork moving across parent network
- Subnetwork survivability
  - Dynamic adaptation of subnetwork topology and distribution of applications and networking functions

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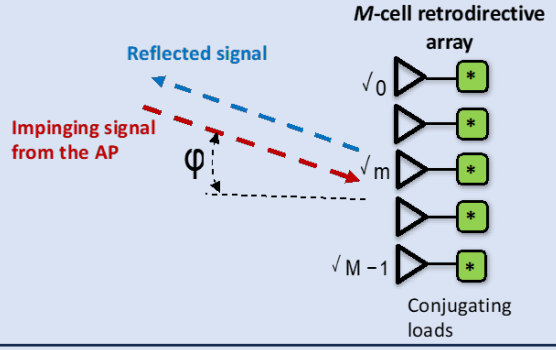
Examples of PHY/MAC innovation

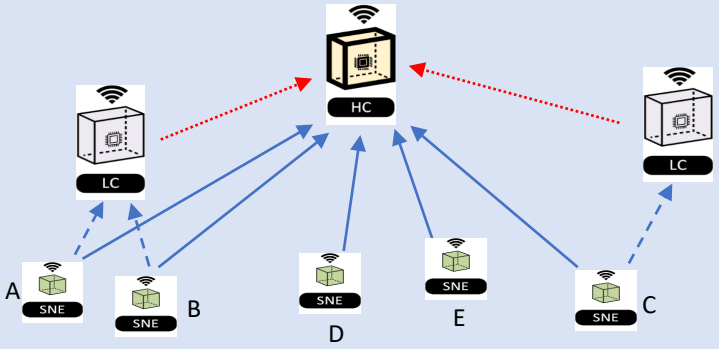
Ultra-low latencies
Low energy consumption

Short range joint beamforming and communication with self-conjugating metasurfaces



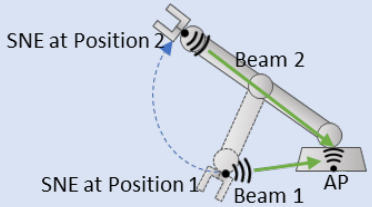
Beam alignment < 20 us,
Low device complexity (no DAC)

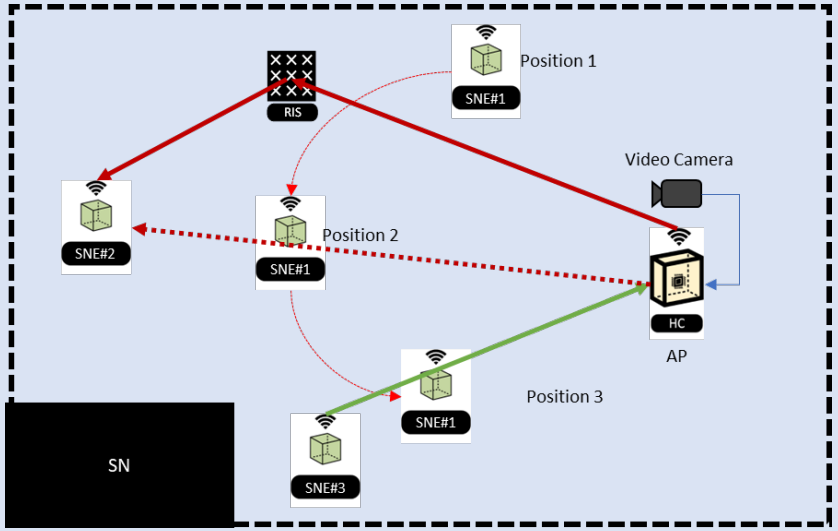
Cooperative in-X protocol



Lower < 7 dB transmit power
~100 us control cycles with 10^{-6} reliability

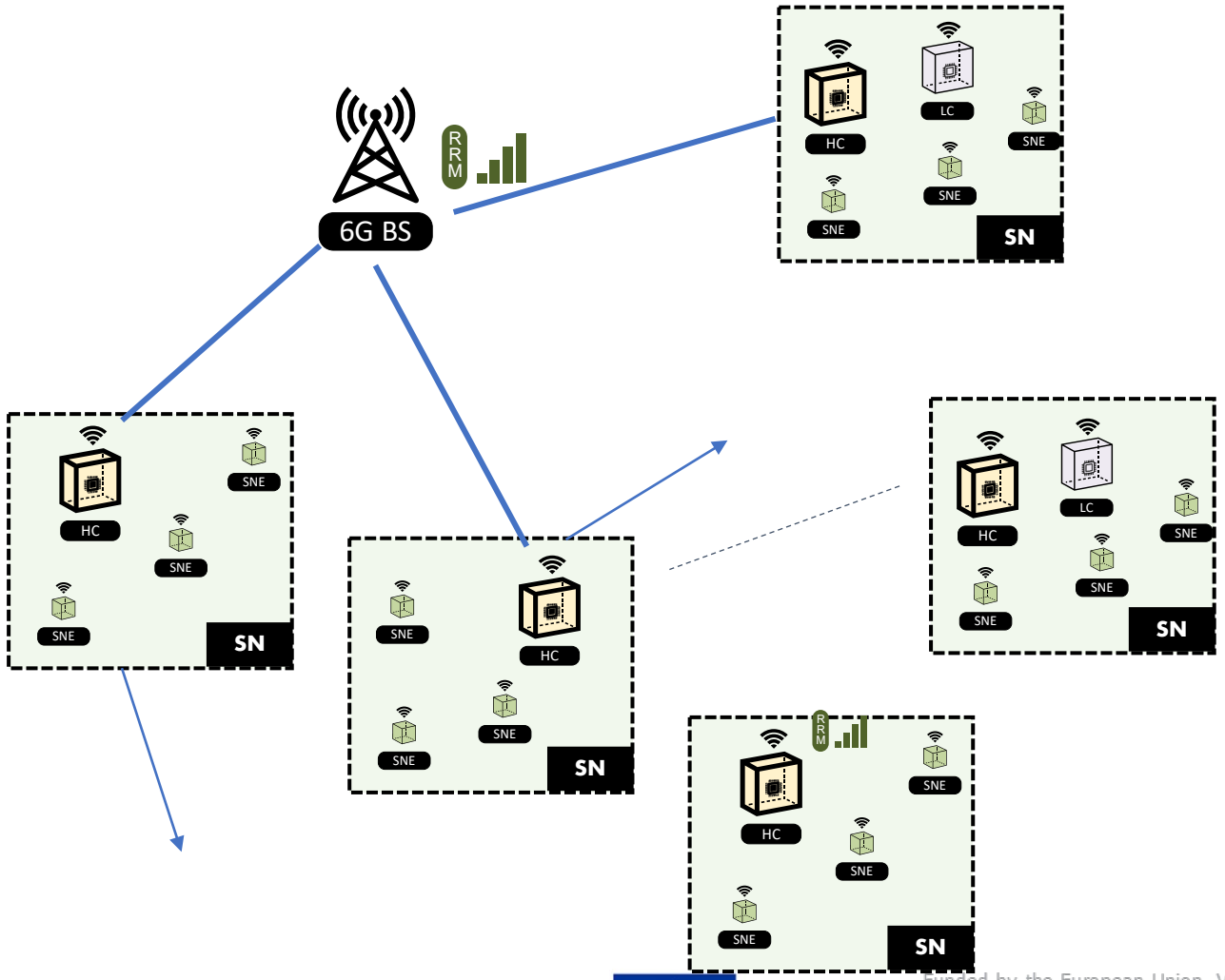
Predictive scheduling





Exploiting predictive characteristics for subnetwork operation and movements for pre-allocating resources → low delays and signalling overhead

Radio resource management innovation



- Subnetworks can spontaneously become very dense
  - Possibly cumbersome and time-varying interference levels

Centralized RRM
- best ideal performance
- poor scalability
- limited by backhaul quality

Distributed RRM
- fully scalable
- limited environment visibility at each subnetwork

Hybrid solutions

- Exploring ML-based approaches to deal with the complexity of the interference scenarios → training in known scenarios reduces complexity for RRM decisions
- Goal-oriented design

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Summary

- In-X subnetworks as a solution to support highly localized high performance services
  →consumer, industrial, in-vehicle applications

- They should be able to operate autonomously, while benefiting from connection with a 6G parent network

- Significant innovation needed in PHY, MAC, radio resource management and network architectures, for achieving demanding performance requirements at a low cost.

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