SWS-240018

The European view on 6G use cases

6G SNS-ICE

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3GPP Stage 1 Workshop on IMT2030 Use Cases

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Introduction

European input

- **3GPP SA1** invited **SNS** to participate in the workshop and present the envisioned 6G Use Cases based on the projects' work
- As SNS values collaboration with all EU stakeholders, it has invited EU National Initiatives to contribute to a coherent European view, formulated through SNS-ICE
- The following projects have contributed:

SNS projects

6G-NTN, 6G-Shine, NANCY, FIDAL, SEASON, TrialsNet, HEXA-X-II

National initiatives

6G Platform Germany (D), RESTART (I), FUTURE 6G NETWORK SERVICES (NL), FRENCH ACCELERATION STRATEGY FOR FUTURE NETWORKS AND TECHNOLOGIES (F)

More detailed material available in the appendix

General 6G considerations

High-level SNS objectives for 6G

- **Disruptive high value applications support**, with performance requirements beyond those of current 5G capabilities (scalability and new KPIs), especially for highly immersive and “digital twinning” applications.
- **Green transition contribution** with significantly lower energy needs for highrate/performance connectivity and capabilities to decrease energy needs of use cases.
- **SDGs support** and in particular connectivity and service availability (coverage), affordability (cost) and accessibility for a large number of use cases of high public value.
- **Innovative business models** based on managed end-to-end service provision over heterogenous business and technological domains.

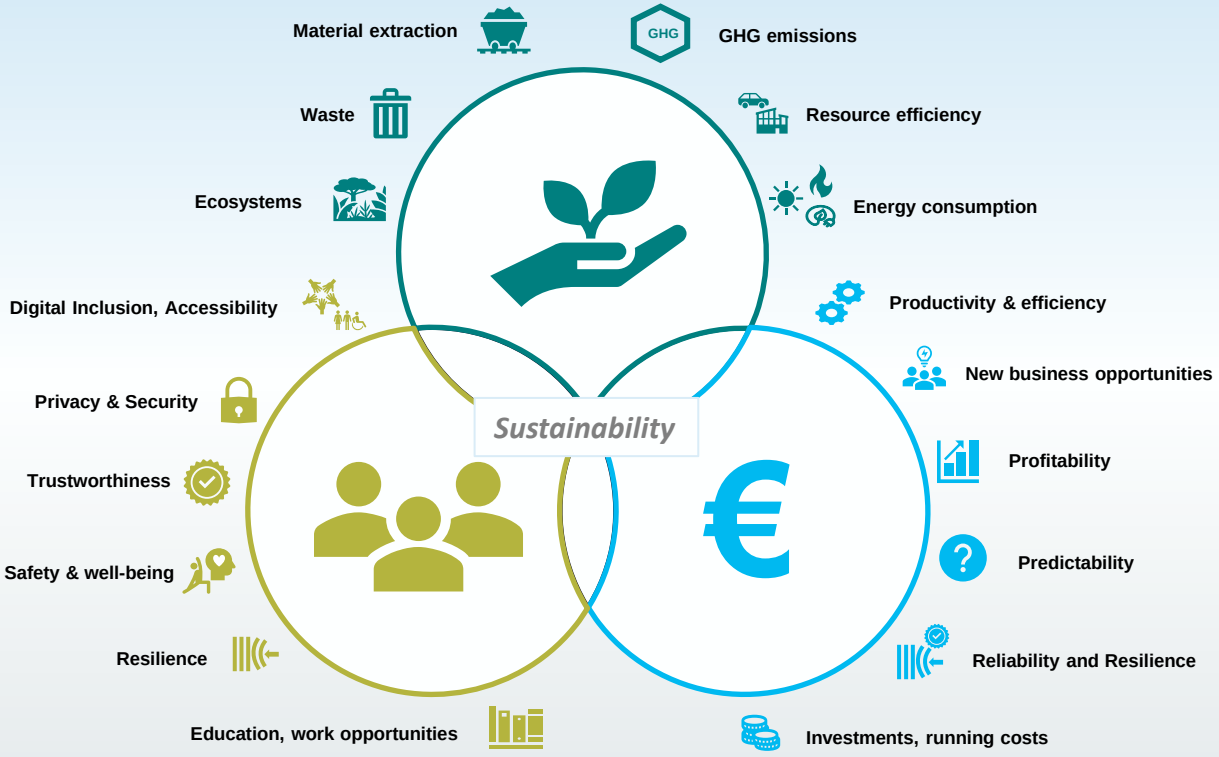
- **Global Single standards for 6G**, enabling interoperability, economies of scale and of scope.

Sustainability considerations

- It is imperative that 6G standardization takes sustainability expectations into consideration
  - Critically, **Sustainable 6G** – minimization of the footprint (negative impact) of ICT operations
  - Additionally, **6G for sustainability** – inducing positive impact and avoiding risks in other sectors (handprint) from use cases

- Key Value Indicators (**KVIs**) are becoming established as a toolset for assessing impact

- <u>SA1 should consider using KVIs in relation to use cases and requirements</u>



Analysis per use case available in the appendix

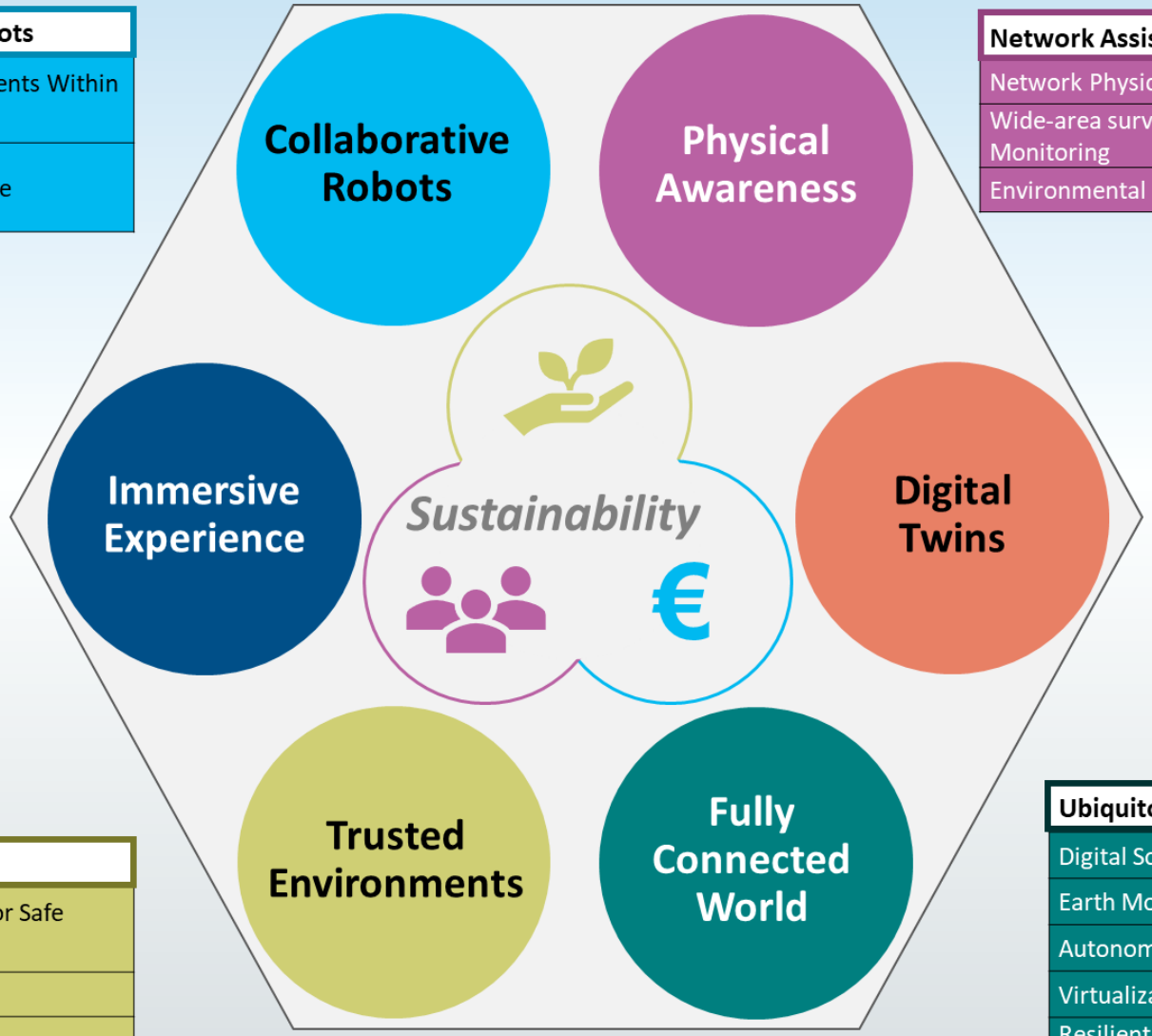
Use cases

Scenarios, problem descriptions, and requirements

Use case families

Cooperating Mobile Robots
- Autonomous Embodied Agents Within Flexible Manufacturing
- Mesh Embodied Intelligence

Network Assisted 3D Mobility
- Network Physical Data Exposure
- Wide-area surveillance/Smart Crowd Monitoring
- Environmental radio sensing



Seamless Immersive Reality
- Immersive Enterprise & Industry
- Immersive Education
- Immersive Gaming
- Live and Interactive Immersive Content Creation

Realtime Digital Twins
- Cloud Continuum
- Smart Maintenance
- Digital Twins (Building Model)
- Public Protection & Disaster Relief Digital Twin

Human-Centric Networks
- Industrial Sensors Network for Safe Production & Manufacturing
- Wireless In-Vehicle Network
- Virtual Control Room

Ubiquitous and Resilient Network
- Digital Sobriety and Enhanced Awareness
- Earth Monitor, Sustainable Food Production
- Autonomous Supply Chain
- Virtualization of Device Functionalities
- Resilient Communication for Safety critical Applications

More details available in the appendix

IMMERSIVE EXPERIENCE

Immersive Experience use cases are based on an evolving XR technology.

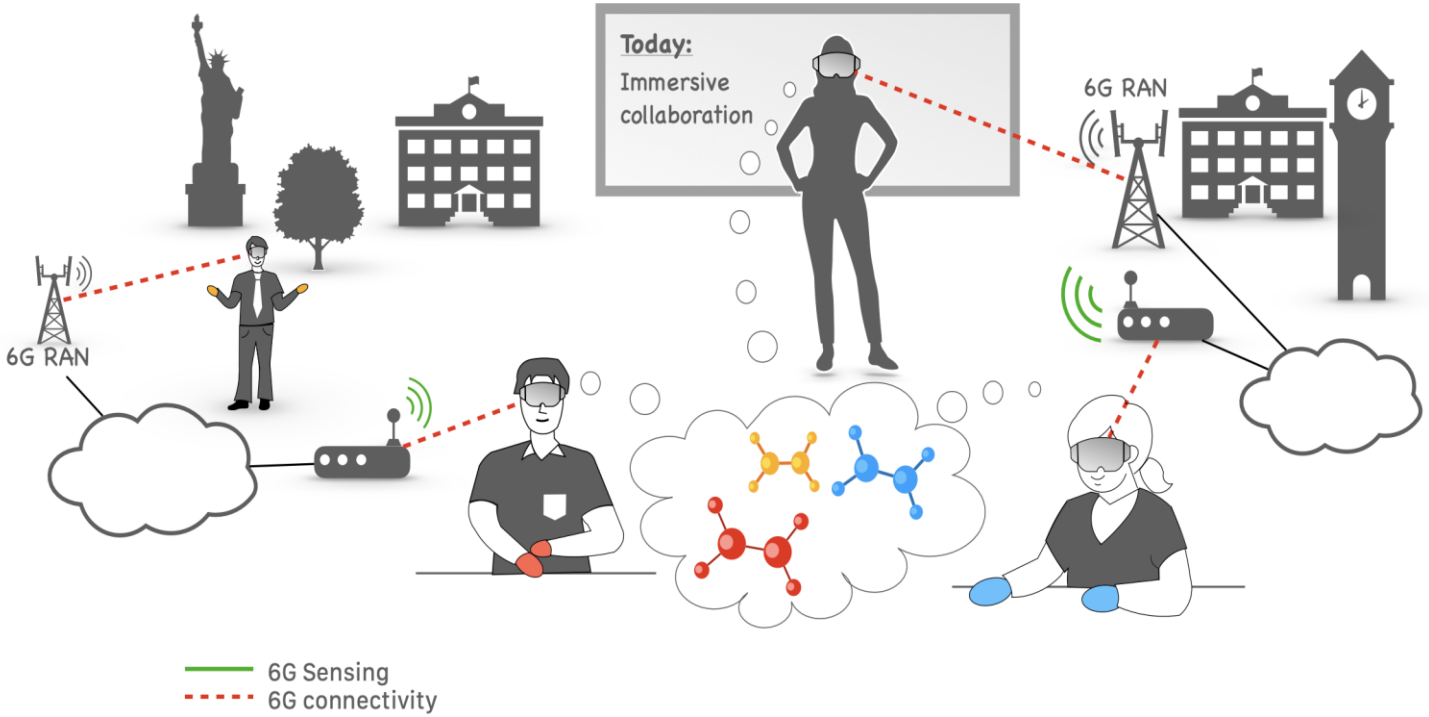
Immersive Experience is all about meeting the fundamental human need of "experiencing" a now digitally extended or virtual environment to understand and to act.

AI-generated image (Dall-E)

Use Cases

Seamless Immersive Reality | Immersive Enterprise & Industry | Immersive Education | Immersive Gaming | Live and Interactive Immersive Content Creation

Seamless Immersive Reality



Immersive collaboration
Mixed reality collaboration and immersive telepresence
e.g., remote lectures

Immersive experience "on the go"
Tailored experience and capabilities depending on user's situation and role
e.g., XR city tour

** digital representation of real object*

Seamless Immersive Reality

Immersive Experience

Functional Requirements

- AI/ML/Compute
- Sensing
- Positioning
- Privacy & Security
- Service Continuity
- Low Latency Synchronization

KPIs

User-experienced data rate [Mb/s]	Depending on scenario: **250**	DL, UL for UE taking role of gateway
Area traffic capacity [Mb/s/m^2]	**20**	Wide area: focus on immersive experience “on the go”
E2E Latency [ms]	**<10**	Split rendering scenario
Positioning [cm]	**<10**	Positioning accuracy (H and V)

COLLABORATIVE ROBOTS

The network's main users are machines.

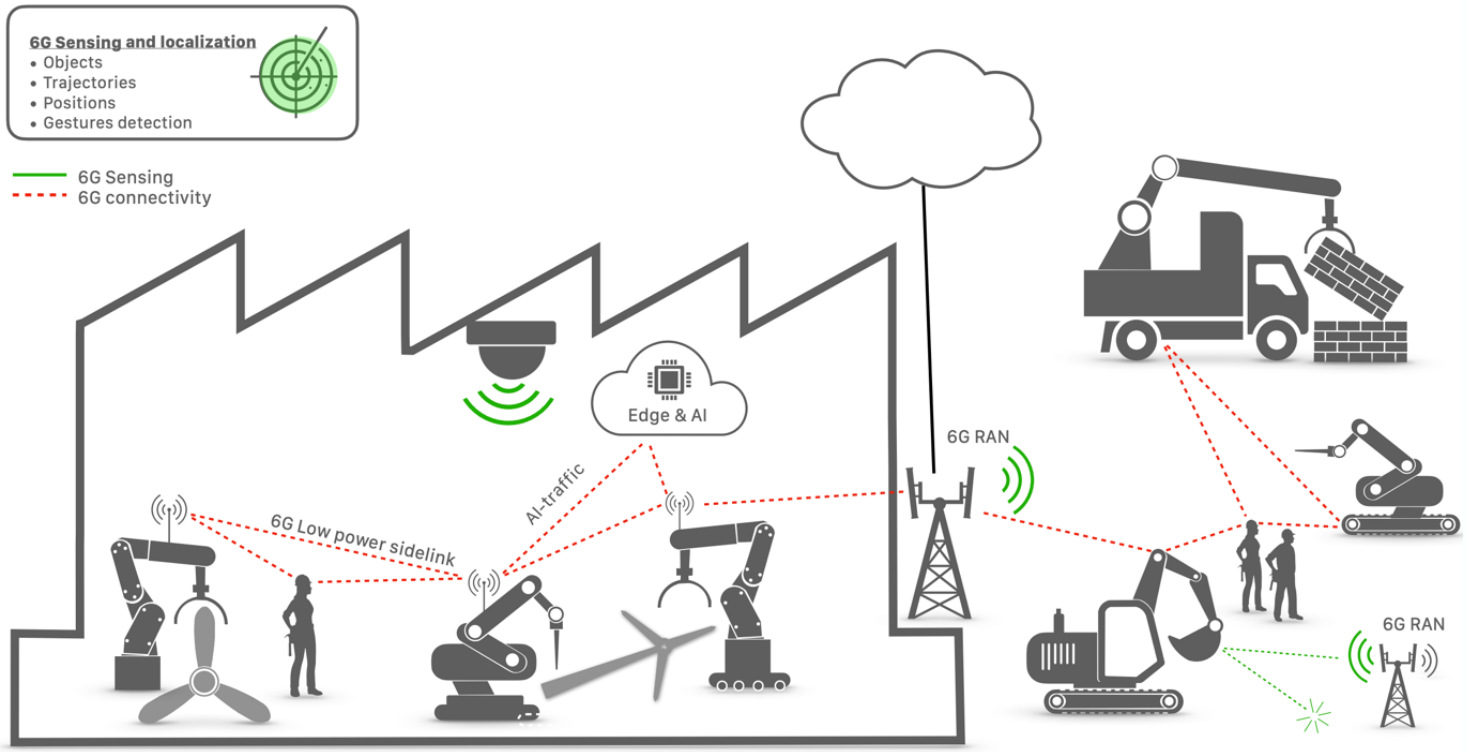
Emphasis lies on task-specific local connectivity. Depending on the task or needs, the network topology may undergo frequent changes. The level of machine autonomy determines the communication requirements.

Use Cases

Cooperating Mobile Robots | Autonomous Embodied Agents with Flexible Manufacturing | Mesh Embodied Intelligence

Cooperating Mobile Robots

Collaborative Robots



Cooperating mobile robots
Robots communicate locally to perform tasks beyond their individual capabilities.
E.g., flexible manufacturing, autonomous construction site

Autonomous embodied agents
AI/ML and integrated sensing enable tools/machines to make decisions.

Cooperating Mobile Robots

Collaborative Robots

Functional Requirements

- Local Connectivity & Mobility
- Dynamic topologies
- E2E Latency
- Positioning
- Sensing
- AI/ML

KPIs

Data rates [Mb/s]	< 10	Data rate between robots and campus network, depends on level of autonomy of robots Can be significantly higher locally in a subnetwork (raw sensor data, ML-related traffic)
Area density [Mb/s/m²]	< 0.1-1	World's largest industrial manufacturing campuses accommodate thousands of robots. 1 m^2 per robot, 10% of the overall area occupied
Mobility [km/h]	< 20	Slow vehicular
E2E Latency [ms]	< 0.8	200 coordination messages per second, x3 for redundancy Transfer interval of 1.67 ms x0.5 to ensure enough margin for error recovery [22.104]
Reliability [%]	99.999 – 99.99999	Application-side mechanism compensate occasional packet losses and delays at link level ("survival time") Selected applications may have an even more strict reliability requirement up to 99.999999% [22.104].

PHYSICAL AWARENESS

Physical Awareness use cases build on beyond-communication capabilities in networks: sensing, positioning, compute, and AI. By gathering 3D data about physical scenarios and situations, efficiency and safety can be improved.

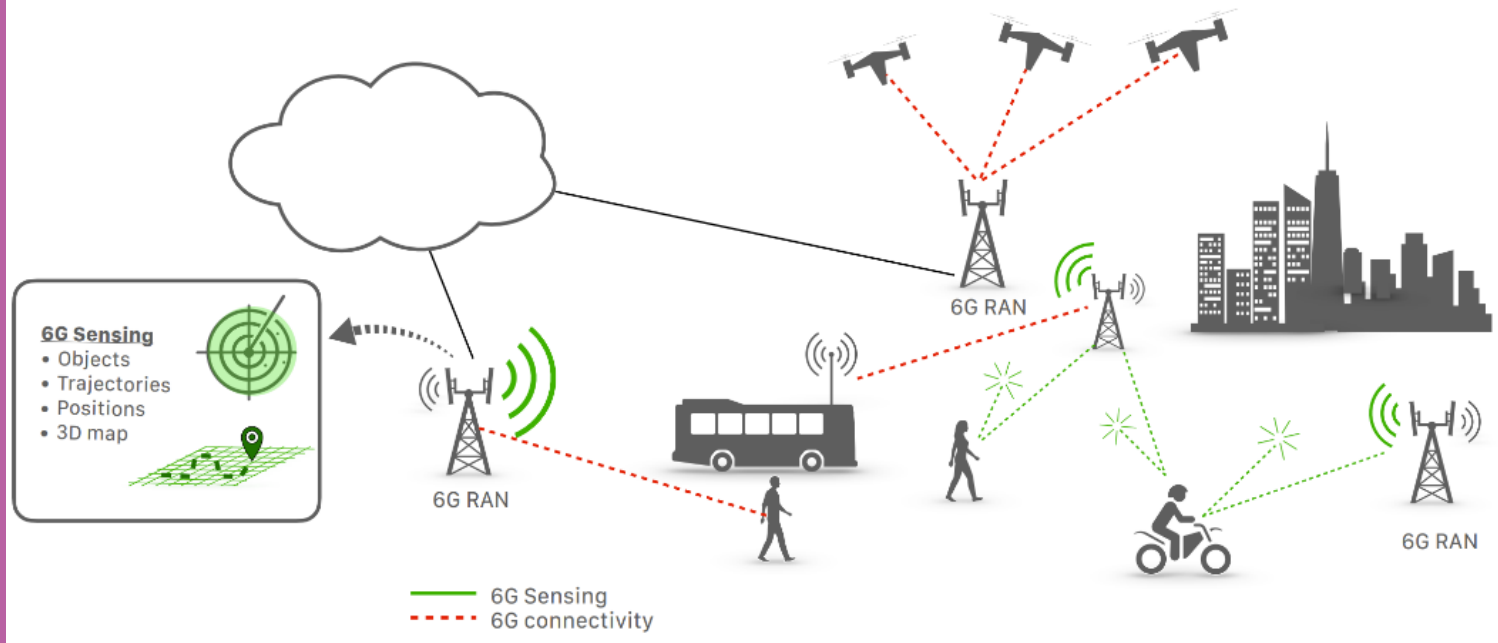
AI-generated image (Dall-E)

Use Cases

Network Assisted 3D Mobility | Network Physical Data Exposure | Wide-area surveillance/Smart Crowd Monitoring | Environmental Radio Sensing

Network-Assisted 3D Mobility

Physical Awareness



Leverages aggregated knowledge of physical scenarios and connected devices

Autonomous drone transport

Safe and efficient guidance of robots

- Using reliable communication links to feed optimal collision-free paths to ground or air drones

Assisted vehicles

Supporting road users with timely traffic data

- Conveying data on connected and unconnected objects in the vicinity

Network-Assisted 3D Mobility

Physical Awareness

Functional Requirements

- Reliability
- Sensing
- Positioning
- Privacy & Security
- AI/ML/Compute

KPIs

Data rates [Mb/s]	1-10	Depends on service type
Location accuracy [m]	1m	Reliable 3D positioning with high availability
Mobility [km/h]	Up to 300	Speed of vehicles (cars, drones, trains) in urban areas
E2E Latency [ms]	1-20	Similar to V2X services.
Reliability [%]	99.99%	Fraction of packets within latency bound E2E
Coverage [%]	99.9%	Fraction of defined 3D service space
Availability [%]	99.99%	Probability to get communication service when requested

DIGITAL TWINS

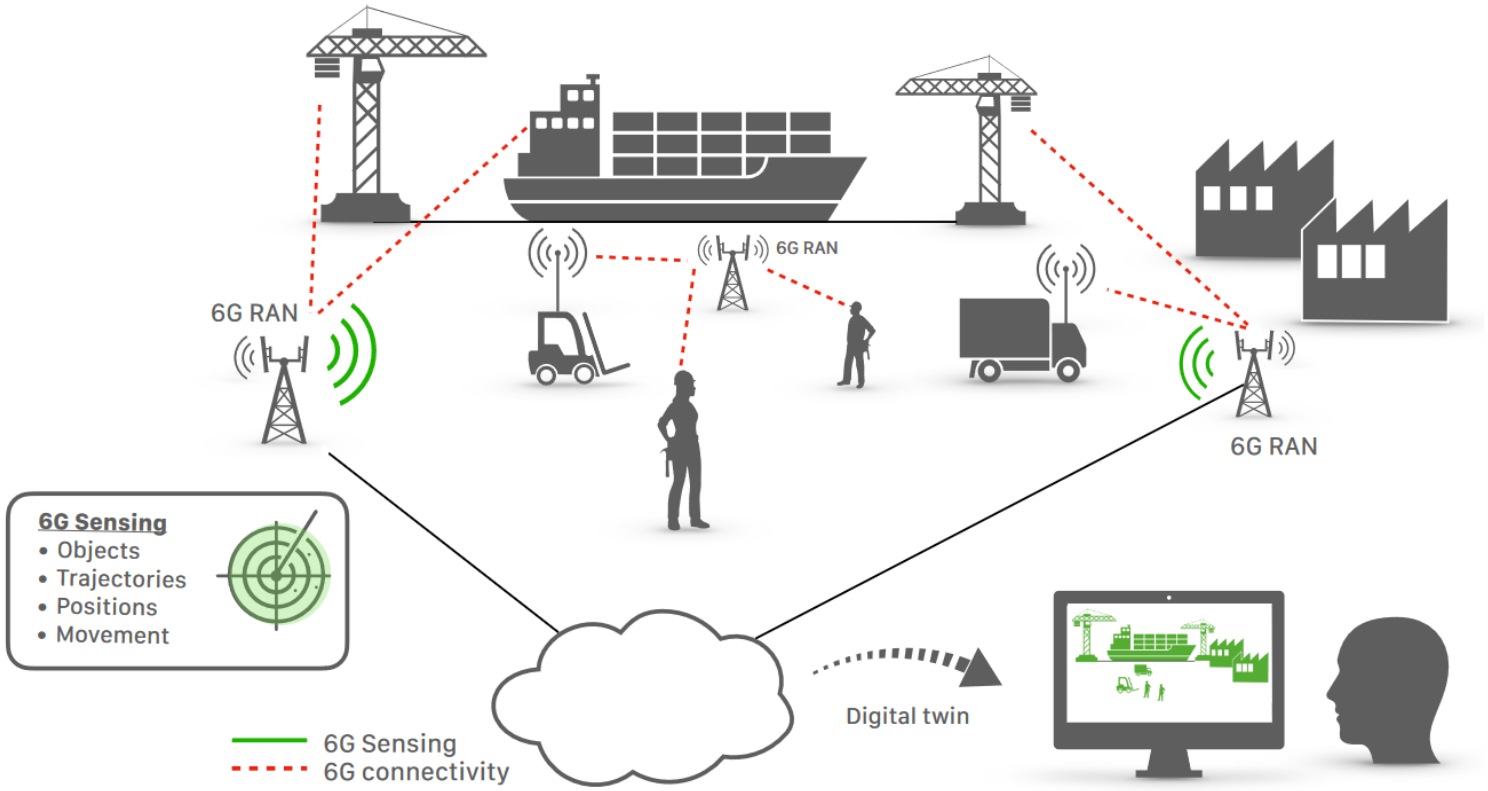
Digital Twins is a set of use cases where digital equivalents of the real world are created and displayed for interaction, control, maintenance, as well as process and component management.

AI-generated image (Dall-E)

Use Cases

Realtime Digital Twins | Cloud Continuum | Smart Maintenance | Digital Twins (Building Model) | PPDR Digital Twin

Realtime Digital Twins



Production plant control

- End-to-end process control (from arrival of the materials, over the production chain, up to the product shipment)
- Expand the DT beyond monitoring and simulating into realtime control of the production, enabled by the low latency and reliable network coverage

Overall Smart City twin

- Seamless, full network coverage over the city (including obstructed areas, both indoor and outdoor)
- Network sensing introduces environment awareness minimizing the need for external sensors

Realtime Digital Twins

Digital Twins

Functional Requirements

- E2E latency
- Coverage
- Interoperability
- Privacy & Security
- AI/ML/Compute
- Sensing

KPIs

Area density [Mb/s/m²]	1-10	High to cope with the high-volume of sensors (with very dispersed data rate needs)
E2E Latency [ms]	< 1	Very low latency for the Realtime aspect
Reliability [%]	99.99999	Very high: The control of Realtime industrial processes requires very high service reliability. Can be lower for non-realtime Digital Twin
Location accuracy [m]	≤ 0.1	High. Accurate Positioning to enrich the Digital Twin model

FULLY CONNECTED WORLD

AI-generated image (Dall-E)

*Ensuring connectivity **everywhere**, expanding beyond purely traditional terrestrial networks to deliver the benefits of communications to everybody.*

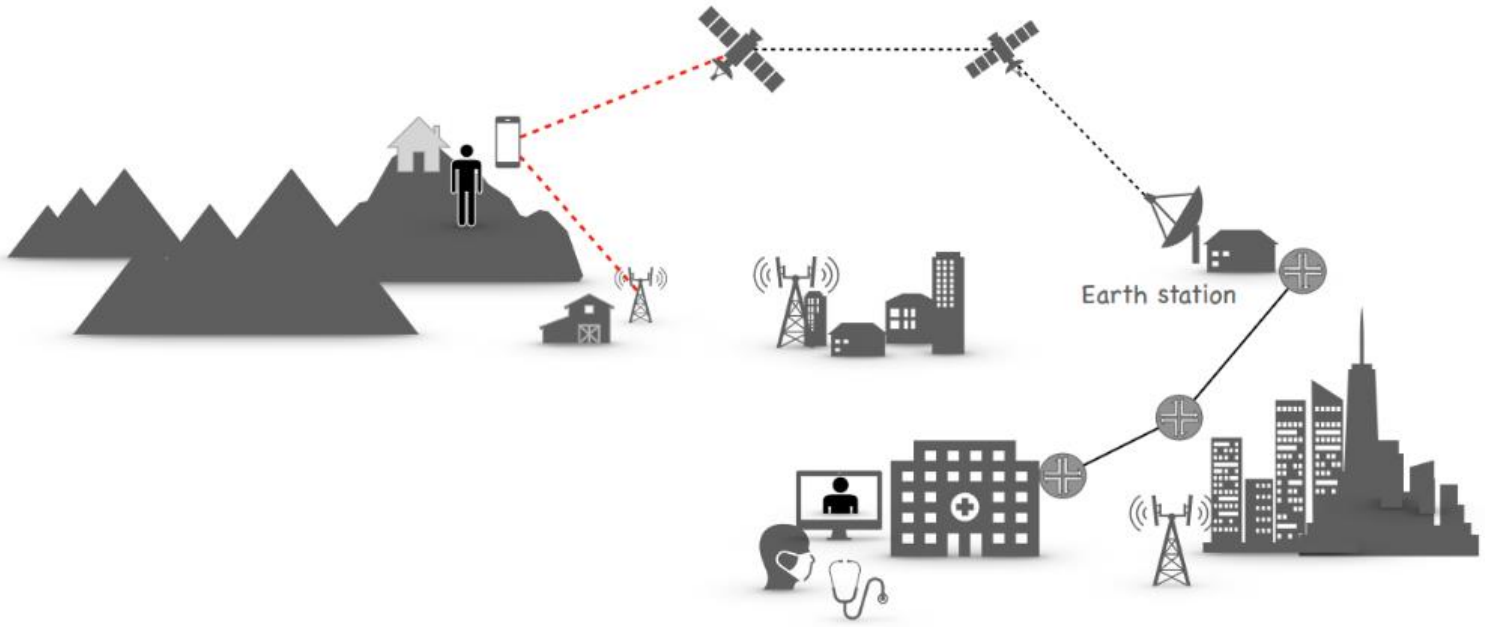
Besides expanding coverage cost-effectively, it also enables network function availability for crisis management, earth monitoring, digital health services, virtualisation of device functionalities, or support of autonomous supply chains.

Use Cases

Ubiquitous and Resilient Networks | Digital Sobriety and Enhanced Awareness | Earth Monitor & Sustainable Food Production | Autonomous Supply Chain | Virtualization of Device Functionalities | Resilient Communication for Safety Critical Applications

Ubiquitous and Resilient Network

Fully Connected World



Delivers Mobile Broadband connectivity to every human on Earth, leaving no “white zones” through tight integration of TN & NTN

Connectivity at Remote Locations

Enabling connectivity in hard-to-reach areas (e.g., cost constraints, deployment difficulties)

- Access to video streaming, remote health consultations, earth monitoring, agricultural services, etc.

Connectivity during natural disasters or emergencies

- Builds resilience in the network

Ubiquitous and Resilient Network

Fully Connected World

Functional Requirements

Coverage/ Connectivity everywhere

Flexibility

Resilience

Privacy & Security

Service continuity across diverse topologies

Affordability

KPIs

Data rates [Mb/s]	0.1 –25 DL 2 UL	For single UE, measured on the device. Based on current standards, from 0.1 (sensor data) to 25 Mb/s (4K video).
Availability [%]	98.5	Appropriate combination of full coverage and capacity to deliver video streaming-like services is required.
Coverage [%]	TN: ≤10-15 km cell radius TN/NTN: 99.9% of human environment	Coverage means both extending the range of TN, but also the coverage % of an area, combining TN & NTN.
E2E Latency [ms]	10-100	Targeting video calls/streaming. 'Real-time' interactions are not considered.
Reliability [%]	99.9 –99.999	Associated with the service requirements, considering fallback between TN & NTN.

TRUSTED ENVIRONMENTS

Comprehends use cases in local environments (streets, hospitals, schools, retirement homes) delivering human-centric services and promoting health, well-being, safety, inclusion, and autonomy in daily life.

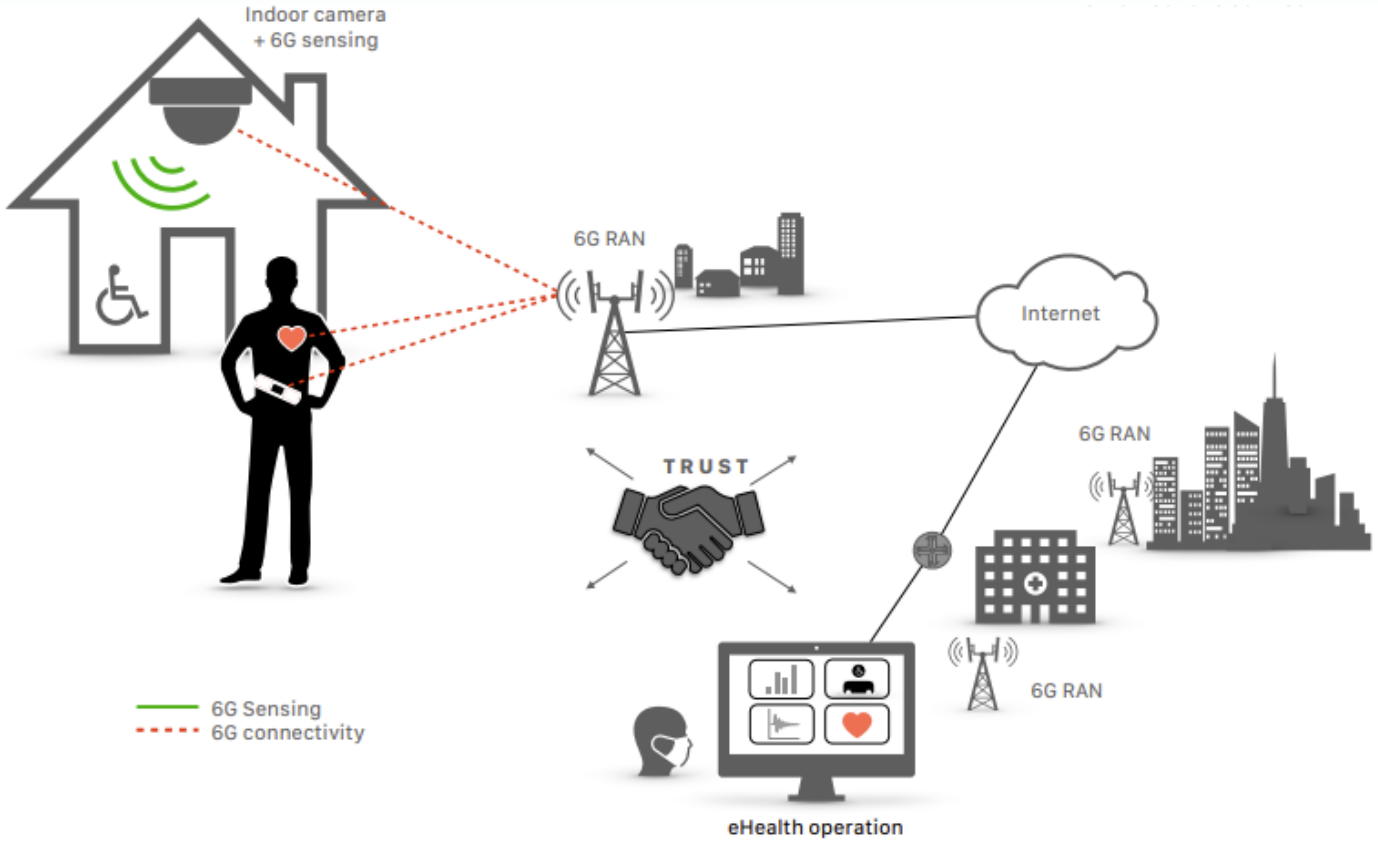
These are based on sensing technologies as well as AI/ML and compute support to create spatial and situation awareness and enable context-driven interventions.

Use Cases

Human-Centric Networks | Industrial Sensors Network for Safe Production & Manufacturing | Wireless In-Vehicle Network

Human-Centric Networks

Trusted Environments



Focuses on the human at the centre of a wide range of 6G services

Precision healthcare
Personalized monitoring, diagnosis, and treatments

Safe environments
Help prevent risky situations and accidents. Able to adapt to different scenarios/stakeholders.

Public safety during big events
Predictive mechanisms to prevent chaotic situations

Human-Centric Networks

Trusted Environments

Functional Requirements

- Privacy & Security
- Reliability
- AI/ML/Compute
- Positioning
- Sensing
- Accurate target & activity identification

KPIs

Area density [Mb/s/m²]	1 to 10 < 0.001	Indoor per floor Outdoor
Location accuracy [m]	< 10 < 0.3 to < 1 < 0.1	Location accuracy Positioning accuracy Relative positioning accuracy, e.g. collision avoidance
E2E Latency [ms]	< 250 < 1000	For AGVs and care robots, e.g. in homes for the elderly and in hospitals. Initiating an intervention in case of an evolving critical situation in a crowd.
Reliability [%]	99.9 – 99.999	High service availability is key for this use case.

Operational aspects

Important additional requirements on the 6G network

Operational aspects

Spectrum aspects

- 6G deployable in 5G bands
- Spectrum sharing support
- Robust connectivity in all frequency bands

Unified interface aspects

- Interface between any devices
- Interfaces between (comm., cloud, app.) service providers
- Intent-based management

Network of network aspects

- One standard for multiple requirements
- Improved TN/NTN convergence

Deployment aspects

- Simplified deployment & management

Migration & mobility aspects

- Smooth migration from 5G
- Smooth 5G / 6G mobility

Feature parity aspects

- 5G functionality supported in 6G

Novel services aspects

- Exposure of new 6G capabilities
- Seamless orchestration across compute continuum
- Native AI/ML capabilities

Smart Networks and Services International and European Cooperation Ecosystem

Thanks for your attention!

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https://smart-networks.europa.eu/csa-s/

https://www.linkedin.com/company/sns-ice/

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Seamless Immersive Reality

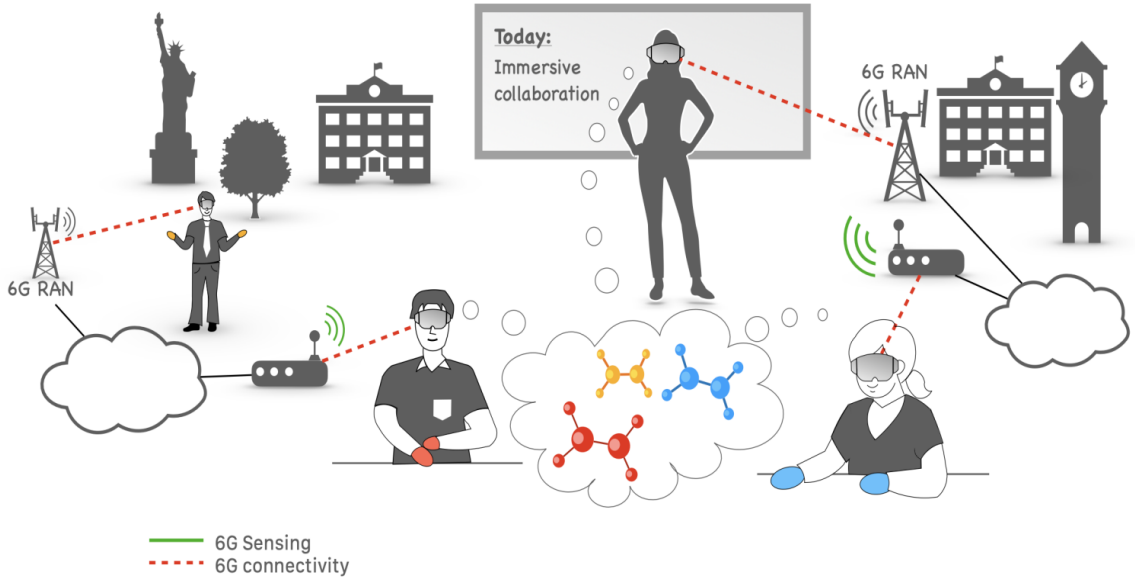
Immersive Experience

Combines mixed reality collaboration and immersive telepresence use cases, referring to seamless real-time interaction with collocated and remote participants and (digital representations of) physical or virtual objects blended into a physical or virtual environment. Seamless Immersive Reality offers a quality of interaction with remote participants (or objects) almost as realistic as if the remote persons (or objects) were present in the same room or physical environment.

This improved quality of experience facilitates interaction, collaboration, co-presence, and co-experience in many if not all aspects of life including aspects of work, be it in the office or on a construction site, education, or healthcare, as well as aspects of our cultural, social, and personal life like enjoying augmented objects in a museum or an immersive game with friends.

Problem(s) to be Solved/Challenges

- Enabling significantly improved quality of experience
- Living and working from anywhere
- Achieve seamless service continuity
- Ensure privacy protection



** digital representation of real object*

Seamless Immersive Reality: Sustainability Analysis

Immersive Experience

	Sustainability Handprints (benefits)	Sustainability Footprints (cost)
Environmental	• Increase in resource efficiency in other sectors, such as transport and energy • Reduces the need for large physical spaces and extensive venue infrastructure	• Increased electronic waste from the disposal of devices and network equipment • Increased material consumption from producing the hardware components and expanding network infrastructure including raw material extraction, manufacturing processes, and transportation • Increased energy consumption and associated Greenhouse Gases (GHG) emissions to power devices, data centres, and active network component
Social	• Enhanced educational possibilities • Enhanced job opportunities • Enabler to participate in social environments (e.g., education, working environments, cultural events, socializing events, etc) • Enhanced quality of life and mental health with more opportunities of social interaction, and due to inclusion and well-being • Enhanced and interactive cultural and educational experiences	• Potential digital divide, digital inequalities depending on access, information technologies (IT) literacy and economic status • Privacy concerns of human digital footprint • Potential risks for trustworthiness in case of hacking • Potential risk for individual isolation and alienation (i.e., loss of human physical contact) • Potential risk for enhancing manipulation (proteus effect: representation of avatar may influence behaviour and attitude)
Economic	• More efficiency/ productivity • Reduced cost for knowledge transfer (efficiency, cost-efficient) • Increased quality with less cost through information exchange • Profitability – new use cases enabled • Economic benefits from the use of efficient virtual training environments	• Equipment cost affecting profitability • Costs from service and maintenance of the gear • Cost of learning as mitigation strategy, equipment needs to be designed for easy use • Massive, initial investment • Like in the case for any new technology, creating potentially

Seamless Immersive Reality: Requirements and KPIs

Immersive Experience

Requirements

- **AI/ML and compute**, device-embedded and/or provided by the network: for creating a seamless immersive experience this use case may require AI/ML and compute capabilities to render 6DoF video and spatial audio, and to solve intelligence tasks for immersion and interaction like for instance object detection and tracking, or gesture recognition.
- **Sensing**: immersive experience requires the human sensory system to receive realistic stimuli from a mixed or virtual reality. Some scenarios may use joint communication and sensing (JCAS) or may apply sensor fusion of network and sensor data of connected sensors.
- **Positioning:** this use case requires accurate positioning for a seamless immersive experience. Network-based positioning may be needed for some immersive telepresence scenarios.
- **Privacy protection:** sensing technology and the need to share data for immersive telepresence create a high demand for privacy protection.
- **Service continuity:** service at a minimum level to provide a sufficient and for the end user comprehensible and satisfactory quality of experience across diverse locations ranging from local wireless networks to the wide area network.
- **On-body and in-body sub-networking capabilities:** for immersive experience including haptic actors and sensors on-body sub-networking capabilities, for in-body monitoring applications even in-body sub-networking capabilities, may need to be supported.
- **Synchronization between participants and data streams:** protocol stacks need to support low E2E latency in synchronization of participants and inter-participant data streams.
- **Digital immersive mapping as a service:** to assist seamless immersive reality, digital immersive mapping is provided as a service by the network.

KPIs

	KPI	Target Range	Justification
Communication	User-experienced data rate [Mb/s]	< 250	DL, also UL, for instance if the UE takes the role of a gateway
	Area traffic capacity [Mb/s/m^2]	< 250 < 20	Indoor: per floor in a multi-story building Wide area: focus on immersive experience “on the go”
	Mobility	seamless HO	Pedestrian up-to vehicular speed for mobile passengers
	End-to-end latency [ms]	< 10 < 50 < 150	Split rendering Voice Collaboration
	Reliability [%]	99.9– 99.999	Depending on service and data stream
Positioning & New Capabilities	Positioning accuracy [cm]	≤ 10 horizontal ≤ 10 vertical	Some services may use network-assisted positioning; high positioning accuracy typically requires device-based sensors and sensor fusion.
	Sensing-related capabilities [Y/N]	Y	Some service scenarios may include JCAS or may apply sensor fusion of network and sensor data of connected devices
	AI/ML-related capabilities [Y/N]	Y	Device-embedded and/or provided by network

Immersive Enterprise and Industry

Expanding on the possibilities introduced in the representative use case **Seamless Immersive Reality**, devices and applications supporting immersive experiences are expected to be beneficial for enterprise and industrial scenarios as well.

There is an almost unlimited range of application scenarios, both in office space as well as on manufacturing, logistic, or construction sites, to:

- enhance productivity
- increase profitability
- fuel creativity and innovation
- enable analysis and exploration
- enable service, maintenance, and education
- establish lean and safe processes
- enable sustainable alternatives

A few examples of what an immersive enterprise or an immersive industry can be are presented below.
An **architecture firm** may combine immersive collaboration and mixed physical and telepresence of employees and clients to enable efficient concept creation. Similarly, a **consulting firm** may efficiently explore solution options in a client site's virtual environment, be it a logistic centre or a crowded airport. Practically, every **supplier**, e.g., a garden centre, a furniture retailer, a boutique shop in a mall, may increase their profitability by immersing customers in their solution concepts based on their products. The service branch of a **manufacturer**, e.g. of automation robots, may enable service teams on-site to safely repair and maintain the equipment using mixed reality guidance. Multi-site **enterprises** can benefit from seamless immersive reality in multiple dimensions. For instance, an **oil company** which includes offices and off-shore sites, may not only set up a safety education program for their workforce but as well enable handling of critical, hazardous situations. Another example would be a global **financial consulting firm** combining highly efficient data analytics with immersive reality-based visualization for internal meetings or meeting with clients.

Immersive Education

Ensuring accessibility and quality of education has been challenging due to a lack of infrastructure, logistic challenges, appropriate tools, and due to the digital divide. An example of such challenge is the COVID-19 pandemic that forced schools all over the world to physically shut down and operate in a remote fashion. Difficulties to establish meaningful student-teacher or student-student interactions, lack of suitable digital learning environments, and low-quality internet connections affected education scope and quality.

How much more students might have benefitted from a class on history, biology, mathematics, or any other subject if immersive experience solutions had been available for meaningful collaboration and immersion in a virtual classroom or a virtual lab. The pleasure of curiously exploring by virtually seeing, hearing, touching, and maybe modifying structures like an ancient building, a molecule, or a 3D model will raise motivation and attention to the content. Likewise, workers for instance on a construction site or an offshore oil platform face very specific safety risks for their own health and the health of their co-workers. Trainings to avoid or to master hazardous, safety-critical situations is costly, if these trainings happen in the actual environment, with actual equipment, and if instructors need to be physically present. A safe, cost-efficient, and environmentally sustainable method could be to train in an immersive virtual reality setting across multiple sites.

Targeting widely extended service coverage, the Immersive Education use case implies universally accessible high-quality wireless networks, extreme coverage including NTN, and local wireless networks as well as local networking based on sidelink and mesh networks embedded in the wide area network. Access to Immersive Education means to provide service continuity at a minimum level to provide a sufficient and for the end user comprehensible and satisfactory QoE across diverse locations ranging from local wireless networks to the wide area network and even to underserved areas connected by satellite.

Immersive Gaming

Immersive Gaming offers 3D immersive experience entertainment in gaming and e-sports to a single player and/or to multiple remote players in an indoor environment such as players' homes, gaming arenas, and schools. Real-time gaming services can be provided to multiple remote players within a network or among different networks. Using AR/VR/MR equipment and sensing a player's motion as well as objects in the room is a requirement for interacting with other players and the virtual world.

Accordingly, high user-experienced data rates with low E2E latency are required. Furthermore, service reliability and positioning accuracy need to be improved.

Live and Interactive Immersive Content Creation

Live and Interactive Immersive Content Creation offers consumers the possibility to enjoy immersive content tailored by content creators. Using network Application Programming Interfaces (APIs) to adapt the service delivery to the changing content allows for creating an engaging immersive experience that fully leverages the network's capabilities.

This use case builds on the seamless immersive reality use case with the following additional requirements: Live content contributors need to be able to transmit at very low latency to a system node ("mixing table") which combines the live content of multiple contributors to a single, well-orchestrated experience. For the best possible experience, content providers need to adapt the content to specific conditions of the consumers. Finally, network APIs are required to include experienced designers into the process of live content creation.

Finally, it is envisioned that raw data will be sent directly to the server, which is crucial for achieving lower latencies. Sending uncompressed or encoded data results in very high data rate requirements. For example, a single stream of Ultra High Definition Video requires over 12 Gb/s (3GPP TS 22.263). For Immersive Experiences, much higher data rates are required as envisaged for 6DoF video with full body tracking.

Cooperating Mobile Robots

Collaborative Robots

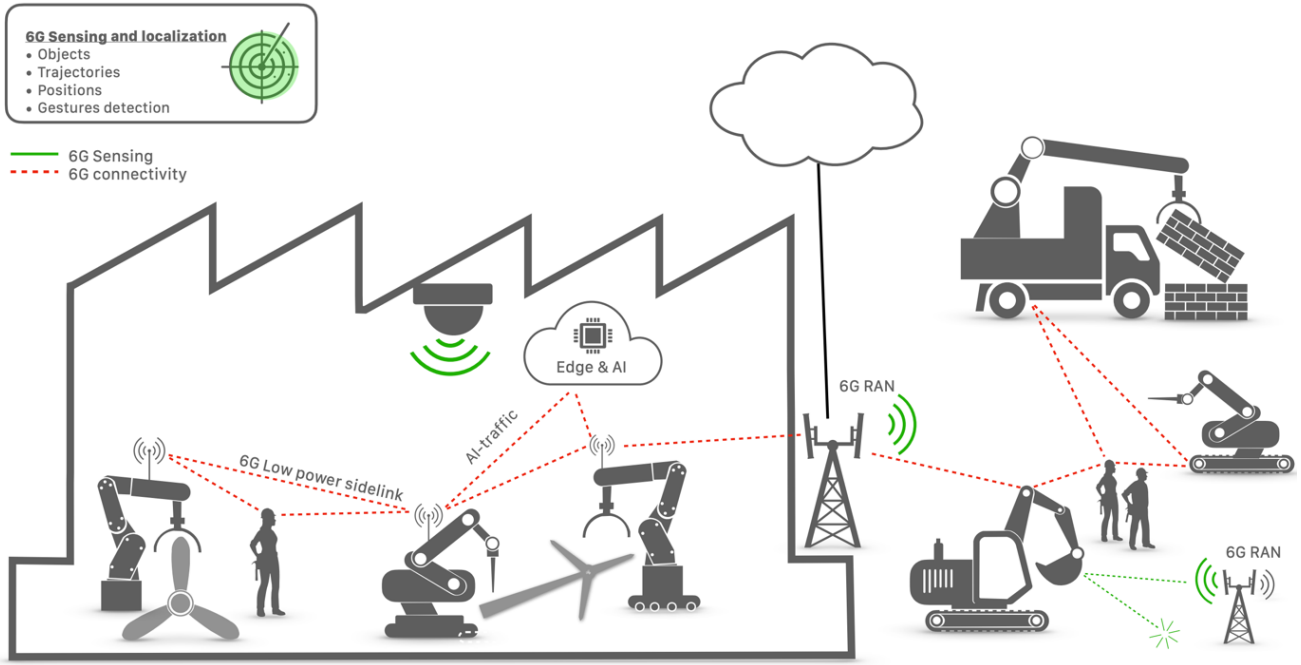
At the centre of this use case are autonomous robots with the ability to move, sense their environment, and perform a productive task. These robots can communicate with one another, with other machines, and with nearby humans to perform individual tasks that contribute to a common cooperative objective. The purpose of communication is safety and cooperation, to enable a group or swarm of robots to perform tasks beyond their individual capabilities and to enable individual robots to perceive their environment beyond their local capabilities. Realtime reconfiguration of the robot function (not only the task) increases the flexibility of their use.

This use case focuses primarily on local ad hoc connectivity embedded in private networks. Scenarios may include industrial manufacturing campus, construction site, and smart living.

In this context, the network of the future is envisioned to enable local cooperation among robots (swarm), to support autonomous task-solving by the robots, to enhance the safety of human-machine interaction, and to ensure that only authorized machines and humans can participate in task solving.

Problem(s) to be Solved/Challenges

- Understanding and addressing the communication requirements of machines in the future
- Using limited resources efficiently
- Adapting to dynamic requirements of the market
- Online changing the function of the robot/Flexibility
- Extended service life
- End-user access to custom manufacturing
- Safe and trustworthy interactions with tools that can make decisions



Cooperating Mobile Robots: Sustainability Analysis

Collaborative Robots

	Sustainability Handprints (benefits)	Sustainability Footprints (cost)
Environmental	• Resource efficiency: Functionalities may be provided by machines with less materials, energy, and waste generated • Function integration eliminates the need for multiple dedicated machines with individual functions	• Energy is consumed and materials are used to manufacture, deploy, and operate robots and associated services • The manufacturing, including material extraction and industrial processes, and transportation of robots generate GHG emissions • The disposal of machines and devices results in increased electronic waste
Social	• Accessibility: help people perform tasks beyond human capabilities • Safer work environment. • Increased trustworthiness of on-time delivery of the expected outcomes • M2H support: Robots could fulfil assistance roles, such as supporting the elderly at home	• Rendering roles obsolete: may eliminate job roles involving manual, linear, and repetitive tasks • Robots and cobots may require human operators to obtain new skills w.r.t. their method of use and maintenance (IT/robots literacy) • Benefits of robots and cobots might not be distributed evenly among society • People's privacy may be breached by unauthorized use of robots' and cobots' sensors
Economic	• Increased productivity and enhanced competitiveness • New business opportunities may emerge from technology leadership in autonomous robotics • New business opportunities for individuals: Cf. "Accessibility" in "Social benefits" • New job opportunities	• Extra R&D investments. • Initial investments to purchase, install, and set up autonomous machines may be a barrier for smaller businesses or those in developing countries. • Increased reliance on robots/cobots can pose a risk in case of failures or cyber-attacks • Monopolization risks • The use of autonomous machines can raise new regulatory and legal issues

Cooperating Mobile Robots: Requirements and KPIs

Collaborative Robots

Requirements

- **Local ad hoc connectivity:** A collaborative task is characterized by its localized nature. Direct communication between connected devices allows this to be exploited, leading to the formation of subnetworks. These subnetworks, envisioned to be task-specific, temporary, and localized, are embedded within broader campus networks. This structure aids in meeting stringent latency and reliability targets within each subnetwork.
  Alternatively, swarms of affordable generic robots may have their intelligence in the network.

- **Extremely reliable and low latency communications:** Interruptions in industrial manufacturing operations typically entail huge financial and material loss. Safety-critical applications are intended to protect human lives. As such, applications in this domain have among the strictest service-level reliability and E2E latency requirements. The service area may be highly localized to subnetworks and increased autonomy in machines may accommodate lower reliability and higher latency.

- **Mobility:** The localized and ad hoc nature of subnetworks in a 6G environment may induce frequent handovers as machines join and leave. These subnetworks, while logically embedded in a campus network, may exhibit nomadic behaviour within it, and the roaming of subnetworks between different campus networks may also occur.

- **Sensing, positioning, and AI/ML:** Integrated sensing capabilities within the 6G network and devices (JCAS/ISAC) can potentially enhance a robot's perception of its environment. The introduction of AI/ML traffic types and AI/ML execution in edge nodes can further enhance robot coordination. For maximum accuracy, it is likely that data from device-based sensors will be utilized in fusion with information from the network.

KPIs

	KPI	Target Range	Justification
Communication	User-experience data rate [Mb/s]	< 10	Data rate between robot and campus network. Can be significantly higher locally in a subnetwork where raw sensor data and/or AI/ML traffic is exchanged.
	Connection density [devices/m^2]	< 0.1 - 1	Mobile robots occupy an area of 1 m2, and it is assumed that they occupy at most 10% of the overall area to ensure fluent mobility. The world's largest industrial manufacturing campuses accommodate thousands of robots. The advent of generic affordable robots can drive density
	Mobility [km/h]	< 20	Slow vehicular
	End-to-end latency [ms]	0.8	Industrial machines may exchange coordination messages up to 200 times per second and can be triplicated for redundancy. This results in a transfer interval of ca. 1.66 ms. E2E latency limit is set to at most half that interval to ensure enough margin for ARQ. [22.104]
	Service-level reliability [%]	99.999 – 99.99999	Application-side safety net mechanism like "survival time" and "grace period" are employed to compensate occasional packet losses and delays at link level. Selected applications may have an even more strict reliability requirement up to 99.999999% [22.104].
	Coverage [%]	—	Localized nature of a joint task makes local ad hoc connectivity favourable.
Positioning & New Capabilities	Positioning accuracy [m]	< 0.1 (fine) < 1 (coarse)	Tasks such as environment mapping, robot navigation, and inventory management require fine positioning. Tasks like robot localization need coarse positioning.
	Positioning availability	99.9%	High positioning availability is required for safety-critical applications.
	Sensing-related capabilities [Y/N]	Y	Robots and cobots depend on capturing the environmental context. Network-integrated sensing may complement or replace dedicated on-board sensors. Efficient transport of data/information from connected external sensors likely needed.
	AI/ML-related capabilities [Y/N]	Y	Robots and cobots depend on advanced machine learning. Execution may be embedded in the device and/or offloaded at a local edge and/or provided by the network as an over-the-top service.

Embodied Intelligence for Mesh Network Architectures

Collaborative Robots

Mesh networks, known for their robust and decentralized design, are complex communication systems where nodes or 'devices' cooperate to distribute data amongst each other. This ensures optimal data paths and redundancy, providing reliable and efficient network communication. Embodied intelligence, on the other hand, refers to the concept of embedding AI and machine learning capabilities directly into devices or 'bodies' within the system. This allows these devices to learn from their environment, adapt to changes, and make decisions autonomously. This topic explores how embodied intelligence can enhance mesh networks. By incorporating AI directly into the network nodes, these systems can become more adaptive and efficient. Nodes can learn optimal data paths, predict potential network issues, and dynamically reroute data when necessary, all while reducing the need for centralized control. Implementing embodied intelligence in mesh network architectures also presents several challenges, such as ensuring the security and privacy of data, maintaining the interoperability of diverse and decentralized devices, and managing the computational and energy demands of running sophisticated AI algorithms.

Problem(s) to be Solved/Challenges

- Energy Efficiency
- Security and Privacy
- Performance Management
- Scalability
- Interoperability

Source: Wirtschaftsförderung Sachsen https://standort-sachsen.de/de/damit-der-roboter-auch-im-funkloch-arbeitet

Autonomous Embodied Agents within Flexible Manufacturing

In future production scenarios, such as industrial grounds, smart cities and hospitals, intelligent machines will be used to complement and even replace human labour. Whereas traditional robots can be defined as movable machines that obey direct commands and have limited self-deciding abilities, these intelligent machines can be understood as an artificial intelligence agent that has been equipped with a physical, movable body. As a result, these machines are referred to as *autonomous embodied agents* rather than robots.

Rather than simply coordinating with each other to fulfill a collective task, autonomous embodied agents oversee more high-level tasks, whose execution requires interpretation and decision making. In that sense, autonomous embodied agents aim at replacing human workers at complex tasks. For example, these agents could be given the order of replacing all instances of part A with part B in the products being manufactured, check the production line for possible problems or inefficiencies, or reconfigure the operation of other machines.

As with humans, autonomous embodied agents are not only the recipients of direct commands, but they can also have the initiative to inform about the status of other components in the factory or even spontaneously raise alarms. For this, they maintain an updated context which is used to translate the combination of abstract orders and the status of their environment into specific actions. This context is the result of processing multiple information sources, such as their own sensors and the communication network itself. Namely, the 6G mobile network providing connectivity to these agents will implement joint communication and sensing capabilities so as to provide the agents with global perception, rather than being limited to local perception. The reason is that, on the one hand, the accuracy of local sensors may not be high enough to ensure safe and efficient operation. On the other hand, having access to only local information for each robot may lead to suboptimal decision making. In this context, JCAS is envisioned to help ensuring power and resource efficiency over what could be accomplished by using separate infrastructures for communication and sensing.

As opposed to unintelligent robots that are directly commanded by an operator or tightly coordinated with one another, low latency and highly reliable communication are not expected to be as critical in this use case. Instead, supporting native access to positioning and sensing information sources, as well as native support for AI training and operation (e.g., by means of federated learning, collective reinforcement training, AI-as-a-Service, etc.) is the most crucial feature that the network must support.

Network-Assisted 3D Mobility

Physical Awareness

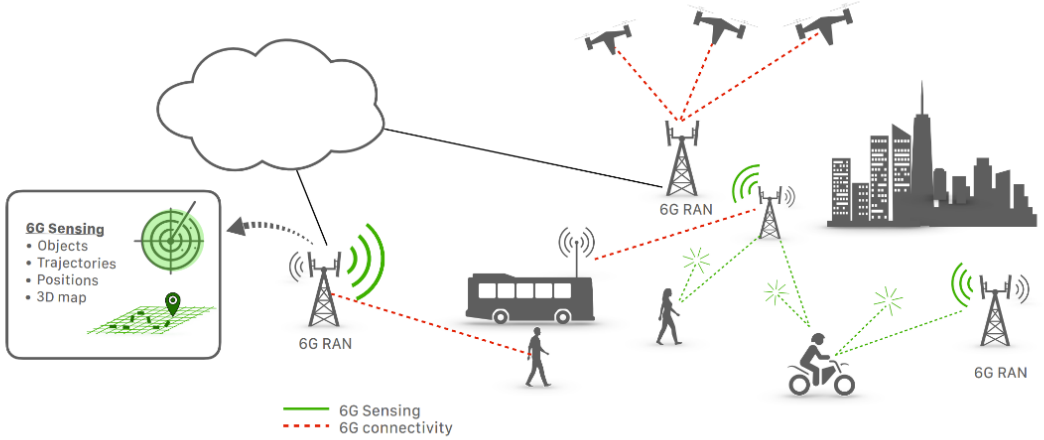
In this use case, participants in (air) traffic (cars, AGVs, drones, etc.) are relying on the network nodes and devices for localization of connected and unconnected objects and for determination of their properties such as size and velocity, contextual info, trajectories etc. Participants in traffic have a reliable connection to the network, with services available in a well-defined service area. Networks measure the physical environment in traffic scenarios and analyse to detect objects, and aggregate data of device positions and from this large data set extract information to relay to vehicles. Position data shared with vehicles can include vulnerable road users (VRUs), such as pedestrians and cyclists.

In more complex (air) traffic environments the data is integrated (sensor fusion) with additional (existing) road/air/rail sensor nodes data to ensure high robustness, trust and compliance with regulations.

This can be done on several levels; networks can provide raw or processed environment and position data, or navigational support ranging from collecting and sharing of data, over navigation assistance, to full operation, leveraging on beyond-communication capabilities. The network can thereby support vehicles with different levels of autonomy and different modes of operation and enable smart transport in urban areas. Furthermore, there is a possibility to use the physical environment understanding around nodes and devices to improve communication to vehicles by tailoring beams, avoid blockers, etc.
Some examples of the services provided by networks are: *network assistance info* (warnings, trajectories, object locations), *network assistance map* (digital 3D map data), *network navigation* (route recommendations), *full operation* (remote control of vehicles) and **context**-*aware communication* (beam forming, path selection, scheduling).

Problem(s) to be Solved/Challenges

- Risk of accidents with intense and automated transport scenarios
- Energy consumption and generated emissions from transport
- Cost of transportation of goods and people
- Access to reliable transport
- Privacy in public spaces
- Network energy consumption



Network-Assisted 3D Mobility: Sustainability Analysis

Physical Awareness

	Sustainability Handprints (benefits)	Sustainability Footprints (cost)
Environmental	• Reduction of GHG emissions by improving the traffic flow at the intersections thus requiring fewer traffic lanes and freeing up space for pedestrians and green spaces next to the roads • Reduction in accidents would help reduce automotive waste generated by repairs and scrapping of unrepairable vehicles and the GHG generated in the process • Supported driving, including network-assisted small driverless electric vehicles, made more efficient will reduce fuels and thereby reduce related emissions	• Increased energy consumption linked to sensing activities, including data collection, processing, and communication within the network, sensing devices operations, as well as real-time requirements • To enable the positioning services, new low power devices would have an additional energy footprint for the compute needed at the core • Materials and energy needed as well as lifecycle emissions for additional Information and Communication Technologies (ICT) infrastructure
Social	• Enhanced safety and well-being through reduced transport-related accidents • Increased availability of transportation: automated/self-driving vehicles would decrease the need for human drivers' availability and could be available any time at any area • Preserved/uncompromised privacy (compared to video-based perception) • Enhanced continuity of transportation service even in rural areas (digital inclusion)	• Potential risks for privacy associated to localization data • Potential risks for trustworthiness in case of hacking (e.g., leading to more accidents) • Potential risks for wrong decisions made by AI/ML • Decreased job opportunities
Economic	• Reduced costs for stakeholders for improved profitability from using the network for the monitoring tasks instead of additional sensors • Improved efficiency from freeing resources for other use that can bring profits	• Safety/predictability risks with potential economic impact • Expenses of network infrastructure to meet the requirements for high reliability of services

Network-Assisted 3D Mobility: Requirements and KPIs

Physical Awareness

Requirements

- **Privacy**: personal identities in public spaces must be handled in such a way that privacy is not jeopardized.

- **Localization**: Network nodes need to be able to perform radar-like measurements using the radio interface, to detect unconnected objects, which is delivered by JCAS functionality. In conjunction with this capability, precise device positioning is required. For both these capabilities, it is expected that networks will only be able to deliver part of the required precision and coverage. A sensor fusion functionality would therefore be needed, where networks collect data from multiple sources, e.g. onboard camera and GPS, and fuse it with the network measurements to create an enhanced dataset that is shared with the device and other devices.
    - High wide-area coverage for positioning and sensing services, also in 3D.
    - High detection probability and identification accuracy of unconnected objects.

- **Connectivity**: Reliable communication is a critical aspect of this use case. For safety reasons, the link to the network should not be allowed to go down other than during very short periods within the service area. This may be difficult to achieve in practice considering 3D mobility within a city where links may be blocked at times. But the network should have the capability to predict and notify the connected vehicles such that they can take preventive action (e.g. stop or switch to a local operation mode). Or that additional sensor nodes can be integrated into the city/ airports/rail. The network should also be able to timely activate adjacent links to ensure connectivity, e.g. to other devices and networks.
    - High resilience, availability, and reliability for connectivity in 3D; preferably without requiring excessive deployment of network nodes.

- **Compute**: Offload from the vehicles to the network of heavy processing tasks and training of models should be supported, as well as in-network real-time processing of sensor data. This means that the networks should have the capability of reliable compute and AI/ML-related functionality that can be accessed at all times from any point in the network.
    - Availability of reliable compute capabilities offered by the network and vehicle which can be used indiscriminately by various applications.

KPIs

	KPI	Target Range	Justification
Communication	Peak Data Rate [Gb/s]	–	Not expected to be a challenge
	User-Experienced Data Rate [Mb/s]	1-10 (<100)	Depends on service type: lower for warnings and assistance, higher for digital maps. (For sensor fusion exchange of data may be higher.)
	Spectrum Efficiency	–	Same as for communication services
	Area Traffic Capacity [Mb/s/m^2]	–	Not expected to be a challenge
	End-to-end latency [ms]	1- 20	Similar to V2X services.
	Reliability [%]	99.99	Fraction of packets within latency bound E2E
	Coverage [%]	99.9	Fraction of defined service space (in 3D) within latency bound.
	Service availability [%]	99.99	Probability to get communication service (as defined with E2E latency) within service space when requested. (Can replace coverage and reliability)
	Connection density [devices/km^2]	10^4	Not expected to be a challenge
	Connection density [devices/m3]	0.01	Not expected to be a challenge on the ground, except for UAV swarms. Note also 3d space should be used not 2D.
	Mobility [km/h]	Up to 300 seamless handover	Speed of vehicles (cars, drones, trains) in urban areas. Handover within latency bound
Positioning & New Capabilities	Location accuracy [m]	1 (3D) precision with 99.9% reliability within 99.9% of service space (0.1)	Reliable positioning with high availability important for use case, but likely multiple sources (e.g. from onboard sensors) can be combined to achieve more precise positioning. (Sensor fusion).
	Sensing-related capabilities [Y/N]	Y	Object detection probability, Object location accuracy/resolution, Object velocity accuracy/resolution, Object size accuracy/resolution.
	AI/ML-related capabilities [Y/N]	Y	Probability of a response time of compute/AI capabilities within a latency limit.

Uncovering Illegal Activities on Ground and Sea

Physical Awareness

Illegal activities on sea and land may be related to border violation, drug smuggling, environmental pollution, violation of trade rules, unauthorized access to protected areas, organized crime, theft and robbery, etc.

Suspicious objects may try to hide themselves, but can be made visible by proper sensors, especially if deployed on 3D mobile platforms. Integrated sensing and communication will be a key enabler for obtaining situation awareness and assessment. The mobile radio interface can be used to receive intentional or unintentional radio emissions of the suspicious objects. If the object is completely silent, it can be made visible by ISAC radio wave illumination and radar sensing. Mobile platforms like swarms of drones allow dedicated missions at favorable positions. The air view supports sensing at otherwise inaccessible positions. This applies even more when satellite-based non-terrestrial Networks (NTN) are equipped with ISAC functionality. This unlocks applications in areas with no adequately provided terrestrial infrastructure and even allows global availability for traffic monitoring on see and even in air. Since ISAC is a part of a ubiquitous communication network, not only sensing is supported but also data fusion and processing in network attached computational facilities.

Problem(s) to be Solved/Challenges

- Unprecedented system requirements for ISAC in NTN networks
- Satellite and UAV cloud operation (sensor cooperation and mission control, data fusion, etc.)
- New sensing performance measures required such as satellite revisit time and dynamic target tracking
- Link budget and sensor revisit time issues in NTN ISAC
- Resource allocation issues (multilink access coordination, beamforming control, integration time)
- Detection, recognition and classification of non-cooperative radio emissions (including out-of-band and atypical (“alien”) radio signals)

Environmental Radio Sensing

Physical Awareness

This use case focuses on sensing the environment as a service of 6G. An effective monitoring of environmental sensing whether satellite-based or using sensing capabilities of terrestrial networks can highly improve the coverage of weather-sensitive frequency band of 6G communication.

The progress in sensing capabilities of 6G communication systems offers important information about weather conditions, which can affect the quality of service tremendously. Besides the characteristics of the transmission channel, the sensing capabilities also offer information about participants in the wireless network like pedestrians using mobile end-user devices or more dynamic participants like connected vehicles as well as points, which require large channel capacity like offices or public buildings. This information about the environment of a communication network offers MNOs new capabilities of dynamic adjustments of their provided network. Furthermore, environmental agencies as well as city management will benefit from the environmental data to predict the level of groundwater or rivers.

Problem(s) to be Solved/Challenges

- Deliver highly important environmental and atmospheric data
- Safety, health, and peace of inhabitants in times of changing climate conditions

Network Physical Data Exposure

Physical Awareness

This use case is about exploiting the network as a source of information on the physical environment, unconnected and connected objects, exposed as a service to a range of applications.

By combining input from network-based sensing and positioning, 3D maps, and sensor fusion of connected sensors, the networks are in a good position to maintain a digital twin of a geographical area. This includes information on the landscape itself and buildings, as well as people, animals, machinery, and vehicles.

Services that can be offered by the network include:

- Generate statistics about vehicles and transportation systems
- Analysis of traffic situations
- Estimating the number of humans or animals in an area, and flow of people
- Locating humans, animals, machinery, and vehicles
- Maintaining a geographical 3D database (physical digital twin).

Compared to Network-Assisted mobility, this use case is on a longer time scale and does not require the same level of reliability and availability.

Realtime Digital Twins

Digital Twins

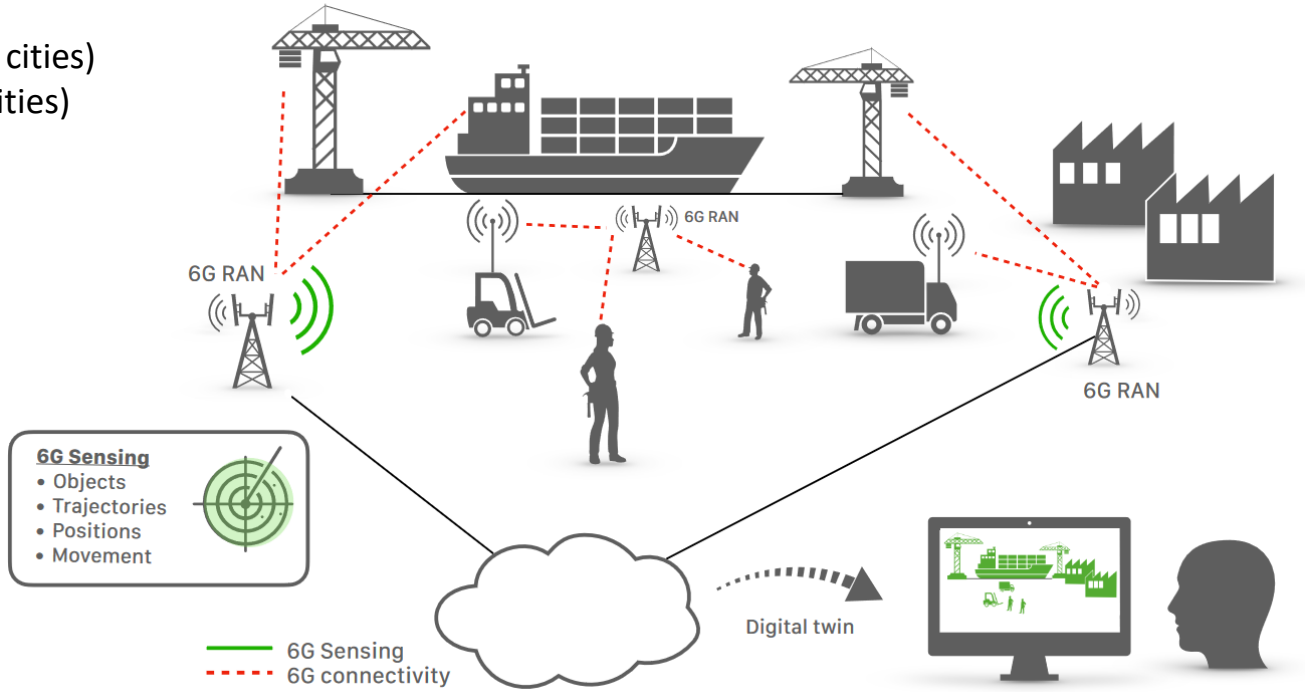
A digital twin is an accurate digital representation of any combination of processes, products, persons, and functionalities of real-world items such as for industry, smart cities, or construction. This contextual digital equivalent of the real world offers a unified access to users and/or agents and is used for interaction, control, prediction, test, maintenance, and management of processes and components. To do so, it needs network connectivity to ingest data from multiple sources, e.g., databases, sensors, tags, network data, data models, and optionally steer / control the respective systems via feedback loops. A digital twin is aggregated, generated, and visualized by running dedicated software, including specialized AI/ML algorithms. The real-time aspect, enabled by the low latency capability of the 6G network, allows to extend the digital twin also towards direct control of the actual physical processes.

This use case covers the following applications (non-exhaustive list)

- DT in a manufacturing plant
- DT for water management and improved traffic management (smart cities)
- DT aggregation of sub-DT to cover complex systems (e.g. full smart cities)
- DT for 6G network planning and operation itself
- DT in port operations.

Problem(s) to be Solved/Challenges

- Increase production quality and efficiency
- Prevent situations where humans are put at risk
- Guaranty the privacy & trustworthiness
- Accessibility of DT models
- Discovery/exposure of compute resources



Realtime Digital Twins Sustainability Analysis

Digital Twins

	Sustainability Handprints (benefits)	Sustainability Footprints (cost)
Environmental	• Reduced usage of natural resource (e.g., water management, smart cities) by improved monitoring • Reduced waste from the increase of the production quality and efficiency • Sustainable urban development • Reduced GHG emissions from avoided visits to monitored areas, and avoiding operations visits for network planning and operation	• Resource intensive IoT and material required to produce sensors and IoT devices • Electronic waste resulting from the deployment of sensors and equipment • Energy consumption required for processing real-time data, DT generation, data centres, IoT devices, and computing resources
Social	• Reduced dependency on humans (e.g., 24/7 monitoring), leading to increased well-being for humans • Enhanced inclusion/opportunities for particular roles, irrespective of age, gender, disabilities, etc • Increased trustworthiness on data /information availability due to real time monitoring /control • Enhanced accessibility to drinking water and food and its management from DT related to water/food supply, agriculture, etc	• Potential risks to the privacy in the event of a cyber-attack • Potential impact on employability and labour market. Must be studied further
Economic	• Economic efficiency improvements from optimizing operations via digital twins • Improved resilience and flexibility • Improved safety from using digital twin for virtual safety checks • Improved profitability from avoiding costs from problems by using digital twin for optimizing operations (avoiding delays and saving costs including testing before production with end users/customers)	• Possible increased costs from complexity of multi-stakeholder ecosystem • Increased costs from energy, digital twin model, equipment, training, maintenance • Safety/predictability of operations – increased business risk from using technology instead of human perception

Realtime Digital Twins: Requirements and KPIs

Digital Twins

Requirements

- **Realtime aspect:** The very low E2E latency is mandatory to achieve a Realtime DT. The latency target is even more stringent to ensure the competitiveness of machines over the lifecycle removal of embedded software to the network edge/cloud facilitates innovation, integration, and AI.
- **Full coverage:** The full physical geography of the DT needs to have complete network coverage with the appropriate QoS levels, including both indoor and outdoor areas and the locations without Line of Sight. In case of handover in the network needs to be seamless or prevented.
- **Network Sensing:** the DT model is based on real-time data collected from the physical world. All sensing data collected by the network itself eliminates the need for external sensors or improves the reliability of existing sensors and reduces the complexity of the DT ecosystem and logistics.
- **Sensors:** Connected sensors are required for all extra data that cannot be provided by the network sensing, to create an accurate replica of the complex Real-time environment. These sensors might also need a technology evolution beyond the current sensor devices for sensitivity/accuracy. The raw data of high-frequency / video sensors these demands can be extremely high.
- **Improved human-machine interaction**: For an effective DT, users must have a seamless immersive interaction with the DT or Connected Intelligence. To achieve this, all the capabilities/features as defined by the "immersive experience" use case family (also including the high-resolution 3D rendering) are required. (These are not duplicated here).
- **Compute** resources to handle complex models and databases with integrated advanced AI skills to simulate, steer and predict in various domains.
- **Privacy/trustworthiness** supported by a secure network. Especially for smart cities, it will be crucial for the end-users to guarantee the privacy of the collected data. But also for industry, the network should fully support all corporate & industry policies.
- **Hierarchy** of Digital Twins: DTs will be covering larger, more complex systems in society (cities, factories,..). As DT's & CI appear on lower levels (machine level, one production line, one specific utility in a city), there will be overarching DT's popping up to cover the full systems with the requirement to ingest, and incorporate several underlying DT's (hierarchy/interop). This is also called "set of twins" or "massive twinning".
- **M&O capabilities** for the RT DT/CI service to cope with the flexible resource allocation, since compute can be spread over the network core, edge, and device. Also, the sensing/sensor data collection needs to be orchestrated: Not all included devices in the DT will have sufficient sensor capabilities and compute resources on board and will need to delegate this to the network (sensing and edge resources) or to other, better-equipped devices in the vicinity.
- **Interoperability:** The DT might include deployed proprietary and legacy systems. Using open interfaces can make the network more flexible and more manageable (also from an orchestration perspective).
- **Strong system integrators** for the complex implementation of the RT DT, due to low compatibility and multiple technologies (networks, sensors, domain-specific software, and other digital twin systems). Also, new software approaches to integration to facilitate low code, behaviour models with intelligence spread over the network.

KPIs

	KPI	Target Range	Justification
Communication	End-to-end latency [ms]	< 1	Very low latency to allow support for high-frequency control loops and removal of pre-processing (embedded software up to motion control) and "upper bound/low jitter" for certain scenarios
	Reliability [%]	99.999-99.99999	Very high: The control of Realtime industrial processes requires very high service reliability. Can be lower for non-realtime DT and processes which can cope with more variance or have several sensor inputs
	Connection density [devices/m^3]	1-10	High to cope with the high-volume of sensors (with very dispersed data rate needs)
	Coverage [%]	99.99 – 99.999%	Service coverage both outdoor & indoor in pre-planned environments should be higher to allow for sufficient flexibility
	Mobility [km/h]	< 100	
Positioning & New Capabilities	Location accuracy [cm]	≤ 10	High. Accurate Positioning to enrich the DT model. It allows removal of sensors or very expensive calibration procedures
	Sensing-related capabilities [Y/N]	Y	Network-sensing: accuracy, resolution, and range to enrich the Digital Twin model
	AI/ML-related capabilities [Y/N]	Y	AI services can be provided by the service itself (embedded AI) or exposed by the 6G network (AI/ML provided by the network)

Cloud Continuum

Digital Twins

Current technologies and market trends are driving a steady increase in the number of services running in the cloud, which will be further expanded in the 6G era. Moreover, 6G is not just about a radio interface, but also about a cloud architecture that supports a wide range of intelligent components (ICs) such as AI applications, immersive media components, or digital twins. These ICs can be implemented anywhere inside the cloud continuum of edge and centralized clouds.

With digital twins (DT) becoming omnipresent, it is foreseeable that companies will deploy DTs of their assets for various purposes. An example is an airline having DTs of all their aircraft engines, which are updated in real-time and hosted by cloud provider A in Paris. For maintenance purposes while in Singapore, engineers can use AR devices (hosted by cloud provider B) to portray the engine and work on it. However, the AR device also needs to optimize the quality of experience, requiring performing further media rendering/stitching in the edge cloud. The latter depicts the importance to have both “intelligent components” of the AR and DT being able to interoperate, even when hosted by different providers, in different locations. Also for DT’s interacting with the “intelligent components” of other 6G-related devices, hosted by different providers, interoperability is key, explaining why a cloud continuum in the 6G era is a must.

For these dispersed ICs to be supported and operate properly it is mandatory that the availability, functionality, and interoperability must be seamless throughout the entire cloud infrastructure, irrespective of the cloud provider. An IC in one cloud infrastructure needs to be able to discover, authorize, and authenticate ICs in another cloud for them to interoperate. Therefore, the requirement towards 6G is to standardize interoperability between ICs across cloud/edge providers. 6G will have to provide a federated cloud architecture that supports all these collaborations.

Smart Maintenance

The smart maintenance use case targets to minimize the downtime of the system covered. It is a top priority for operators, manufacturers, and service providers to avoid downtimes. Given the pervasive nature of IT systems in our daily lives, downtime can have severe consequences for society and economy. Therefore, the ability to predict and prevent outages is crucial in reducing downtime and mitigating its negative impact.

The smart maintenance relies on fault prediction, which involves collecting and storing all related data while using AI/ML and/or statistical algorithms to predict system behaviour, including failure events. Another key aspect is to trigger proactive interventions on systems, before their predicted faults occur, preventing system outages.

The storage and computational requirements may be very high, depending on the model and algorithms employed, as well as the number of devices and parameters monitored. This can be addressed by leveraging cloud computing resources located conveniently without latency-distance constraints from the devices. The other Realtime Digital Twin KPIs as latency and reliability are not that critical for this use case.

The smart maintenance use case can be deployed for multiple scenarios, including smart industries, smart homes, smart cities, as well as for the 6G network itself.

Digital Twins (Building Model)

The global construction industry is a massive one: expenditure surpassed $11 trillion in 2022, so approximately 13% of the global GDP. It promotes economic development and brings many non-monetary benefits to countries such as safe and clean housing for all. However, the construction industry also faces serious challenges related to low productivity, sustainability issues, conservative processes, and high levels of hazards and risks. Stakeholders are continuously focusing on improving all aspects of sustainability, including safety and efficiency.

Introducing a cloud-based digital twin, with its associated data, of a construction would enable all stakeholders and employees in a complex construction project (it can be considered as a temporary manufacturing plant) to have access to this digital twin via XR at any time, both outdoors and indoors and even in rural areas. Multiple simultaneous users can use it and enjoy a smooth, glitch-free, and accurate experience.

Complex project aspects can be fully experienced, understood, and adjusted in real-time using high-fidelity XR. Virtual safety inspections and guidance supported by AR overlays projected on smart helmet's visors help increase safety. Interactive collaboration is possible, including the use of shared digital objects and with immediate haptic feedback. Telepresence and shared virtual rooms allow experts to participate remotely. Network sensing and external sensors for continuous scanning of the project progress supported by AI for early detection of discrepancies and risks help to increase safety, efficiency, and environmental sustainability. Also in the property sales process, the digital twin will play a key role.

6G will bring the required ultra-fast, reliable, low-latency wireless access to the twins, also at remote sites, enabling seamless connectivity across organizations, exchange of vast amounts of accurate real-time data, remote collaboration and virtual high fidelity XR meetings and training for better safety and efficiency, vast arrays of sensors and devices, drones, robots/cobots, remote real-time monitoring of construction processes and environmental conditions, advanced AI supported data analytics and simulation of construction scenarios, network sensing and external sensors for real-time alerts to prevent physical collisions and for very accurate monitoring of a project's progress in real-time including even the smallest deviations from its twin.

Public Protection and Disaster Relief Digital Twin

The PPDR Digital Twin use case is based on creating digital replicas of a given infrastructure. Then, in the case of an emergency (e.g., fire), automatic deployment of hazard detection and monitoring algorithms can provide to the first responders detailed information on the evolving conditions of the hazard and a short-term risk assessment. This includes fire situation monitoring, monitoring of ground assets, prediction of fire propagation based on environmental conditions, and fire spread disseminated to mobile users.

Ubiquitous and Resilient Networks

Fully Connected World

The use case focuses on delivering Mobile Broadband connectivity to every human on Earth, leaving no “white zones”. It therefore involves providing network access everywhere, encompassing remote areas, zones with harsh geographical conditions (e.g., mountains, forests), the airspace for aerial operation (e.g., drone operation), as well as the open ocean.

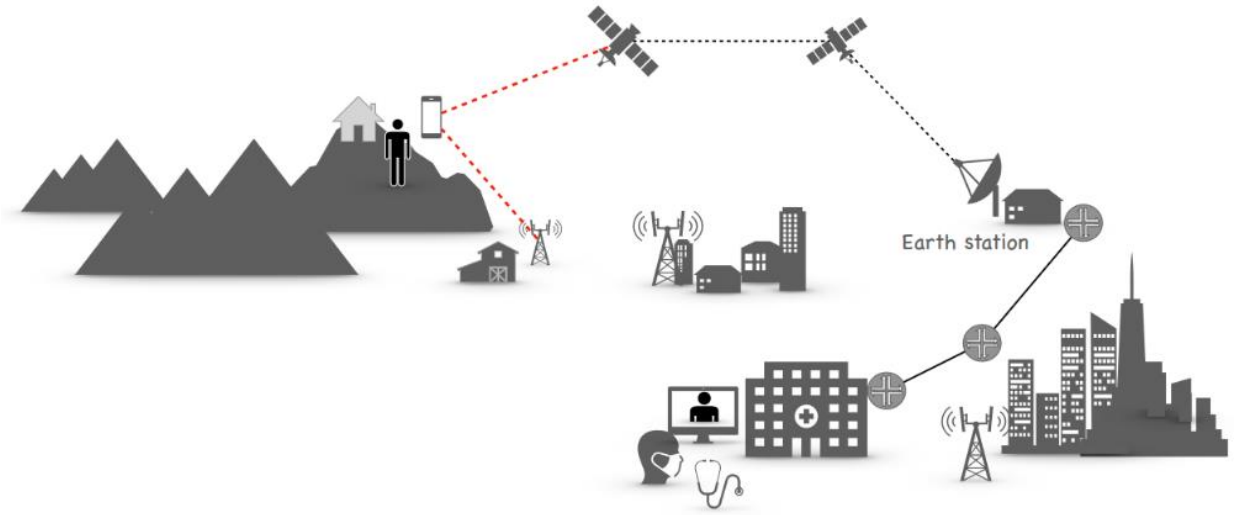
This ubiquitous network will be enabled through seamless access to both TN and NTN – including satellites, High Altitude Platform Stations (HAPS), air-to-ground networks, and unmanned aerial vehicles/drones – in a transparent way for the end user, meeting the requirements (e.g., bit rates, latency) to ensure that every-day needs are covered, with the desired quality of service (QoS). Connectivity will be available everywhere, addressing both pedestrian and vehicles, in outdoor and (light) indoor/in-car environments. Although most users in these areas will not be able to enjoy the services with the utmost performance (e.g., no URLLC, or the most immersive experiences), they will be able to benefit from a wide set of services with reliable connectivity, including high-quality voice or video streaming services. Moreover, the configuration could also enable other 6G-related use cases, such as compute offloading if the technical/physical limitations allow it (e.g., no URLLC due to the use of satellites).

Ubiquitous Network will allow everyone on Earth to access the Internet and its most common uses, but it will also enable the delivery of new services, such as digital health services. Remote consultations with doctors will be possible in areas lacking medical infrastructure. Some institutions, such as schools, could also benefit from more advanced applications for remote virtual education.

Finally, integrating TN with NTN, allows the network to deliver guaranteed connectivity whatever the conditions, maintaining a minimum set of services even in the event of a crisis. This network resilience will be crucial for emergency services, in difficult climatic conditions such as storms (in which network elements may be damaged), or in natural disasters, such as floodings, earthquakes, tsunamis, human-induced catastrophes (e.g., conflicts) or other events that nowadays cause network downtime.

Problem(s) to be Solved/Challenges

- Digital inclusion
- Reduce educational and health-services gaps
- Enabler for earth monitoring
- Delivers increased network resilience, crucial in the event of disasters



Ubiquitous and Resilient Network: Sustainability Analysis

Fully Connected World

	Sustainability Handprints (benefits)	Sustainability Footprints (cost)
Environmental	• Preventing travel-related emissions as a result of remote access to services • Enabling collection of environmental data for Earth monitoring • Access to precise status information can enable precision farming practices (agriculture, aquaculture) to reduce the use of fertilizers, pesticides, and fresh water	• Increased material and energy use to build this ecosystem (e.g., devices, base stations, satellites) • Increased land use (e.g., networks, data centres) could potentially impact existing habitat, and thus, biodiversity • Potential increase of e-waste on land, oceans and space if not handled properly (e.g., collection, 100% biodegradable)
Social	• Providing everyone access to the digital ecosystem • Providing access to digital services to all (e.g., entertainment, education, transactions, voting, etc.) à Bridging the digital divide • Contribute to making networks reliable (perception), everywhere • Enhanced trustworthiness of digital services (availability and accountability) • Delivering increased resilience in networks, crucial in unexpected events (e.g., natural disasters) • Enhanced healthcare and education to reach new areas • Increases food yield from enhanced agricultural management • New job opportunities	• Potential digital divide for people with functional variation / ageing population / IT literacy if all services are meant to be handled digitally • Potential risk to privacy if all services are meant to be handled digitally • Potential mental health problem due to possibility of always being connected and being traceable
Economic	• Improved economic resilience from wider availability of connectivity for different services • Efficiency improvements from the reuse of resources • Economic benefits (profitability) to society/country from combining ubiquitous network with other use cases (e.g. in public services)	• Profitability challenge from the network investment • Resilience challenges from the maintenance of network

Ubiquitous and Resilient Networks: Requirements and KPIs

Fully Connected World

Requirements

- **Connectivity**: The 6G system will need to provide ubiquitous access even in the most remote or hard-to-reach areas with extreme coverage needs. The range of the network will need to be extended to cover any "white zones" (outdoor and indoor) even in areas where it is not possible to deploy dedicated network infrastructure. Finally, it is not only required to provide connectivity on the surface but also allows for 3D coverage targeted at commercial drone operations or deep underground areas where signal conditions are very poor.
- **Resilience**: The 6G system should be able to ensure resilient, seamless operation even in environments with intermittent or limited network connectivity. Services characteristics might vary through the coverage area, but basic services must be guaranteed.
- **Flexibility**: The 6G system must be able to deploy flexible network topologies (based on different accesses) to overcome obstacles such as limited infrastructure or signal attenuation/interference. End-user devices must be able to connect with different possibilities, e.g., allowing connection or offloading to a better proximity or more resource-efficient/capable device, or via multi-hop scenarios.
- **Service Continuity:** Tight integration between different topologies and network elements is needed, including the integration between terrestrial and non-terrestrial networks so service continuity can be assured for devices moving between different network topologies or deployments.
- **Privacy and Security:** Privacy and security requirements must be consistent and guaranteed, regardless of the access network (TN or NTN), and during handovers between each.
- **Affordability:** It is crucial to provide a cost-efficient E2E ecosystem (end-user devices, network infrastructure/operation) to ensure widespread adoption.
- **6G-NTN convergence**: In the vast part of the world, where fixed networks are not much deployed due to topography or high costs of deployment or low investment capability, mobile and NTN should push convergence where terrestrial-based and NTN-based solutions can complement each other, however having different service and cost characteristics. All necessary services should work properly, irrespective of the network on which the service is running. Additionally, the convergence of these two networks requires that parameters, or other information, currently being used for a particular action will be provided by both TN and NTN. An example of such is the information related to "to which base station a handset is connected", which enables emergency alerts to be sent (e.g., sending tsunami threat alarms to all devices connected to base stations near the coastline in a given region).

KPIs

	KPI	Target Range	Justification
Communication	End-to-end latency [ms]	10-100	Depending on the service. It is targeting video calls/streaming. 'Real-time' interactions are not considered as part of this requirement (e.g., no remote surgeries).
	Reliability [%]	99.9 –99.999	The reliability KPI could be associated with the expected service (e.g., given NTN coverage, what is the probability of successfully fallback from TN to NTN and achieving a data rate of at least 100 kb/s). Success rate for this should be high.
	Availability [%]	98.5	Tightly connected to reliability (qualifying the success of transmission) is the availability of connectivity (qualifying the percentage of time the service can be delivered). Appropriate combination of full coverage and capacity to deliver video streaming-like services is required. Reaching new areas can promote new use cases/businesses/ services. As there is no viable alternative, those services will fully rely on this connectivity (e.g., Health services require high reliability and availability of the connectivity). Also, Maintainability requirements need to be high for them not being a cause for downtime. Moreover, the ecosystem needs to be designed in a fully reliable and resilient way in case of emergencies. As deployment cannot be defined through design, KPIs such as 'seconds of system downtime upon handover' could be implemented.
	User experienced data rate [Mb/s]	0.1 –25 Downlink/ 2 Uplink	Good quality video streaming should be delivered (not extreme experience). The data rate refers to a single UE, measured on the device. Based on current standards, from 0.1 (sensor data) to 25 Mb/s (4K video, based on current video requirements) are the expected bit rates, at least for Downlink. It may be revisited based on the evolution of video standards by 2030.
	Connection density [devices/m^2]	Up to 0.1	Connection density is not a stringent requirement, as it does not target massively connected deployments. Also, connection densisty for rural areas are low. However, urban settings could require 0.1 devices/m^2, in case of crisis scenario.
	Coverage [%]	- Up to 10-15 kms range (cell radius) for TN - 99.9% human environment coverage with TN/NTN	Coverage means both extending the range of terrestrial networks, reaching larger cell size, but also the percentage of coverage of a given area, combining the different types of access, TN and NTN. NTN coverage is outdoor and light indoor only.
	Mobility [km/h]	up to 120	Mobility related to seamless handover between TN and NTN. It should support terrestrial vehicle speed's
Positioning & New Capab.	Location accuracy [m]	Low (≈ 10)	Global coverage option is not prone to high accuracy requirements.
	Positioning availability	99%	High positioning reliability is required to support emergency services.
	Positioning latency	1 s	Global coverage option is not prone to low latency positioning requirements; however, some applications may require lower latency.
	Sensing [Y/N]	N	Sensing usually not needed, except for some specific cases (during a crisis to obtain information)
	AI/ML-related capabilities [Y/N]	N	AI services can be provided offline, utilizing big data analytics. It might require AI capabilities to tweak routes, or other outcomes to minimize disruption time.

Earth Monitor / Sustainable Food Production

The use case builds on two use cases described in Hexa-X D1.2 and D1.3, Earth monitoring and sustainable food production. This use case involves a large deployment of sensors to monitor and protect the environment while managing risks to people and agriculture. Since the areas to be covered correspond primarily to rural/deep rural or uninhabited areas, the use case relies on the interconnection of terrestrial and non-terrestrial networks, as well as a myriad of devices.

It can be illustrated by two examples:

- Earth Monitor for Environment Protection: A global environmental monitoring system, powered by bio-friendly sensors, widely deployed, provides real-time data on critical environmental factors like weather, climate change, and biodiversity. This system, accessible even in remote areas, enhances weather/climate models, enables disaster early warnings, and safeguards ecosystems from illegal activities. Connectivity can be based on, for example, NTN, long-range terrestrial or local mesh networks.

- Earth Monitor for Sustainable Food Production: Addressing UN's SDGs like ending hunger and ensuring food security is crucial. Building on new tools such as Digital Twins to improve efficiency of agricultural production through real-time monitoring of micro-locations, optimized plant treatments, experimentation with various strategies, and the use of semi-autonomous ground robots. The synchronized digital representation of the physical world proves instrumental in optimizing agricultural production and managing threats. This use case involves transferring large volumes of data from underserved areas, emphasizing the need for close synchronization. This approach tackles pressing global challenges related to sustainability, global coverage, inclusivity, and opportunity.

The adoption of 6G for Earth monitoring signifies a substantial leap forward in our ability to safeguard and understand the planet's ecological well-being, inaugurating a new era of precision and efficiency in environmental protection. In particular, 6G provides:

- Near real-time monitoring of critical environmental aspects such as weather patterns, climate change indicators, and biodiversity metrics through data collected from multiple sensors.
- Reaching even the most remote and inaccessible areas, providing comprehensive coverage for environmental monitoring efforts.
- Enhancing the processing and analysis of environmental data, enabling more accurate and timely insights through integration with AI and machine learning algorithms.

Autonomous Supply Chain

To ensure a fully integrated autonomous supply chain, the demand of scoping, ordering, sourcing, packaging, routing and delivery must be automated using local and central AI agents continuously optimizing the process, for example, in relation to unexpected events such as natural events, disasters or political circumstances [HEX21-D12]. 6G will enable a fully automated supply chain, at reasonable cost and complexity. With global E2E lifecycle tracking of goods from production, shipping, distribution, usage and recycling; higher resource efficiency and reduced material and energy consumption can be achieved. The use of 6G-connected micro tags on goods can simplify tracking, customs, safety checks, and bookkeeping, allowing it to be done without manual interference.

6G's increased and ubiquitous coverage, low latency, and advanced connectivity capabilities make it a crucial enabler for the development and implementation of autonomous supply chain systems, ultimately leading to more efficient, agile, and resilient supply chain operations. In particular:

- Real-time monitoring and decision-making in the supply chain through fast data transmission.
- Minimal delay in data transmission, which is essential for tasks that require immediate response, such as autonomous vehicle navigation, order processing, and inventory management through low latency.
- Remote assistance, training, and visualization to enhance the autonomy and efficiency of the supply chain through integration with XR technologies.

Virtualization of Device Functionalities

Current handsets have evolved to become highly complex and precise machines. The numerous functionalities that a handset can offer (and on which many of us rely on) require highly intricate design and a myriad of raw materials sourced from all over the globe, to name a few. As a result, most of the product's footprint comes from production stages, rather than usage stages. This is highly detrimental for the environment considering that the average lifespan of users' handsets is only a couple of years, further contributing to the already huge problem of e-waste and resource depletion.

As numerous services are being migrated to the cloud ecosystem, it is foreseeable that many handset functionalities might follow the same path. As 6G network availability and trustworthiness will increase, it would then be possible to shift processes and/or storage from the handset to the cloud, while still providing a seamless experience for the end-user. The ecosystem's evolution (radio, core, cloud) is key to the enablement of this use case.

Virtualizing functionalities and relying on cloud ecosystems allows handsets to evolve into less complex machines, creating several benefits and opportunities. First, as materiality in terminals will be reduced, it allows to decrease the environmental impact (e.g., e-waste, resource depletion, complexity of recycling). Second, it can untap new markets and/or allow new business models to be deployed at reduced cost. Examples of such can be (a) subscription-based phones (shifting responsibility to manufacturers rather than users), (b) producing a single handset model, and paying extra based on the processing needs of each user, or even (c) promoting handset modularity. Third, producing cheaper handsets will also contribute to digital inclusion. Moreover, handsets could also be easily adapted to the special requirements of the user (e.g., the elderly). Finally, other foreseeable benefits are higher energy efficiency/longer-lasting batteries, decreased supply chain risks, and the ability to upgrade the handset's software instantly on the cloud. These benefits will have to be balanced with the possible side effects on the cloud and impact on deployment, to guarantee that global balance is favorable for sustainability.

Digital Sobriety and Enhanced Awareness

The energy consumption and contribution to GHG by the ICT industry is considerable and expected to keep growing due to society's increasing dependency and pervasiveness of these services, despite the technical efficiency gains achieved. Unfortunately, advances in energy efficiency have been primarily led by industry, usually leaving the end user out. Furthermore, it has not provided the information necessary for creating awareness of the end user's digital footprint, nor the tools to manage this behaviour.

Knowledge is power. Therefore, this use case relies on AI capabilities and a deeper understanding of the impact of different elements throughout the value chain to (1) unravel the E2E energy consumption (including networks, applications, and devices), (2) the particular settings affecting that energy consumption (e.g., data route chosen, the country's energy mix where the service is running), as well as (3) incorporating information regarding the environmental impact of different elements (e.g., sourcing, life-cycle footprint). Currently, this information has not been made available nor deemed relevant for the end-user's experience.

Building on the availability of this information to create awareness of the environmental impacts each user is responsible for, the end user will have the ability and freedom to adjust the trade-off between the quality of service and environmental footprint. An example of such is to explicitly show metrics such as "instant carbon footprint" while watching a video, coupled with suggestions on how to manage the total impact (e.g., lower video resolution, accept higher latency, avoid paths involving non-circular material usage, or even switching providers). Making this information transparent, allows the user to evaluate the trade-offs between service performance and quality from one side, and the environmental impact on the other side.

Resilient Communication for Safety Critical Applications

Elements of safety critical and otherwise important infrastructure are often territorially widely scattered and located at positions, which may not be easily accessible. Well-known examples are traffic routes and other extended linear infrastructure elements such as communication networks, pipelines, power supply networks, and water supply stations. Moreover, the transition to renewable energies is strongly accelerating the trend towards decentralization of power networks. The elements of this essential and important infrastructure entities need to be permanently controlled and monitored with adequate timing and reliability requirements to meet robust operational performance and to avoid threats. Integrity and identity of service nodes will be achieved or strengthened by integrated site-specific sensing functionalities. With its increased connectivity, available sensing and computation capabilities as well as dedicated network slicing and cognitive adaptation, next-generation wireless communication is becoming more and more important to support resilient communication for safety-critical systems.

Some problems to be solved/challenges are:

- Take advantage from meshed network connectivity in environments with incomplete infrastructure access
- ISAC results for sensor integrity and user identity required
- Integration of meshed data access and distributed multisensor ICAS
- Sensing of radio environments for interference mitigation and cognitive network adaptation

Human-Centric Networks

Trusted Environments

This use case genuinely focuses on the human at the centre of a wide range of 6G services. Human-centric services demand the use of trusted environments where privacy and reliability are key characteristics to make the services trustable by the public. Some examples of these services are:

Precision healthcare: health monitoring, diagnosis, and therapy will enable personalized diagnosis and treatment. A 6G tele-medical paradigm can be enabled by both in-body and off-body sensing and AI/ML-based analytics in conjunction with wide-area connectivity.

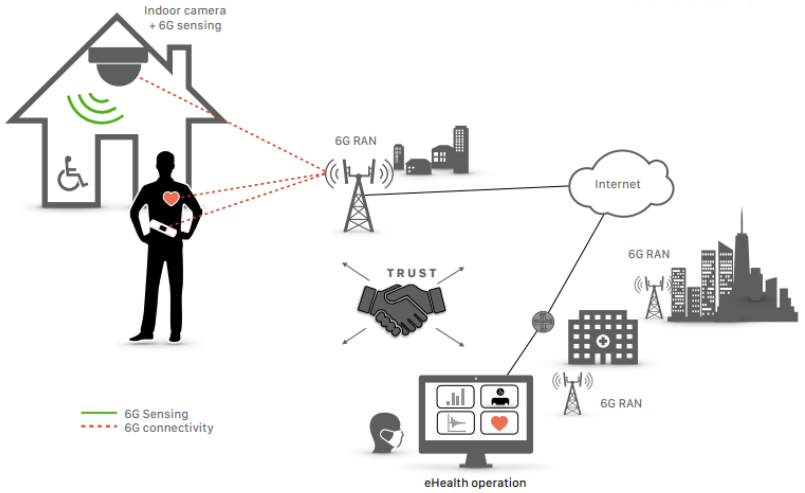
Safe environments such as kinder gardens, schools, homes, day-care, workplaces, or hospitals will be of help to establish well-being, safety, inclusion, autonomy for children, elderly, and people with disabilities. Sensing and AI/ML compute for accurate localization, target identification, behavioural analysis and spatial-temporal situation-awareness as well as for appropriate alerting will help to avoid physically risky situations and accidents as well as socially critical situations and potential incidents. Prevention and avoidance can also be adaptive to the type of the environment; safety of children on a playground vs safety of patients in a hospital differ in aspects and requirements. Personal automation services add onto localization and situation awareness in that sensing can trigger adaptations of the surroundings. For instance, ramps can be made available when a person in a wheelchair is about to enter a building.

Public safety services during big events: at big public events such as football matches, big concerts, or parades, public safety services may use human-centric information, e.g., location, personalized data, and emergency contacts, which need to be anonymized and privacy-protected.

Human-centric services impose very high privacy requirements not only comprising consent management but even more so technical solutions such as anonymization, pseudonymization, advanced information coding, or additive homomorphic technologies. Moreover, solutions to privacy protection cannot exclusively reside in the application domain and must be built into the 6G system. To guarantee the safety of thousands of people at a big event or of hundreds of workers on a construction or a chemical manufacturing site, the 6G network deployment needs to achieve very high service availability or service reliability.

Problem(s) to be Solved/Challenges

- Extended access to high-end health monitoring and diagnosis
- Deliver safe environments for increased well-being, mental health, safety, inclusion, and autonomy
- Safety, health, and peace of mind for hard-hat workers, as well as visitors of big public events
- Deal with huge amounts of data from multiple sources in real time
- Human centric privacy models



Human-Centric Networks: Sustainability Analysis

Trusted Environments

	Sustainability Handprints (benefits)	Sustainability Footprints (cost)
Environmental	• If used for smart services, potential reduction in GHG emissions resulting from reduced commuting and optimized use of travel infrastructure • If used for healthcare, potential reduced in medical waste	• Increased material consumption for new devices and network deployment • Energy consumption to support AI/ML and e-health operations, storage, and processing of extensive healthcare data • Electronic waste from disposal of body sensing and computing devices
Social	• Increased availability of human-centric services • Enhanced safety • Enhanced freedom of movement for people needing continuous health monitoring (outside hospitals) and thus, quality of life • Enhanced trustworthiness of digital services • Optimizing the time of care (relevance of transportation)	• Privacy risks from monitoring humans • Potential risks for trustworthiness/safety in case of hacking
Economic	• Economic efficiency improvements and reduced costs for human-centric services • Economic predictability from creating trust with human-centric services	• Pressure on demand side can impact efficiency • Safety degradations from new risks related to new services

Human-Centric Networks: Requirements and KPIs

Trusted Environments

Requirements

- **High privacy protection:** due to the private character of the data, privacy protection is key for this use case. This privacy will be enabled by new techniques such as local anonymization, pseudonymization, advanced information coding and additive homomorphic technology. In addition, physical privacy solutions are required for a body-subnetwork of sensors, actors, and evaluation devices.
- **High service reliability:** the reliability of the services is key for user trust, especially in human-centric applications. Safe environments require high service availability to predict and avoid catastrophic situations, as well as providing timely alerts.
- **Guaranteed QoS:** ensuring the use of network capabilities to guarantee QoS on health and well-being related scenarios (e.g., through network slicing)
- **Localization**: Accurate detection and localization of multiple device-free targets is required for performing behavioural analysis and extracting relevant analytics. The 6G sensing system must provide adequate resolution for retrieving accurate positional information of targets.
- **Accurate target identification and activity recognition:** The 6G sensing system must provide high-accuracy target identification and activity recognition based on backscattered waveforms.

KPIs

	KPI	Target Range	Justification
Communication	End-to-end latency [ms]	< 250 < 1000	For AGVs and care robots, e.g. in homes for the elderly and in hospitals. Initiating an intervention in case of an evolving critical situation in a crowd.
	Reliability [%]	99.9 – 99.999	High service availability is key for this use case.
	Connection density [devices/m^2]	1 to 10 < 0.001	Indoor per floor Outdoor
	Mobility	pedestrian, slow vehicular	
Positioning & New Capabilities	Location and positioning accuracy [m]	< 10 < 0.3 to < 1 < 0.1	Location accuracy Positioning accuracy Relative positioning accuracy, e.g. collision avoidance
	Positioning availability	99.9%	High positioning reliability is required for most of human-centric applications
	Positioning latency [ms]	[10]	Low- latency positioning is required for most human-centric applications
	Sensing-related capabilities [Y/N]	Y	Relevant for most of the scenarios
	AI/ML-related capabilities [Y/N]	Y	Relevant for most of the scenarios

Wireless In-Vehicle Network

This use case involves replacing in-vehicle wiring with wireless connectivity to address current problems with design and installation complexity, complicated and expensive maintenance, vehicle weight, cost and difficulty during the introduction of additional in-cabin features and autonomous driving features. *Wireless In-Vehicle Network* can bring significant benefits varying from manufacturing to maintenance and operation cost reduction. It is also expected to ease the introduction of new features e.g., new backseat entertainment system and new sensors. Additionally, these mechanisms are envisioned to be further expanded to other realms, such as cable replacement for industrial real-time applications and machinery.

Due to the privacy of the data, high reliability, ultra-low latency, time-sensitive deterministic capable wireless networks, and high data rates for supporting automotive ethernet links; trusted environments beyond 5G are needed for this use case.

Industrial Sensors Network for Safe Production & Manufacturing

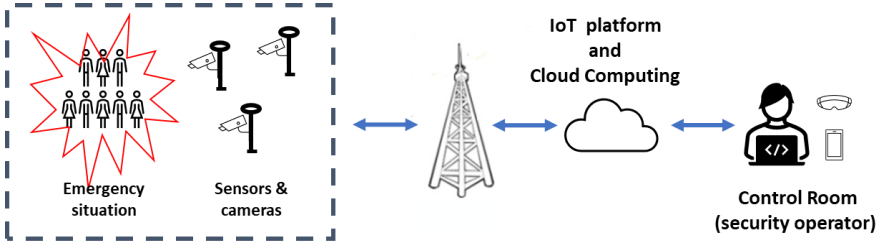
Trusted Environments

Safety at the factory floor is critical for workers. Sensors deployed in a factory can help to alert workers of dangerous areas or situations. A good example is light curtains [IFM][Sic20], where a transmitter sending parallel beams towards a receiver is installed around dangerous or sensitive equipment. If one or more beams are broken, a signal or alarm can be generated.

To ensure the correct functioning of these critical safety measures, a highly reliable network beyond what 5G can provide will be needed (a trusted environment).

Virtual Control Room

Trusted Environments

The use case aims to enhance the operational efficiency of security forces, including the Police, Emergency services, Ambulances, and Firefighters. This is achieved by establishing a collaborative master control room accessible from any location using a secure access code. The scenario relates to a public event (e.g., concert, rally) where all security stakeholders have coordinated an action plan in case of an emergency.

The main objective is to enable more effective interventions with reduced mission completion time by establishing a collaborative virtual space where communication and information exchange among all actors can run efficiently.