HEXA-X-II D1.2 Deliverable

6G Use Cases and Requirements

Hexa-X-II

hexa-x-ii.eu

Introduction

WP1 and D1.2 objectives

WP1 - Objectives

Overall Objective

WP1 will set the prerequisites to define a 6G system

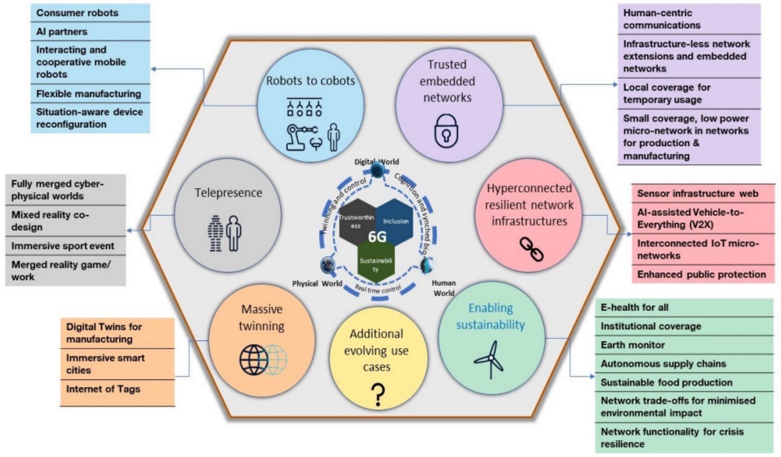
- **Acting as enabler for environmental sustainability**
- **Providing value for the society**
- **Being economically sustainable**

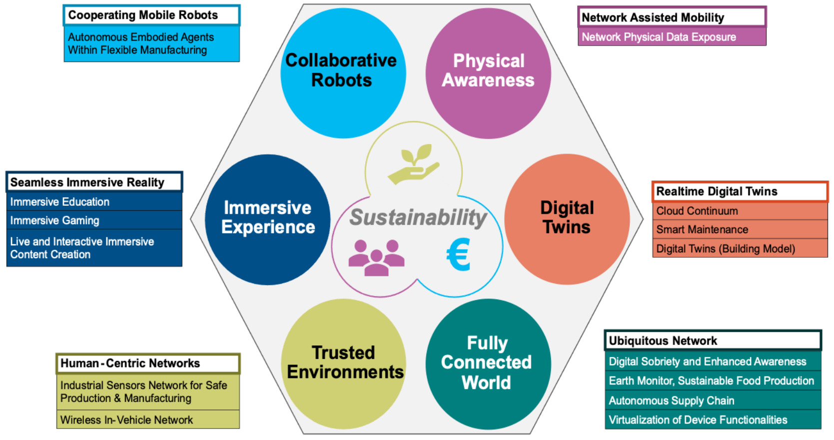
Objective 1	Ensure foundation of 6G design will integrate environmental, social and economic sustainability
D1.2 → **Objective 2**	**Define use cases and determine requirements to drive 6G design**
Objective 3	Connect HEXA-X-II with the business ecosystem & anchoring 6G in society

Hexa-X-II Use cases

Hexa-X-II Use Case Families II

- The Hexa-X-II project's objective is to go beyond Hexa-X by taking a comprehensive view on sustainability considering environmental, social, and economic aspects as the three pillars for these 6G use cases
  - The initial set of use cases from D1.1 has been widened and evolved
- New 6 Use Cases Families have been revisited and enhanced
- 6 " Representative Use cases" have been chosen for deeper analysis
  - One per family representing the key aspects of the family
  - Analysis provides a sustainability analysis, requirements, and KPIs, among other aspects



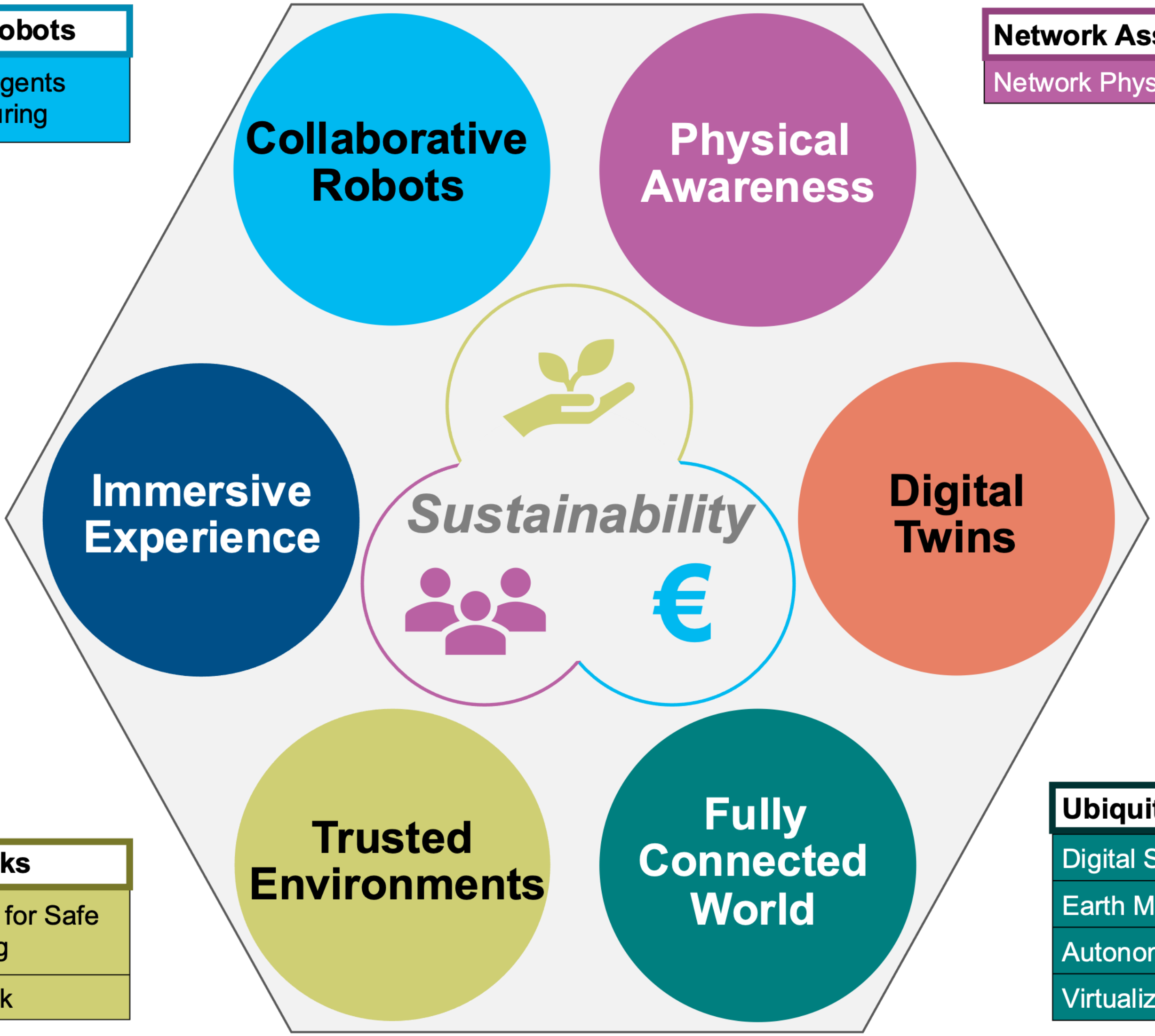


Hexa-X-II Use Cases with Highlighted Representative Use Cases

Hexa-X-II Use Case Families

Cooperating Mobile Robots
- Autonomous Embodied Agents Within Flexible Manufacturing

Network Assisted Mobility
- Network Physical Data Exposure



Seamless Immersive Reality
- Immersive Education
- Immersive Gaming
- Live and Interactive Immersive Content Creation

Realtime Digital Twins
- Cloud Continuum
- Smart Maintenance
- Digital Twins (Building Model)

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

Ubiquitous Network
- Digital Sobriety and Enhanced Awareness
- Earth Monitor, Sustainable Food Production
- Autonomous Supply Chain
- Virtualization of Device Functionalities

Hexa-X-II Use Cases with **Highlighted** Representative Use Cases

Seamless Immersive Reality

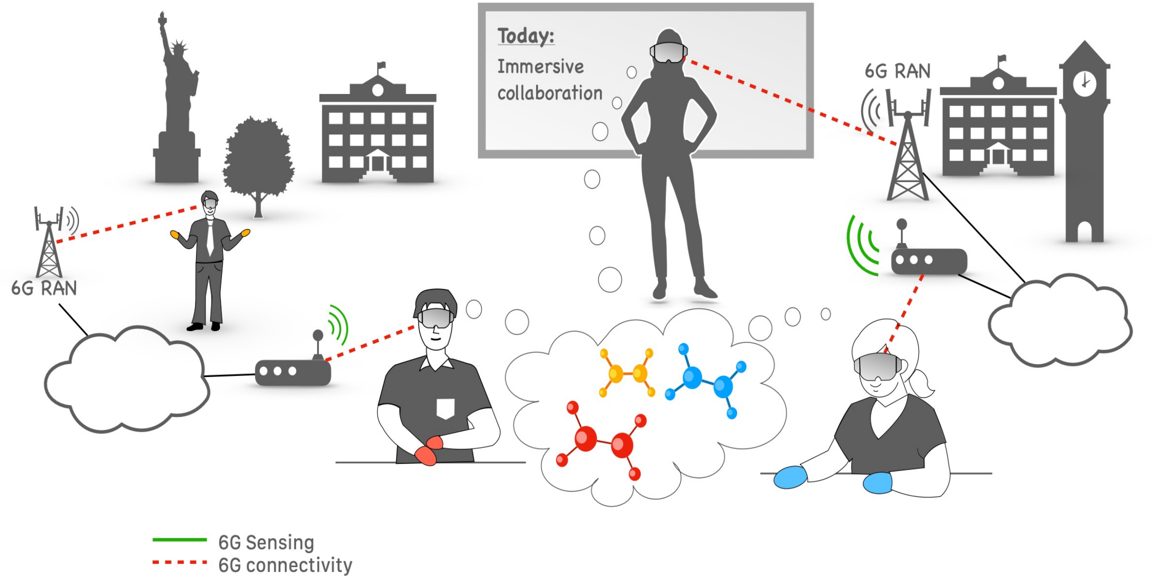
Immersive Experience

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

	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

Immersive Experience

Seamless Immersive Reality: Requirements and KPIs

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

Cooperating Mobile Robots

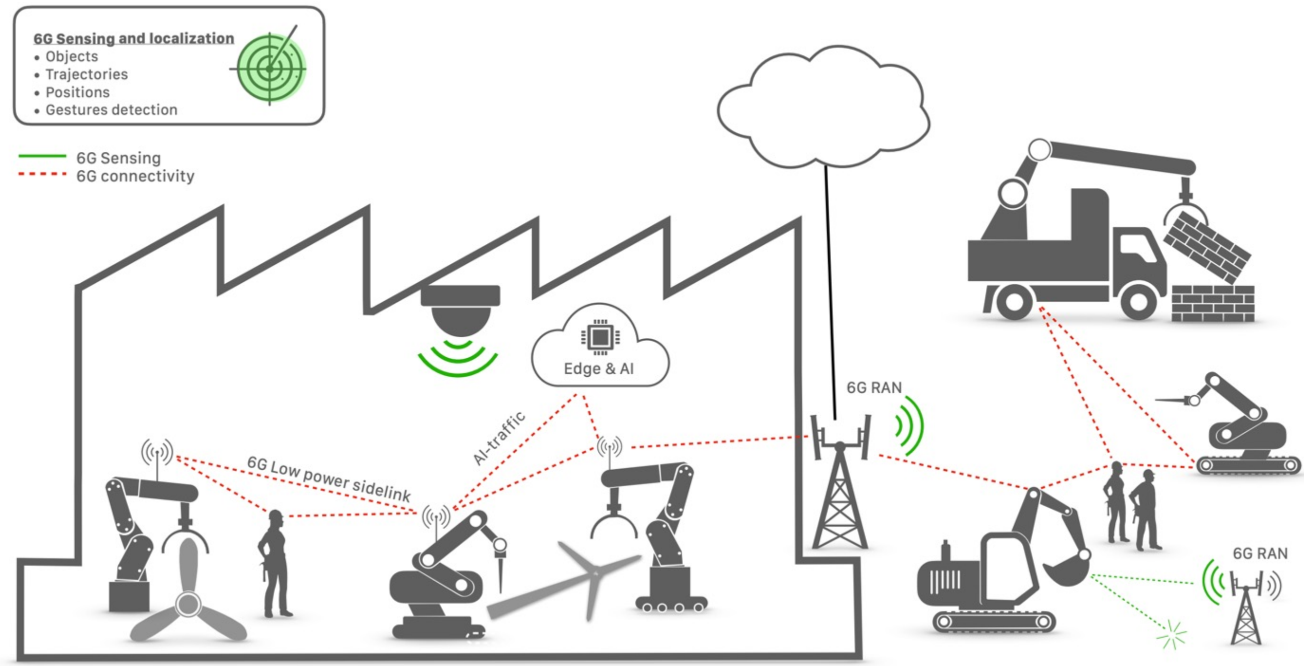
At the centre of this use case are autonomous robots with the ability to move, sense their environment, and perform a productive task. These robots can communicate with one another, with other machines, and with nearby humans to perform individual tasks that contribute to a common cooperative objective. The purpose of communication is safety and cooperation, to enable a group of robots to perform tasks beyond their individual capabilities and to enable individual robots to perceive their environment beyond their local capabilities.

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, 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
- 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

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.

- **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 behavior 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.
Communication	Connection density [devices/m^2]	< 0.1	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.
Communication	Mobility [km/h]	< 20	Slow vehicular
Communication	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]
Communication	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].
Communication	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 & New Capabilities	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.
Positioning & New Capabilities	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.

Network-Assisted Mobility

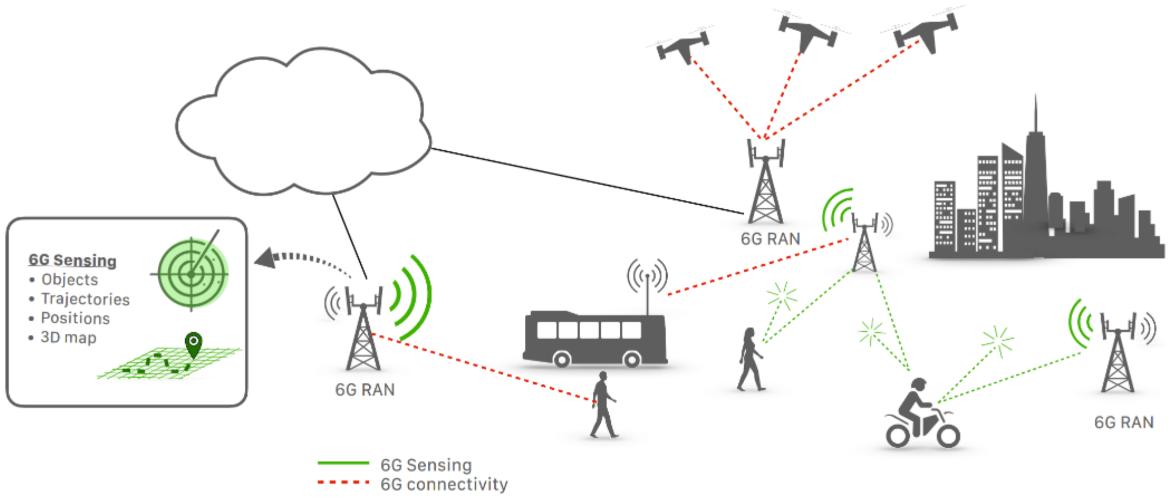
In this use case, vehicles (cars, AGVs, drones, etc.) are relying on the network nodes and devices for localization of connected and unconnected objects and for determination of their properties such as size and velocity, contextual info, trajectories etc. Vehicles have a reliable connection to the network, 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.

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-Assisted 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 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 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). 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.

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]	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
	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.

Realtime Digital Twins

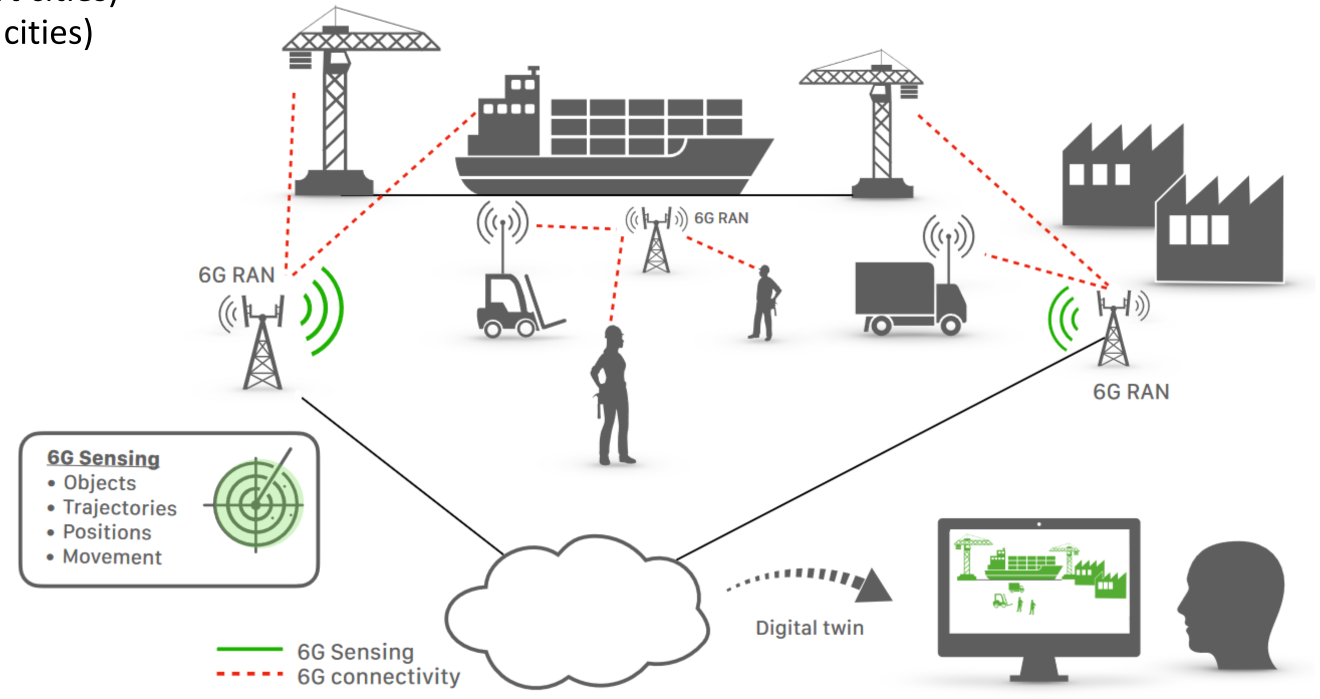
A digital twin is an accurate digital representation of any combination of processes, products, persons, and functionalities of real-world items such as for industry, smart cities, or construction. This contextual digital equivalent of the real world offers a unified access to users and/or agents and 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



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.
- **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. Any handover in the network needs to be seamless.
- **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 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 Realtime environmen,. These sensors might also need a technology evolution beyond the current sensor devices for the sensitivity/accuracy.
- **Improved human-machine interaction**: For an effective DT, it is crucial for users to have a seamless immersive interaction with the DT. 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 the complex DT models and databases with the integrated advanced AI skills to simulate, steer and predict.
- **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.
- **Hierarchy** of Digital Twins: DTs will be covering larger, more complex systems as full cities and/or factories. As DT’s will first appear on lower level (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, incorporate a number of underlying DT’s (hierarchy/interop). This is also called “set of twins” or “massive twinning”.
- **M&O capabilities** for the RT DT service to cope with the flexible resource allocation, since compute can be spread over the network core, edge, 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 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, other digital twin systems)

KPIs

	KPI	Target Range	Justification
Communication	End-to-end latency [ms]	order of ms	Very low latency for the Realtime aspect
Communication	Reliability [%]	99.99999	Very high: The control of Realtime industrial processes requires very high service reliability. Can be lower for non-realtime DT
Communication	User experienced data rate [Mb/s]	< 100	Low. It is expected video will be most demanding (up to 100 Mb/s)
Communication	Connection density [devices/m^2]	1-10	High to cope with the high-volume of sensors (with very dispersed data rate needs)
Communication	Coverage [%]	99.99	Service coverage both outdoor & indoor
Communication	Mobility [km/h]	< 100	
Positioning & New Capabilities	Location accuracy [cm]	≤ 10	High. Accurate Positioning to enrich the DT model
Positioning & New Capabilities	Sensing-related capabilities [Y/N]	Y	Network-sensing: accuracy, resolution, and range to enrich the Digital Twin model
Positioning & New Capabilities	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) but no AI-Native required (6G network AI).

Ubiquitous Network

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.

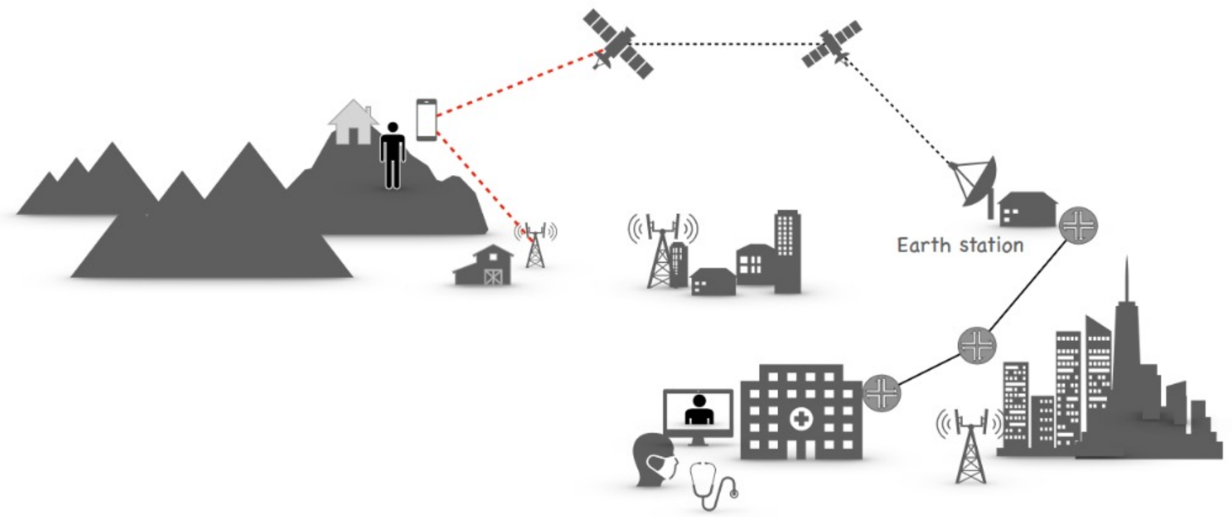
This ubiquitous network will be enabled through seamless access to both TN and NTN – including satellites, High Altitude Platform Stations (HAPS), air-to-ground networks, and unmanned aerial vehicles/drones – in a transparent way for the end user, meeting the requirements (e.g., bit rates, latency) to ensure that every-day needs are covered, with the desired quality of service (QoS). 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 Network: Sustainability Analysis

	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 Network: Requirements and KPIs

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 in the surface, but also allow 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 in which the service is running on. 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).
Communication	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.
Communication	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.
Communication	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.
Communication	Connection density [devices/m^2]	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.
Communication	Coverage [%]	- Up to 10-15 km range (cell radius) for TN - 99.9% earth human environment on earth area 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.
Communication	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 & New Capab.	Sensing [Y/N]	N	Sensing usually not needed, except for some specific cases (during a crisis to obtain information)
Positioning & New Capab.	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.

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 in-body sensing and AI/ML-based analytics in conjunction with wide-area connectivity.

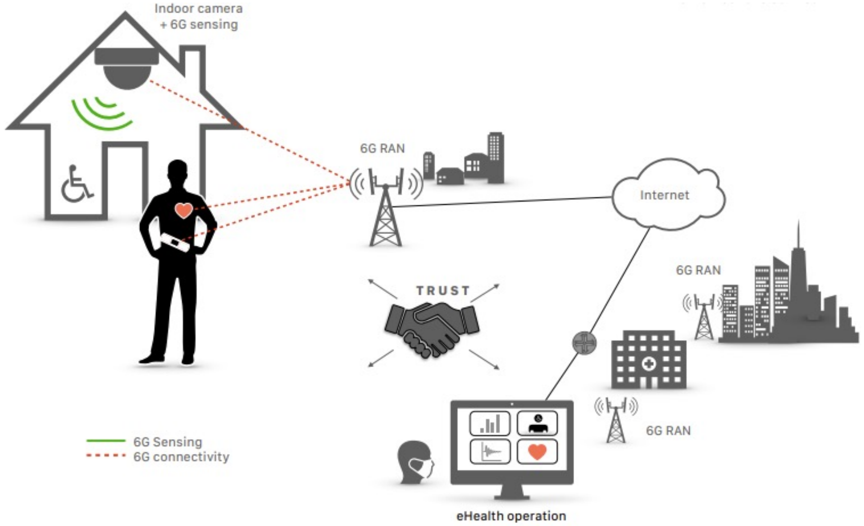
Safe environments such as kinder gardens, schools, homes, day-care, workplaces, or hospitals will be of help to establish well-being, safety, inclusion, autonomy for children, elderly, and people with disabilities. Sensing and AI/ML compute for accurate localization, spatial- and situation-awareness 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



Trusted Environments

Human-Centric Networks: Sustainability Analysis

	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

Requirements

- **High privacy protection:** due to the private character of the data, privacy protection is of 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:** when talking human-centric services, the reliability of the services is key for the user trust. Besides, in scenarios such as safe environments or public safety, a high service availability is crucial to avoid catastrophic situations.

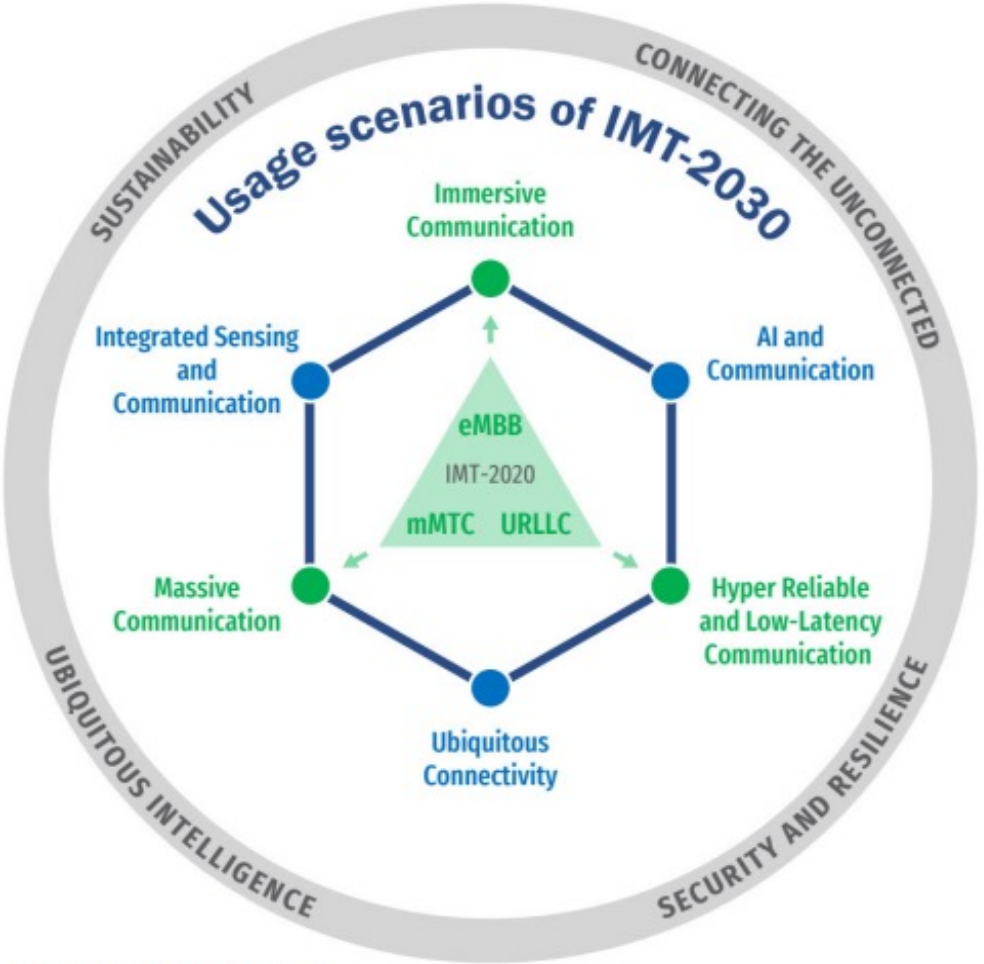
KPIs

	KPI	Target Range	Justification
Communication	User experience data rate [Mb/s]	–	
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.
Communication	Reliability [%]	99.9 – 99.999	High service availability is key for this use case.
Communication	Connection density [devices/m^2]	1 to 10 < 0.001	Indoor per floor Outdoor
Communication	Coverage	–	
Communication	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 & New Capabilities	Sensing-related capabilities [Y/N]	Y	Relevant for most of the scenarios
Positioning & New Capabilities	AI/ML-related capabilities [Y/N]	Y	Relevant for most of the scenarios

Worldwide activities in 6G

IMT-2030

Usage scenarios

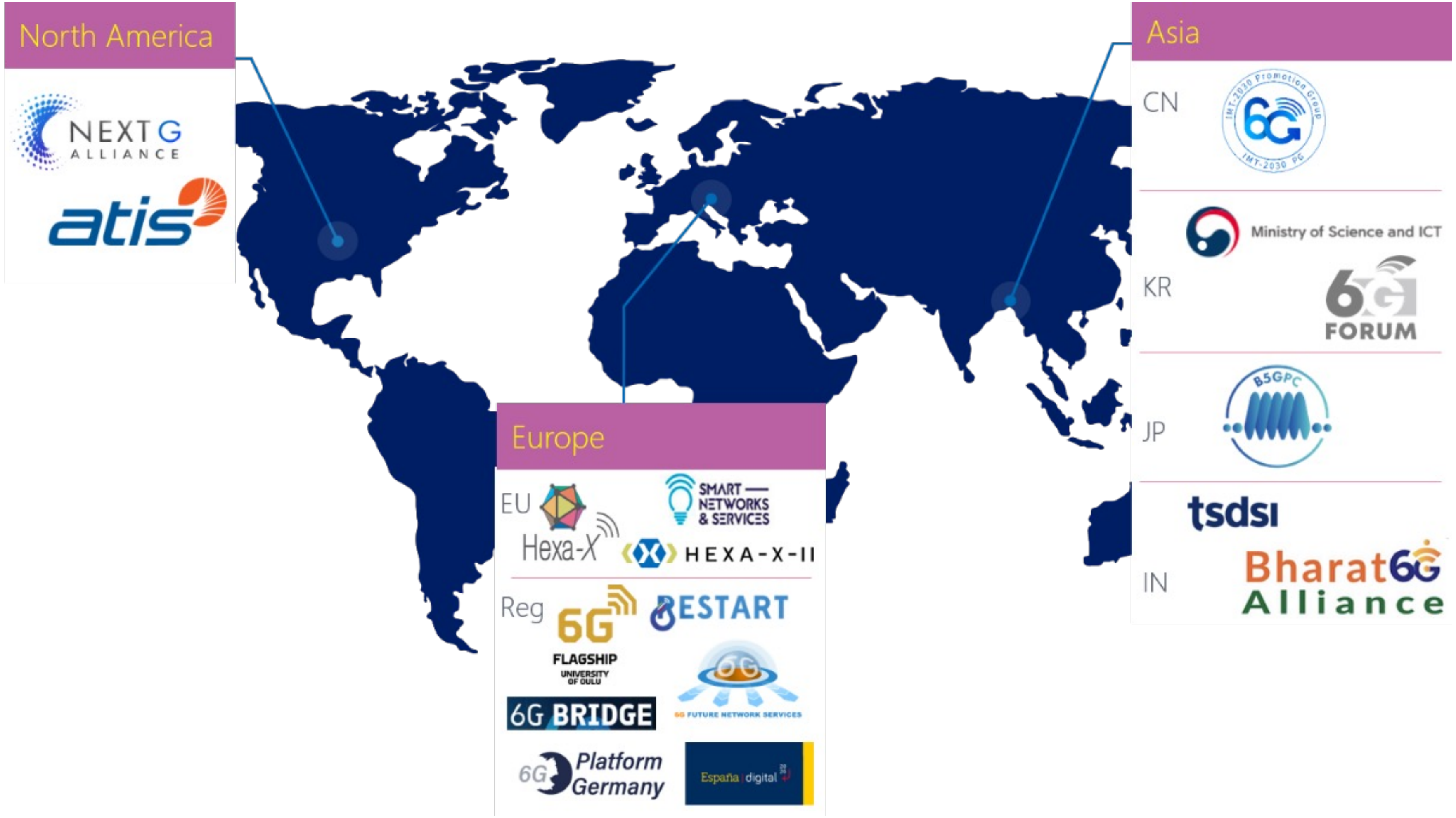


So called "Wheel diagram"
Source: Document 5/131 and edited in SG 5

- ITU-R has set up the basic framework and timeline for the development of 6G
- 6 usage scenarios have been identified:
  - 3 scenarios extending from IMT-2020
  - 3 new scenarios
- Complemented by 4 overarching aspects

Key Worldwide Activities in 6G

Key worldwide initiatives were studied to comprehend their approach, proposed use cases, and intended capabilities for 6G.



- **Europe**
  - NGMN
  - HEXA-X
  - Other national initiatives
- **United States**
  - ATIS NGA
- **China**
  - IMT-2030 Promotion Group
- **Japan**
  - Beyond 5G Promotion Consortium
- **South Korea**
  - Ministry of Science and ICT
- **India**
  - TSDSI (Telecommunications Standards Development Society, India)
  - Bharat 6G (Ministry of Communications)

Key Worldwide Activities in 6G: Similarities and Differences

Extreme Communication Requirements

- All initiatives have further pushed the limits of current 5G capabilities:
  - Enhanced Mobile Broadband
  - Ultra Reliable Low-Latency Communications
  - Massive Machine Type Communications
- All initiatives have acknowledged the need for ubiquitous connectivity (indoor and outdoor)
  - Various applications requiring ubiquitous connectivity (IoT, DTs, Sensing, Entertainment)
  - Scope differs throughout initiatives (pure terrestrial or including sea, air, space)

New Capabilities

- AI/ML widely present for a wide variety of applications
  - Strongly embedded in 6G designs
- The use of robots is widely mentioned for different purposes
  - Residential (aid/support)
  - Industrial use (efficiency purposes or replacing humans in risky tasks)
- Sensing, positioning/tracking, AI orchestration capabilities are widely mentioned as enablers for several use cases

Technologies

- Immersive experiences frequently mentioned
  - The use of AR/VR/MR devices play a key role
  - Among the few applications aimed at the mass market
- Digital Twins
  - Fully embedded in many use cases
  - Interacts with other 6G capabilities

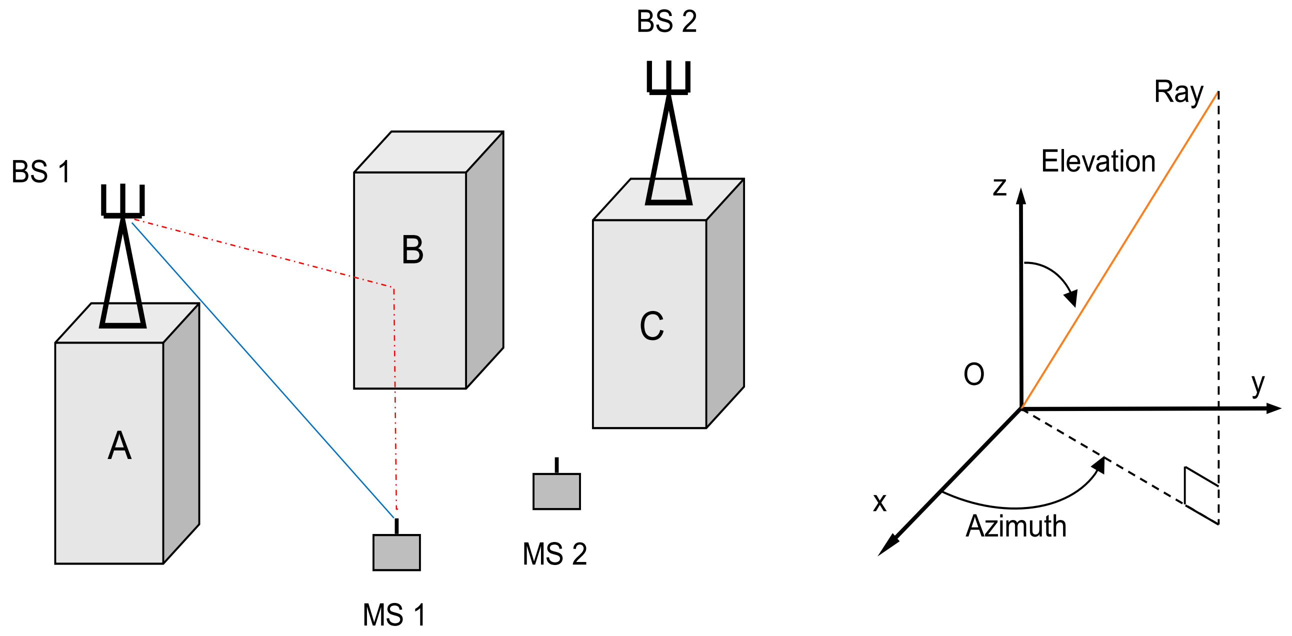
Sustainability

- Where the most diverse approaches were identified
- Energy efficiency and CO_2 reduction are widely mentioned
- Some initiatives mention broader sustainability challenges (e.g., digital inclusion). However, these are rarely identified
- Current approach falls short. Room for improvement.

Channel models

Channel model: Definition

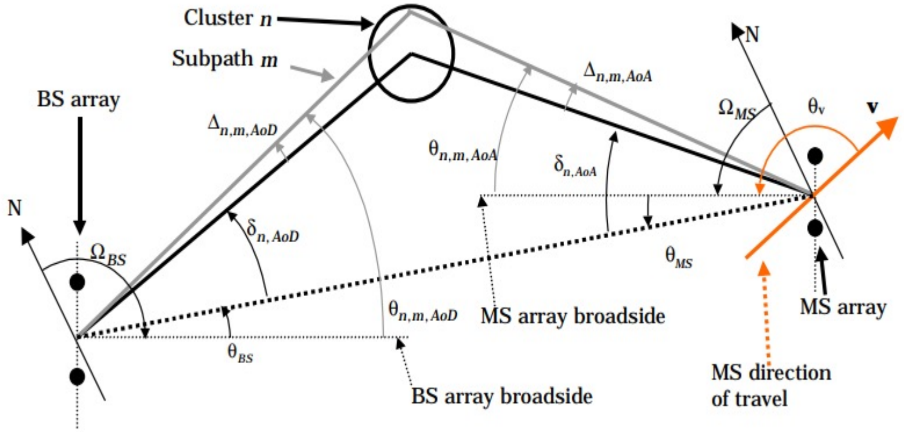
- *Propagation channel* between a transmitter and a receiver can be modelled by a set of rays (always assuming far-field conditions)



- The propagation channel from Base Station 1 (BS1) to Mobile Station 1 (MS1) is modelled using two rays: the *blue one* represents the direct path, *the dashed red one* represents the reflected ray on building B

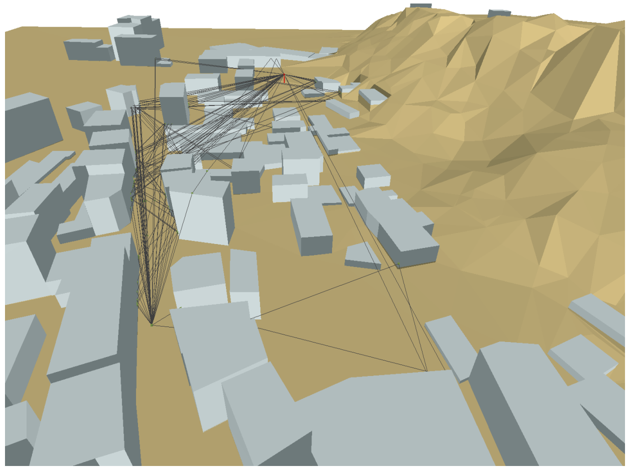
Channel Models: State of the Art

Statistical Geometric Models



- Based on a pure geometrical approach: the set of rays is defined by statistical distributions, mathematical equations, or geometrical considerations
- Adopted for the first time in 2003 by 3GPP with the Spatial Channel Model (SCM)
- Procedure to determine the ray features:
  1. Path loss and large-scale parameters are generated for specific environment and propagation conditions
  2. The set of rays is generated according to mathematical equations defined as a function of the path-loss and large-scale parameters

Deterministic Models



- Use a geographical database or digital map that describes the environment
- These channel models do not contain any statistical components as was the case for statistical channel models
- Geographical databases are much simpler than the reality

Channels Models and Hexa-X-II Use Cases

- The comparison between the propagation channel model state-of-the-art and the Hexa-X-II use cases highlights some lacks for the current propagation channel models and suggests the following enhancements:
  - Model extension for frequencies above 100 GHz: Current models are limited to 100 GHz whereas some use cases plan to use frequencies above 100 GHz
  - Special feature implementation for JCAS: Channel models were developed for wireless communication performance evaluation and not for sensing applications. For instance, there is a need to model the radar cross-section of urban objects or to define channel models with the transmitter and receiver located at the same point
  - Spatial consistency improvement: Spatial consistency is a key feature for sensing applications to resolve different objects from the time-angular channel impulse response. It is also a key feature for multi-point deployment schemes
- The propagation channel modelling work in Hexa-X I and II is focused on the first bullet with the extension of ITU-R and 3GPP model above 100 GHz

Business models

Business models

- Business models describe how a company creates, captures, and delivers value
- To derive business models including revenue models, is the ultimate goal of a use case
- In Hexa-X-II, a new ecosystem-level business modelling approach has been developed. It consists of three steps:
  - **ecosystem business model canvas**: ecosystem-level business model for the use case including identification of stakeholder
  - **stakeholder analysis**: analysis of key stakeholders
  - **ecosystem pie**: ecosystem-level business model visualization
- This new approach has been applied to three of the representative use cases (seamless immersive reality, real-time digital twins, and ubiquitous network)
- The use cases were selected as a good set to explore the different business offerings and ecosystems around the use cases in 6G

Seamless Immersive Reality: Business Model Canvas

Immersive Experience

Supply Side

- **Stakeholders/key partners:** Providers of equipment of seamless reality technologies; Providers of seamless experience applications (including content and marketplace for services); Telecom infrastructure providers (network vendor); Network operator / service provider; Other end users.
- **Resources:** Internet of senses; devices; compute resources; AI algorithms; data and access to data; domain specific competence; communication network (can be local private network); funding; design processes; IPR.
- **Activities**: Design and develop seamless experience and applications; capturing content; deploying suitable network; traditional operations.

Ecosystem Value Propositions

- **Value proposition:** Enhanced ability to get shared understanding of an interaction with multi-dimensional and/or textual objects/topics/people with increased output quality of interaction.
- **Value co-creations:** Enhanced mutual interactions with people far away (telepresence) and co-experience for increased common understandings; improved quality of experience (QoE) facilitating interaction, collaboration, co-presence, and co-experience in many aspects of life including work, education, or healthcare, and cultural, social, and personal lives. Marketplace for services (commerce in virtual world).
- **Value capture:** users, or those wanting immersive reality to be applied, will capture value; in turn, others take advantage of increased quality such as patients, employers, customers of manufactured components, art consumers).
- **Value co-destruction:** Competition for owning end-user/customer relationship; timing in launches by different stakeholders; non-compatibility limits interaction; role of advertisements
- **Partnerships:** Providers of connectivity, Immersive reality equipment, Content, SW.

Demand Side

- **Customer segments:** consumer; employer / institution (industry, architects, health, education) - for end-users; game/immersive reality publisher; immersive reality equipment providers.
- **Stakeholders/key partners:** End users; Subscriber of the service (who pays);
- **Customer relationships:** Business to Consumer/user; Business to Business user; Business to User equipment provider to Consumer.
- **Channels:** Digital channels; Direct sale; distributors; partner distributors; tenders.

Outcomes

- **Benefits:** Efficiency and productivity improvements; fostering a healthy social life (inclusion; pleasure of social interaction, and well-being); allowing for new ways of working; enhancements to innovation; carbon footprint reductions.
- **Revenues (revenue streams):** Alternative streams: customers can buy bundles of equipment/connectivity/services, or direct to all providers. Examples: Payments from user/customer to operator; Payments from employer/institution to operator (of private network - wide area network); Payments from employer to equipment provider to operator; Payments from employer to equipment provider AND operator AND content provider.
- **Pricing:** Different models: subscriptions per end-user/user equipment; wholesale prices, per subscription or per volume level (to e.g., game publishers or equipment providers who bundle connectivity into service); as-much/many UEs-as-you-can-eat limited by geography; time.
- **Costs:** High costs for general support for immersive reality; requirements for ubiquitous QoS in the intended coverage area and the reality of lower and unpredictable QoS in wide area network; growth of immersive reality in socially not-so-acceptable or illegal domains; unintended growth of digital storage and resource usage (waste).

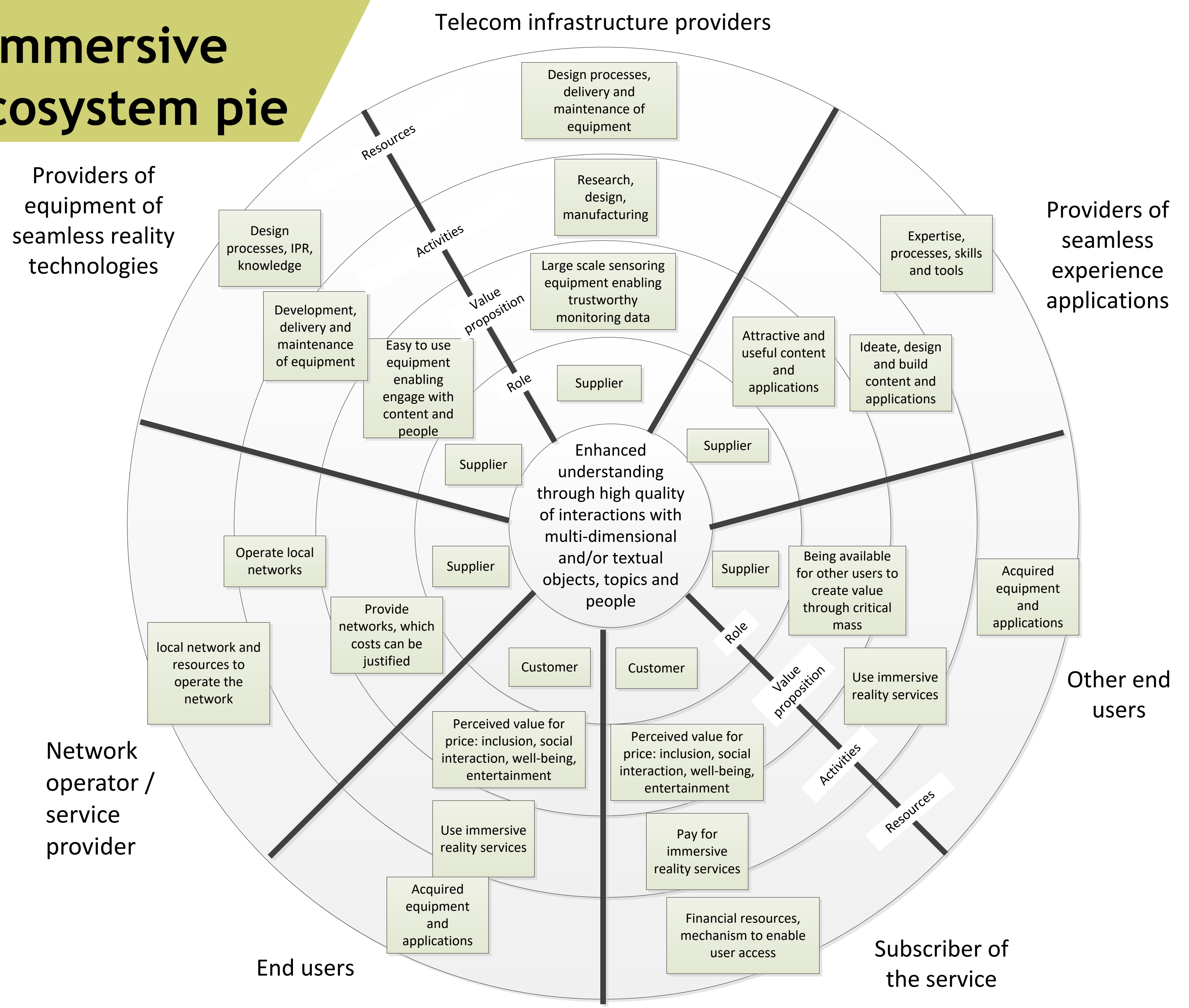
Seamless Immersive Reality: Stakeholder Analysis

Immersive Experience

Stakeholder	Description	Role	Value proposition	Activities	Resources
Providers of equipment of seamless reality technologies	Providers of equipment of seamless reality	Supplier	Equipment which is easy to use and set-up, to engage with content personal equpment, or easily shared with other people	Development, delivery and maintenance of equipment. Research, design, manufacturing (outsourced), sale/distribution	Design processes. IPR, knowledge. People. Own factories - or outsourcing expertise.
Providers of seamless experience applications (including content and marketplace for services)	Providers of applications and content for seamless experience	Supplier	Attractive and useful content that can be made available efficiently in a marketplace	Ideate, design, build content. Share. Manage users, and potential purchasers of content creation and the sharing. Sales and customer relationships.	Expertise. Processes. Skills and tools. Capital. Brand.
Telecom infrastructure providers (network vendor)	Vendor of communication network infrastructure, which has sensing capability.	Supplier	Robust and predictable general purpose large scale sensoring equipment and make available trustworthy monitoring data.	Research, design, manufacturing (outsourced), sale/distribution,	Design processes. IPR, knowledge. People. Own factories - or outsourcing expertise. Scaling capabilities.
Network operator / service provider	Provider of local / wide area connectivity services supporting immersive experience.	Supplier	Investment and costs in network can be justified by the use and users, and what they pay for deploying and running the network. For business modelling: a need to identify more uses for privat networks to make a business case	Operate local network. Handle relationship with network owner/financer - and users, access rights of network.	Local active (and passive network). Human operation and support. Financial resources. Spectrum ownership. Installed network (infrastructure and people). Knowledge about network sourcing and deployment. Customer base.
End users	students, teachers, common people	Customer	Perceived value for price: inclusion, social interaction, well-being and being entertained; productivity, innovation, quality, motivation. Reduced carbon footprint. Test before purchase.	Use the immersive reality services. Potentially pay for services for immersive experience. Require support.	Acquired equipment and applications to use the services. Sufficient financial resources. Rented devices (rental model for sharing and limiting devices proliferation).
Subscriber of the service (who pays)	Financing actor/sponsor of content / applications / connectivity, e.g., education	Customer	Perceived value for price:Productivity, innovation, quiality, motivation, better use of scarce human resources, inclusion, reduced carbon footprint, test before deployment (product, medicine…).	Pay for services for immersive experience, on behalf of users	Sufficient financial resources, mechanisms which enables to assess, prioritize, and purchase "new" tools (pioneer)
Other end users	other end users to use the seamless experience with	Supplier	Being available for other end users who would want to reach to create critical mass	Use the immersive reality services.	Acquired equipment and applications to use the services.

Seamless Immersive Reality: Ecosystem pie

Immersive Experience



Realtime Digital Twin: Business Model Canvas

Digital Twins

Supply Side

- **Stakeholders/key partners:** Sensor providers; Digital twin providers; Telecom infrastructure providers; Network operator/service provider; End user equipment providers; Providers of components that need to be digital twinned; Provider/integrator of applications on top of the digital twin
- **Resources:** IoT devices; robots; compute resources; AI algorithms; data and access to data; digital twin data; domain specific competence; communication network; funding; buildings; infrastructure; natural resources and raw materials; Design processes; IPR; Factories Workforce;
- **Activities**: Coordination and cooperation between stakeholders; development of twin/replication of a large entity for interactions; providing connectivity; R&D; design; manufacturing; deployment; sales; operation maintenance; circular business; sustainability management; life cycle management; ethical management; authentication

Ecosystem Value Propositions

- **Value proposition:** New business opportunities and increased efficiency from multiple stakeholders meeting in a virtual digital twin being immersed and bringing together capabilities to co-create value by solving challenges remotely and collaboratively.
- **Value co-creations:** Increased efficiency of stakeholders' operations by multiple stakeholders meeting in digital twins through automation, remote monitoring and handling of infrastructure allowing better information sharing and coordination of stakeholders' processes in the value chain and common system development and changing the ways of working/collaboration through better coordination (example: industrial metaverse).
- **Value capture:** Those in control of processes can extract value from the use of digital twins to optimize the processes.
- **Value co-destruction:** Complex collaboration contracts; Risk of not being able to create a full digital twin (getting data from all involved stakeholders); need for standardization to allow digital twins to collaborate and exchange information.
- **Partnerships:** Relation between the digital twin provider and the user of the digital twin (can be different models: as a service (aaS)).

Demand Side

- **Customer segments:** Building/site/facility owners/operators
- **Stakeholders/key partners:** Building/site/facility owners/operators; Owner of the digital twin; Humans/real users (humans using digital twin in the site and those being monitored);
- **Customer relationships:** Business to owner of digital twin (money flow); Business to the users of digital twin (customer support)
- **Channels:** Tenders; direct sale;

Outcomes

- **Benefits:** Resource savings (including materials, energy); reduced waste; reuse of materials over product/construction cycles; safety improvements; reduced costs; reduced burden on environment (achieving sustainability targets); making the world more manageable 24/7; reduced dependency on human resources and burden on humans doing things right; better overview of what resources are used - a system to manage circularity; new jobs for new competences; making use of digital twin for the network in the location (network management); using of digital twin before constructs are finished for training/preparing before opening; better working environment for the person/worker.
- **Revenues (revenue streams):** Different financing/charging models for the use of digital twin (as a service-monthly fees; invest yourself; different stakeholders to invest to provide revenues for digital twin providers); reduced costs; multiple use cases needed to justify the cost.
- **Pricing:** Different models: everything aaS from one stakeholder; buying/doing yourself the sensors/analysis/digital twin; subscriptions for devices & services (incl. connectivity); aggregation of subscriptions.
- **Costs:** More dependency on specific skills/systems; costs of training of workers; costs of creating and maintaining digital twin; footprint from devices; cost of exposing critical information about infrastructure and operations.

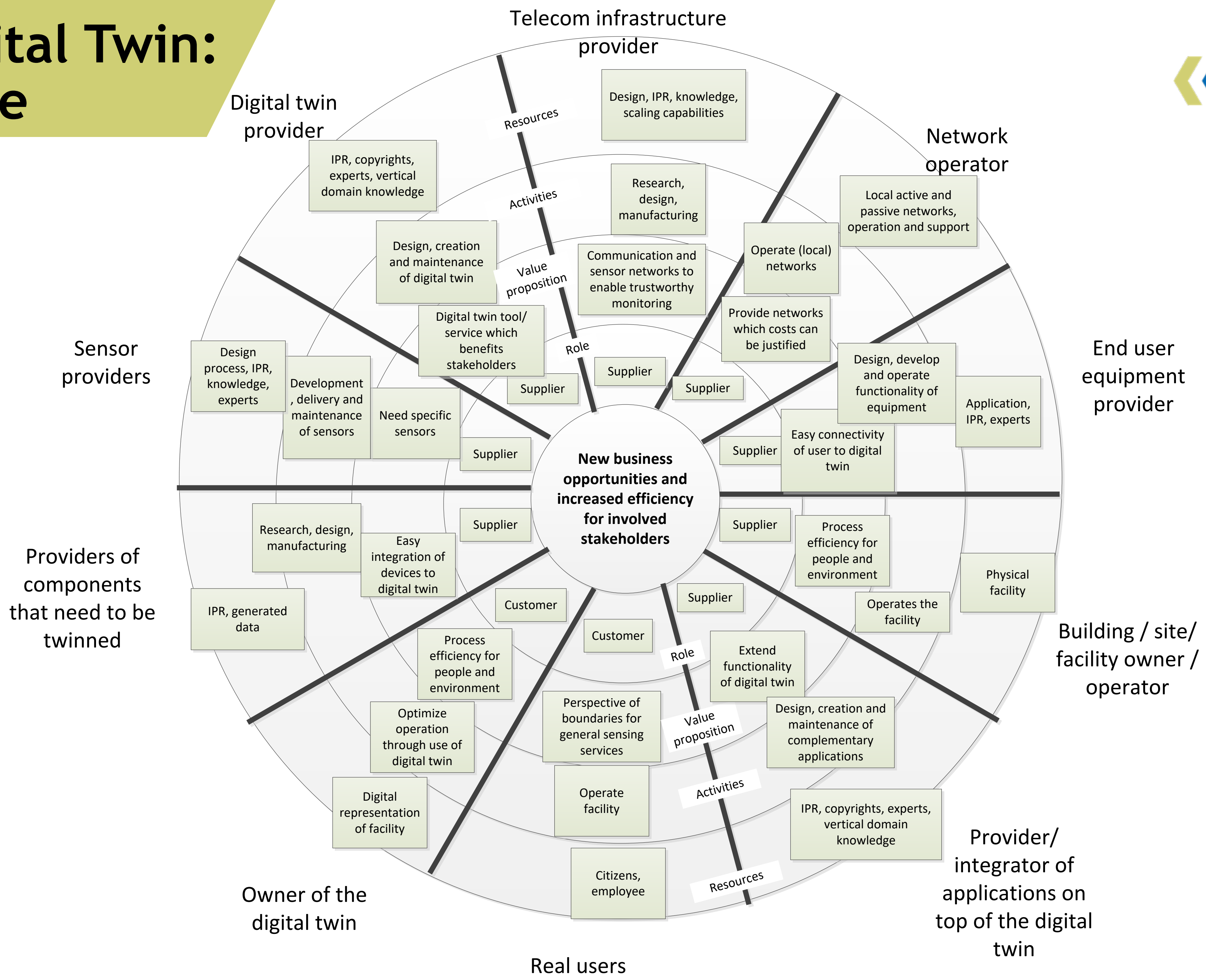
Realtime Digital Twin: Stakeholder Analysis

Digital Twins

Stakeholder	Description	Role	Value proposition	Activities	Resources
Sensor providers	Providers of sensors of different types	supplier	Robust and predictable installations of need-specific sensors.	Development, delivery and maintenance of sensors. Sales and customer relationships. Logistics. Inventory services.	Design processes. IPR, knowledge, experts. Scaling capabilities. Logistics and preconfiguration capabilities/systems/processes.
Digital twin providers	Provider of digital twin including digital twin applications SW and HW.	supplier	To offer a digital twin tool/service, which benefits stakeholders / users in their daily work.	Design, creation and maintenance of digital twin application and HW. Management of use and access. Sales and customer relationships. Authentication.	IPR and copyrightc, experts, vertical domain knowledge.
Telecom infrastructure providers (network vendor)	Vendor of communication network infrastructure, which has sensing capability.	supplier	Robust communication network infrastructure which allows stakeholders to use and develop the digital twin. Robust and predictable general purpose large scale sensoring equipment, and make available trustworthy monitoring data .	Research, design, manufacturing (outsourced), sale/distribution,	Design processes. IPR, knowledge. People. Own factories - or outsourcing expertise. Scaling capabilities.
Network operator / service provider	Provider of the connectivity service supporting digital twinning, especially for the local area of twinning. Can be public network or local private network.	supplier	Investment and costs in network can ce justified by the use and users, and what they pay for deploying and running the network. For business modelling: a need to identify more uses for privat networks to make a business case	Operate local network. Handle relationship with network owner/financer - and users, access rights of network. Authentication.	Local active (and passive network). Human operation and support.
End user equipment providers	Provider of equipment that end users use to access to digital twin.	supplier	Easily connect user of digital twin applications, new and for the first time.	Design, develop, operate application / functionality / equipment. Manage IDs and users, privacy regime. Sell and promote.	Algorithms. Applications (code). IPR. Experts.
Providers of components that need to be digital twinned	(e.g., machines in factory);	supplier	Easy integration of devices into digital twin environment; easy replicability	Research, design, manufacturing, sale/distribution,	IPR; data generated by the components
Building/site/facility owners/operators	Owners/operators of buildings/sites/ facilities which are the core of the digital twin.	customer	Efficiency in processes for people and environment	Operate the facility	Physical facilities
Owner of the digital twin	Owner of the digital twin	customer	Efficiency in processes for people and environment	Make use of the digital twin. Optimize the operation of the facility	Digital representation of the facility
Provider/integrator of applications on top of the digital twin	Provider of applications that make use of the digital twin or integrate to the digital twin	supplier	To extend the digital twin beyond what the digital twin provider can do itself	Design, creation and maintenance of applications on top of digital twin Sales and customer relationships.	IPR and copyrightc, experts, vertical domain knowledge.
Humans/real users (humans using digital twin in the site+those being monitored);	Human users of the digital twin.	customer	Perspectives on boundaries for general sensing services	Carry out normal and expected activity. Respond precautious and reactively to sensing environments. Give feedback.	Citizens. Employee. Right to be heard.

Realtime Digital Twin: Ecosystem Pie

Digital Twins



Ubiquitous Network: Business Model Canvas

Fully Connected World

Supply

- **Stakeholders/key partners:** Infrastructure NW provider; NTN incl Earth station providers; Wide area network provider (CSP, ISP); Local networks provider (DSP) and small-scale base station operator/owner (radio resource); Provider of energy infrastructure; Planet Earth and Future Generations
- **Resources:** Design processes; IPR; Factories; TN & NTN infrastructure; Raw materials; Water; Workforce; Energy; Collaborative funding
- **Activities**: Research, Development ; Design; Manufacturing; Deployment; Sales; Operation Maintenance; Circular business; Sustainability Management; Life cycle management; Ethical management

Value

- **Value proposition:** Giving everyone, everywhere the possibility to access digital services. Global mobile broadband connectivity through reliable integration of multiple networks securing digital inclusion and privacy
- **Value co-creations:** Examples: Suppliers: re-use of infrastructure and collaboration reduce costs for R&D. Customer&Supplier: Sharing of customer data can be used to improve services. Enhanced knowledge in workforce. Co-funding of investments.
- **Value capture:** More customers when global connectivity (but probably many customers with low income), higher efficiency, shared investments, new business opportunities
- **Value co-destruction:** Complex collaboration contracts; Exploitation of commons; Unintended Reduced Fundamental Freedoms
- **Partnerships:** Partnerships needed for covering the unconnected but also to expand services given, i.e. payments; education; health services based on local needs and legislation

Demand

- **Customer segments:** end-user; subscriber
- **Stakeholders/key partners:** end-user; authorities; private companies; governments; Non-Governmental Organizations (NGOs); Planet Earth and Future Generations; Workforce
- **Customer relationships:** B2B and B2C and B2B2C
- **Channels:** Word of mouth (trusted); Social media; Government/Authority channels; Feedback channels from stakeholders

Outcomes

- **Benefits (incl. benefits to environmental and social):** digital inclusion; reuse of resources; faster distribution of information and new ideas; increased competition; facilitated market transactions; environmental monitoring; reduced GHG emissions if more services can be accessed without travelling; enhanced trustworthiness of networks
- **Revenues (revenue streams):** Fixed yearly fee per government, private companies, NGOs giving basic service. Additional fee for end-users based on usage.
- **Pricing:** Differentiated pricing for countries based on GDP and purchasing power among individuals
- **Costs (incl. costs to environmental and social):** Shared infrastructure investments and cost to create interfaces between networks; higher energy and maintenance costs; GHG emissions; Waste handling; Imposed monitoring; Increased land use could cause biodiversity loss; Higher energy usage; Potential digital divide if all services digital

Ubiquitous Network: Stakeholder Analysis

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Stakeholder	Description	Role	Value proposition	Activities	Resources
Infrastructure equipment provider	Provider of the HW necessary to set-up network	Supplier	Extended market geographically and technically gives new opportunities and ways of sharing R&D investments	R&D, design & manufacturing of infrastructure and providing network services	Competence; design processes, IPR, factories
Non-Terrestrial-Network-Connectivity incl Earth station	NTN provider has the satellites, and signals must be captured/sent via an earth station to TN	Supplier	Connecting the unconnected when NTN and TN is combined	R&D, deployment, operation, maintenance of NTN incl. earth stations	NTN and earth stations; expertise; frequencies
Wide area networks provider (CSP, ISP)	Provides connectivity (the CSP role) in wider areas, via the Internet (the ISP role)	Supplier	Mobilize total market, cost and energy reduction/efficiency. Resource sharing/optimization.	Deploy and operate networks. Sell, onboard-support-offboard users/customers.	Installed/controlled network (infrastructure, spectrum, customers and people). Knowledge about network sourcing and deployment.
Local networks provider (DSP). Local, small-scale base station operator/owner (radio resource)	Provides connectivity in very local areas. Layer 2, plus 3. Can be more networks using the same radio.	Supplier	Enable local community inclusion, or other stakeholders to finance local radio coverage.	Operate active local network infrastructure. Handle interconnectivity and roaming agreements.	Installed/controlled local network (infrastructure, spectrum, customers and people) used within geographical area of radio. Knowledge about network sourcing and deployment.
Provider of energy infrastructure	Power companies	Supplier	Enable operation of network services by providing energy	Power generation preferably through renewable sources	Energy infrastructure, permits to operate, capital to invest
End-user	The person who is receiving services, at a geographically specific place	Customer	Access to trustworthy basic citizen services (UE, network, application), reliable in private events of high importance.	Use services: login, use, share with others,	Skill, time, motivation, perceived benefits, give feedback to suppliers.
Subscriber (governments, authorities, NGOs, private companies)	The entity which is paying for realizing a service. Many B2B2B2C configurations.	Customer	Finance local networks to secure availability of basic citizen digital services to everyone.	Use decision rights, controlling mechanisms as legislation to direct investments. Sign up for subscription of services.	Ability to pay, policy decision rights over some resources, give feedback to suppliers.

Ubiquitous Network: Ecosystem pie

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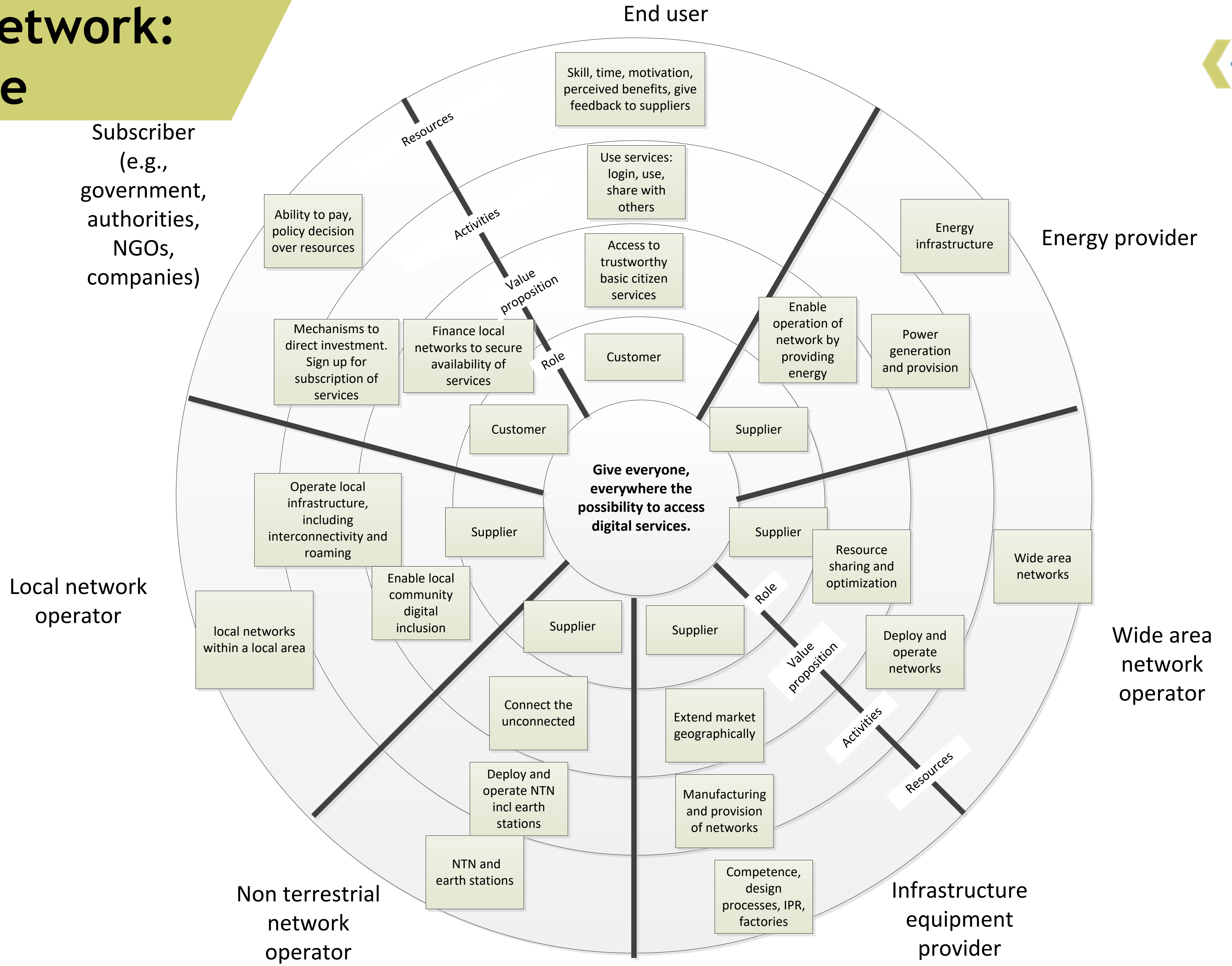

Next Steps

Next Steps - up-coming deliverables

Deliverable	Content of the deliverable		
D1.3 – Environmental and societal impacts of 6G **(March 2024)**	Provide a comprehensive view of the business ecosystem (including the identification of key stakeholders)	+ Provide an analysis of the challenges and risks to meet environmental, economic and social sustainability	+ Give first view on social acceptance
D1.4 – 6G Value, requirements and ecosystem **(April 2025)**	Provide the final analysis on the value to be created by 6G for society & people (incl. environmental and economic sustainability)	+ Provide the final set of use cases and requirements	+ Present the outcome of various exchanges with the ecosystem

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