SNS Stream B/D Projects Workshop on KPIs and KVIs

Status on project's KPIs and KVIs

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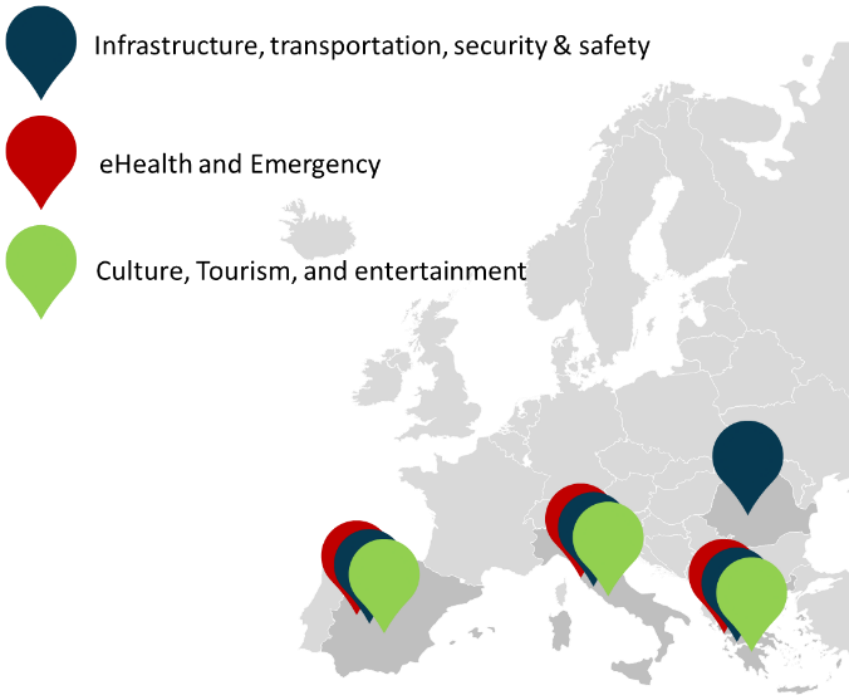
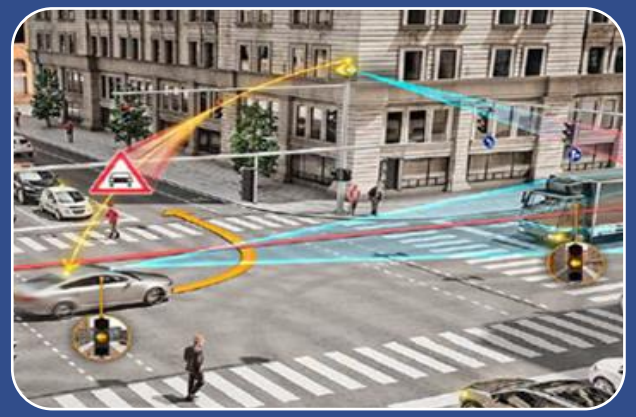
TrialsNet project has received funding from the European Union's Horizon-JU-SNS-2022 Research and Innovation Programme under Grant Agreement No. 101095871

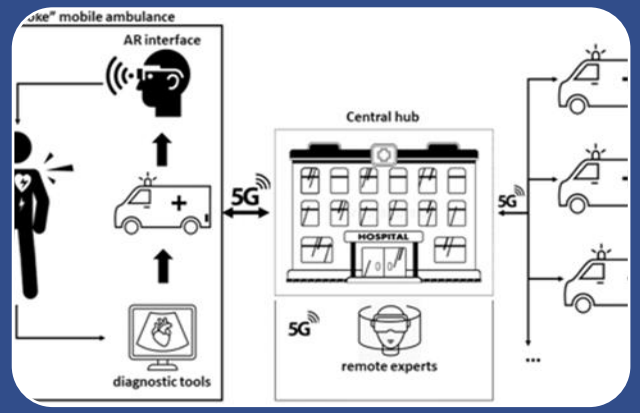
Main objectives

- Deployment of **full large-scale trials** to implement a heterogenous and comprehensive set of **innovative 6G applications** based on various technologies and **covering 3 domains**
- Design and implementation of **13 use cases** developed over **wide coverage areas** with the involvement of **extended sets of real users** in **4 clusters**
- Design and integration of **platforms and network solutions** with **advanced functionalities** (e.g., E2E orchestration, MEC, AI/ML methods, etc.) on **different network architectures** (3GPP and O-RAN)
- Definition and validation of **specific KPIs** and **KVIs**
- Learn from these activities to understand:
  - where the **current network capabilities** are **not sufficient** to provide the performance requirements needed by the implemented use cases, and this way
  - devising the **new requirements** for the forthcoming generation of mobile networks
- Further strength project's results through the Open Call



TrialsNet Use Cases





Infrastructure, Transportation, Security & Safety

UC1: Smart Crowd Monitoring

UC2: Proactive Public Infrastructure Assets Management

UC3: Autonomous APRON

UC4: Smart Traffic Management

UC5: Control Room in Metaverse

eHealth & Emergency

UC6: MCI and Emergency Rescue in Populated Area

UC7: Remote Proctoring

UC8: Smart Ambulance

UC9: Adaptive Control of Hannes Prosthetic Device

Culture, Tourism & Entertainment

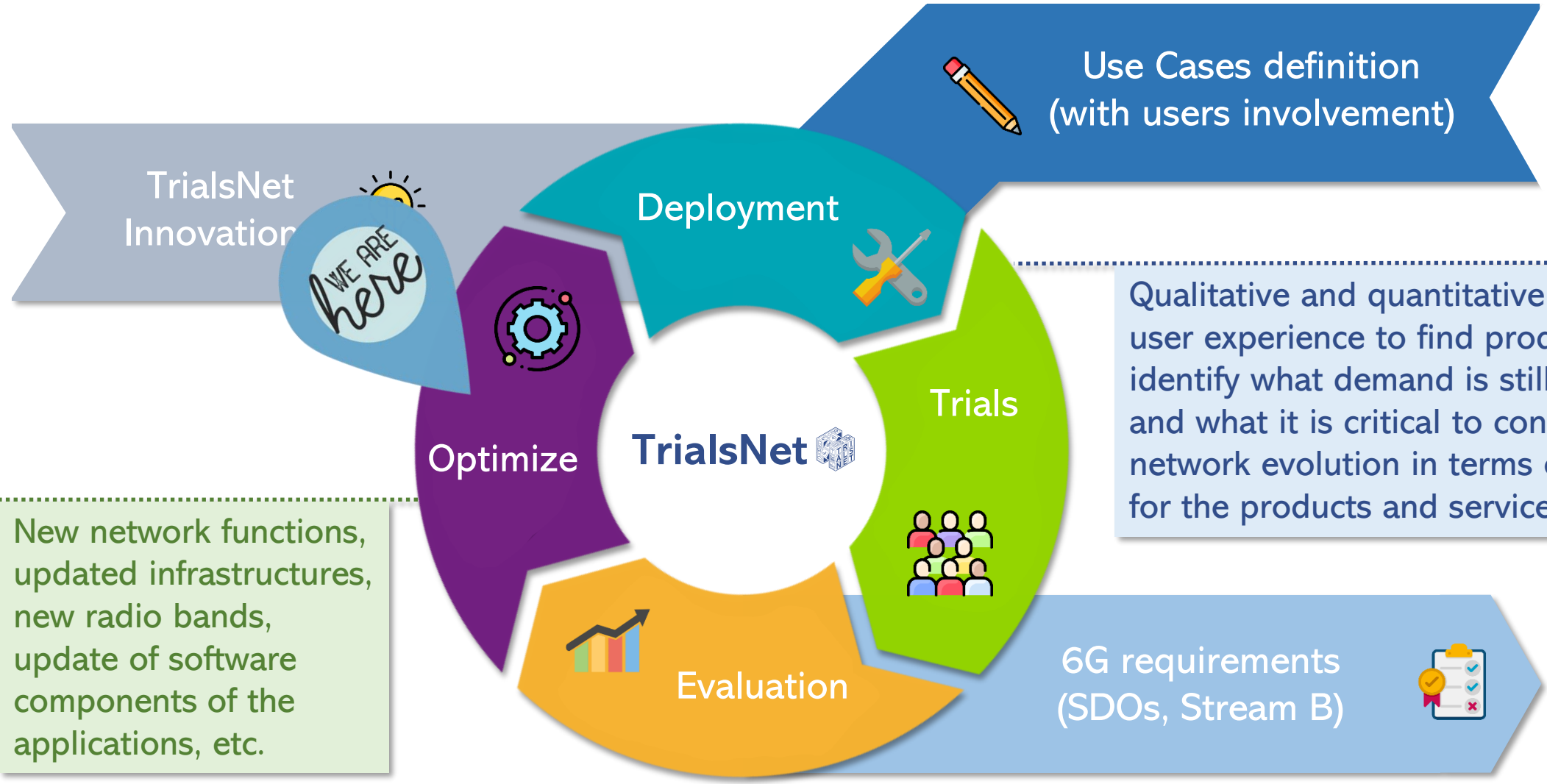
UC10: Immersive Fan Engagement

UC11: Service Robots for Enhanced Passengers' Experience

UC12: City Parks in Metaverse

UC13: Extended XR Museums Experience

Methodology



Qualitative and quantitative analysis of the user experience to find product/market fit, identify what demand is still not covered, and what it is critical to consider for future network evolution in terms of requirements for the products and services

New network functions, updated infrastructures, new radio bands, update of software components of the applications, etc.

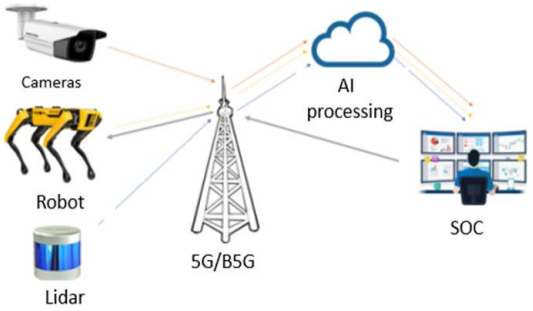
Introducing the KPIs

- Goal: Definition of measurable metrics for the use cases
- Common KPI terminology obtained by:
  - Iteratively harmonizing the KPIs defined in the different use cases
  - Making the definitions aligned with guidelines/methodology in reference documents by ETSI, 3GPP, and 5GPP
- Open to revise the adopted definitions based on the most updated documents by 5GPP Test, Measurement, and KPIs Validation (TMV) Working Group

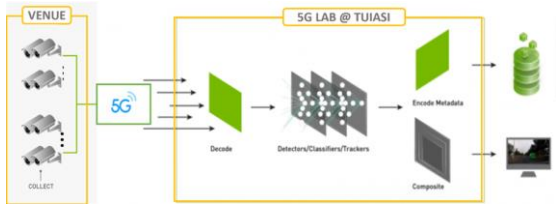
Use Cases and KPIs for ITSS domain (1/3)

Use case implementation status and Requirements

- **UC1 "Smart Crowd Monitoring" (Madrid):** aims to test and detect abnormal situations such us crowds preventing the free access to the facility, violent activity such as people fighting or riots, vandalism, weapons, suspicious activity such as loitering, or person running and abandoned bags. Different setups have been implemented including different devices configuration with robot, camera and Light Detection and Ranging (LiDAR). Preliminary lab tests showcased that the 5G network can support the operation while it offers adequate latency for video stream only if compression is applied. Moreover, the use of LiDARs is challenging for the network as 250 Mbps is required in the uplink. During the measurements with LiDAR OS0, camera and Kiro Robot the average latency value is also over the expected limit of 300 ms, which will increase the difficulty in the future to use of AI algorithms to analyze video streams and cloud points from the LiDAR.



- **UC1 "Smart Crowd Monitoring" (Iasi):** focuses on outdoor public events by managing people counting, density, and dynamics of large number of persons. Preparatory activities were done such as installation of cameras and 5G CPE, Wi-Fi Access Points and the development of the image processing application, and dashboard. For the 5G network measurements, the conclusion is that the tests performed were in line with the expectations, i.e., the 5G NSA commercial setup is working fine in case of not congested network but it is complicate to deliver the expected performance during huge events. KPIS measurements have been done with all 14 cameras on field and different resolutions settings:



Main KPIs

KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink aggregate throughput	200-500 Mbps	6 Mbps	5
	Uplink aggregate throughput	20-100 Mbps	80 Mbps	5
	Uplink cell capacity	150 Mbps		5
Latency	E2E application latency	<100ms		4
	Application one way latency	<100ms	503 ms	5
Coverage	Reliability	99%		4
	Coverage	99%		4
	Service availability	99%		4

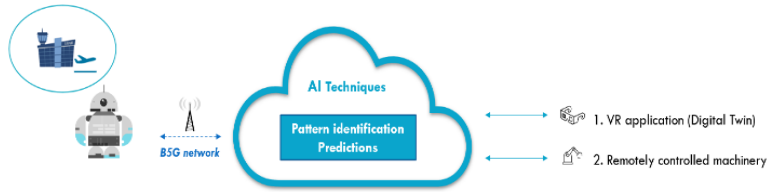
KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Uplink user experience data rate	111 Mbps	98 Mbps	5
	Downlink cell capacity	1.5 Gbps		3
	Uplink cell capacity	150 Mbps		5
Latency	Application-level latency	<100ms		4
	E2E latency	<50ms	28 ms	5
Service	Reliability	99%		4
	Service availability	99%		4

Use Cases and KPIs for ITSS domain (2/3)

Use case implementation status and Requirements

- **UC2 "Public Infrastructure Assets Management" (Athens):** offers a solution to improve the management and maintenance of infrastructure assets in Athens International Airport (AIA) and public infrastructure in Athens. Application algorithm precision KPIs have been measured with a positive outcome. For the 5G network, streaming and re-streaming measurements have been done focusing on the E2E latency. The required latency was achieved, but it is expected that in real environments the 5G network will be stressed enough and network latency performances challenged.

- **UC3 "Autonomous APRON" (Athens):** The use case demonstrates how autonomous and smart systems can perform ground handling operations at the airport APRON. The preliminary tests consisted mainly in end-to-end (E2E) latency measurement using both Wi-Fi and 5G networks. In this context, the E2E latency measurements showcased that the 5G network offers improved latency with respect to Wi-Fi, with less variability, but still not as low or consistent as might be desired for critical applications. Wi-Fi latency results are in the range of 80 ms.



Main KPIs

KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per device	150Mbps		3
	Uplink throughput per device	30Mbps		3
Latency	E2E latency	10-100 ms		5
	Application-level latency	800 ms	636 ms	5
Compute	Precision	0.8	0.9	5
	Recall	0.6	0.86	5
Service	Service availability	100%	99.933	4
	Service reliability	100%	99.99	4

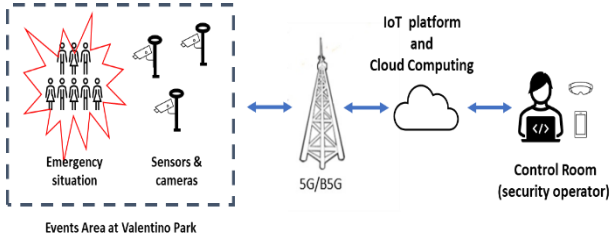
KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per device	150Mbps		3
	Uplink throughput per device	30Mbps		3
Latency	E2E latency	10-100 ms		5
	Application-level latency	80 ms	60 ms	5
Compute	Precision	0.8		5
	Recall	0.6		5
Service	Service availability	100%		4
	Service reliability	100%		4

Use Cases and KPIs for ITSS domain (3/3)

Use case implementation status and Requirements

- **UC4 "Smart Traffic Management" (Iasi):** focuses on traffic comfort and safety functions. Based on a similar infrastructure as UC1 in Iasi, the SW platform ingests available data from cameras deployed throughout the city, communicating over 5G commercial network. A series of tests were conducted, focused on assessing the accuracy of the models in low-light conditions and adverse weather scenarios. KPIs have been measured under poor 5G coverage environment and evaluation against application requirements has been assessed. Measurements have been done with All 6 cameras at resolution 1280x720, 4 at 25fps, 1 at 15fps and 1 at 10 fps during normal traffic hours, average movement. Throughput value scales almost linearly with number of cameras.

- **UC5 "Control Room in Metaverse" (Turin):** The purpose of this use case is to employ Extended Reality (XR), Metaverse, DT, and Internet of Things (IoT) technologies for remote, multi-agency and environment tailored XR training and real-time visualization of behavioral anomalies/ movement patterns. The virtual space for the Metaverse Control Room (MCR) has been constructed within the metaverse. The IoT platform has been also installed in the servers of the PoliTO premises. The main conclusion is that the throughput and E2E latency for one client/camera are supported by the network but is expected to not be sufficient for medium to large events requiring more on-site cameras and agents. The bitrate and round-trip delay for one client are below the network specs for small to medium events, but not sufficient for medium to large events requiring more on-site cameras and agents.



Main KPIs

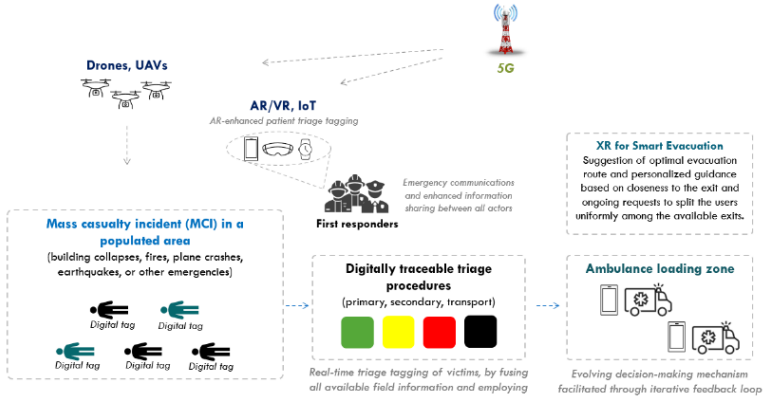
KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Uplink user experience data rate	14 Mbps	22 Mbps	5
	Downlink cell capacity	1.5 Gbps		3
	Uplink cell capacity	150 Mbps		5
Latency	Application-level latency	<100ms	140 ms	4
	E2E latency	<50ms		5
Service	Reliability	99%		4
	Service availability	99%		4

KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per user	100Mbps	24 Mbps	4
	Uplink throughput per user	100Mbps	4 Mbps	4
	Downlink throughput per application	10.12 users @ min 20Mbps up to 100Mbps		4
Latency	E2E latency	< 100 msec		5

Use Cases and KPIs for eHE domain (1/2)

Use case implementation status and Requirements

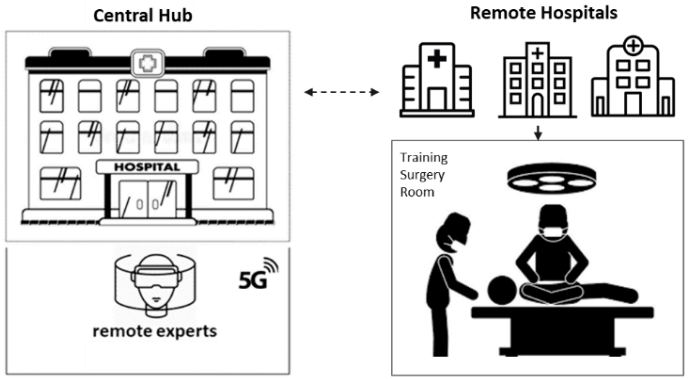
- **UC6 "Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area" (Athens/Madrid):** It aims to offer cutting-edge technological solutions created by TrialsNet for the most effective coordination for first-case responders in the context of triage and coordination of resources at the scene of mass casualty incidents, which could be building collapses, earthquakes, fires, or other large-scale emergencies, and emergency evacuation in the context of a crowded sporting or cultural event.



Main KPIs

KPI/Project		Target Range	Preliminary results	Relevance
Latency	Application-level latency (round trip)	10 -100 ms	69 ms	5
Compute	Precision	0.80	0.84	5
	Recall	0.65	0.53	5
	F1 score	0.70	0.65	4
Service	Service availability	100%		4
	Service reliability	100%		4

- **UC7 "Remote Proctoring" (Pisa):** It aims to support remote proctoring activities in the field of interventional cardiology, offering innovative solutions based on smart tools for telepresence in the surgical field to connect expert proctors and remote hospitals (Pisa and Massa). It is going to be deployed by connecting two sites at a geographical distance. A private 5G will cover the site where the proctor is located. The tests aimed to assess the impact of latency on the performance of eXtended Reality (XR), aimed to assess the influence of the proposed technological innovations on the psychophysiological states and manual task performance of clinical users, identifying the maximum application one-way latency (defined as the amount of time it takes at application level from the source to the destination application) in about 20 ms, compatible with 5G SA performances. .

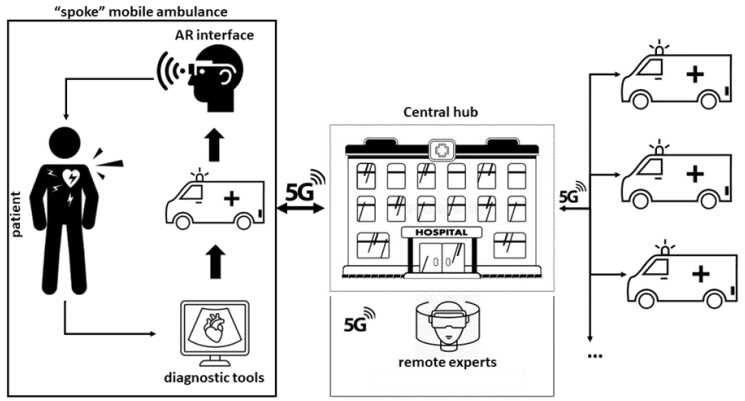


KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per device	50Mbps	30Mbps	4
Latency	E2E latency	20 ms	23 ms	5
Service	Service availability	100%	N/A	4
	Service reliability	100%	N/A	4

Use Cases and KPIs for eHE domain (2/2)

Use case implementation status and Requirements

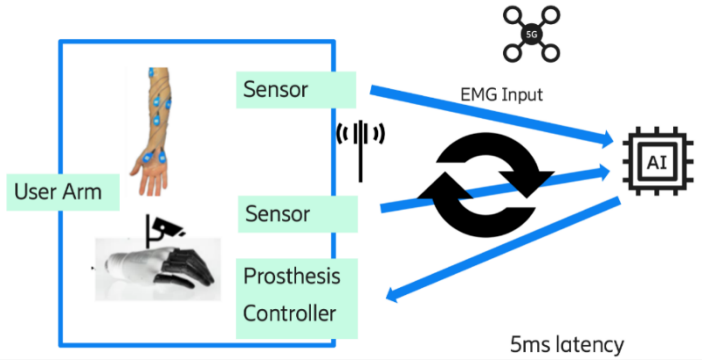
- **UC8 "Smart Ambulance" (Pisa):** 5G-connected smart ambulance operating outdoor in mobility. The use case is going to develop an infrastructure enabling ambulances to share diagnostic in-formation with the main centre. The proposed infrastructure is designed and implemented to equip the ambulance with new audio/video communication tools adopting AR/VR, diagnostic tools for cardiological pathology and devices for an efficient and fast 5G connection in remote locations and mobility conditions. The lab tests were intended to test the XR devices that will also be used in the context of the smart ambulance, albeit in a mobility scenario.



Main KPIs

KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per device	50Mbps	30Mbps	4
Latency	E2E latency	20 ms	23 ms	5
Service	Service availability	100%	N/A	4
	Service reliability	100%	N/A	4

- **UC9 "Adaptive Control of Hannes Prosthetic Device" (Genoa / Pisa):** It focuses on designing advanced control capabilities for prostheses using AI methods and deployment on the Hannes arm. The aim is to improve the user experience, leveraging radio 5G connectivity to provide sufficient computing power to the prosthesis to deploy AI methods with high reliability and low latency. In this first phase the goal is the assessment of the prototypes and their integration until an advanced level of readiness of the system is achieved. A set of tests has been already carried out to define the network performance baselines. One of the aims of these activities was to characterize the components to find the best configuration for each of them and to detect the possible network and application bottlenecks.



KPI/Project		Target Range	Preliminary results	Relevance
Latency	Application-level latency (one way)	10-15 ms	20-40 ms	5
Service	Service availability	100%		4
	Service reliability	100%		4

Use Cases and KPIs for CTE domain (1/3)

Use case implementation status and Requirements

- **UC10 "Immersive fan engagement" (Madrid):** This use case aims at increasing the engagement of people who are fans of sport. Preliminary test was performed in 5Tonic Lab test. Pre-trial will be conducted in July 2024 involving the laboratory network upgrade to 3GPP Rel-17 as soon as the compliant terminals will be available. The third and final step will occur at the selected venue, deploying a fully equipped use case with real users. Current 5G uplink network provides bandwidth values that fall short of the requirements for live video transmission in venue and at home use cases. Tests conducted involved limiting the uplink bandwidth to 18-20 Mbps, whereas the typical bandwidth needed for the described setup in the immersive Fan Experience in-venue use case scenario is approximately 80Mbps.

Main KPIs

KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per user			5
	Uplink throughput per user			5
	Downlink aggregate throughput	12-25Mbps	22Mbps	5
	Uplink aggregate throughput	100-300Mbps	22Mbps	5
Localization	Location accuracy	Not tested yet		4

- **UC11 "Service Robots for enhanced passengers' experience" (Athens):** This use case aims at improving passengers' comfort at AIA. With the use of IoT sensors and AI-powered algorithms, the passenger flow would become smoother by reducing waiting times. Passenger needs will be collected from various applications, based on which AI-enabled robots will assist/inform/entertain them during their permanence at the airport. Preliminary tests demonstrated the main capabilities of the application software developed. They validate the overall architecture of the application, showing it is capable of video analysis, streaming, real-time processing, restreaming of the video with the human detection model output and visualization of the basic analytics data.

KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per device			5
	Uplink throughput per device			5
Latency	Application one-way latency			2
	Application round trip latency	800ms	517ms	5
Compute	Precision	0,8	0,8286	3
	Recall	0,6	0,5274	3
	F1 score	0,68	0,6474	3
Service	Service reliability	99,99%	99,99%	3
	Service availability	99,99%	99,95%	3

Use Cases and KPIs for CTE domain (2/3)

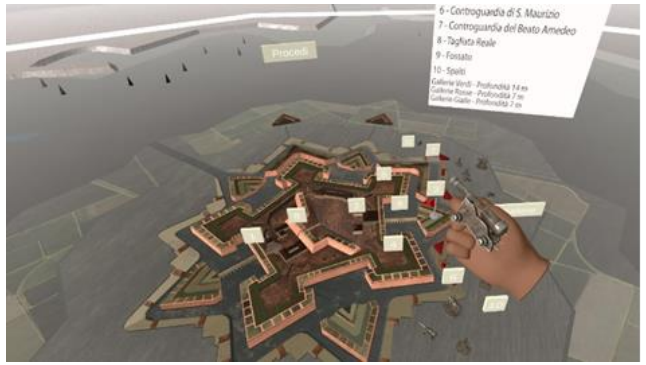
Use case implementation status and Requirements

- **UC12 "City Parks in the Metaverse" (Turin):** This use case develops around the social metaverse concept. A team of four players with a tablet is tasked with acquiring a series of virtual artefacts (keys) by solving different challenges in four cultural-historical spots of the Valentino Park in Turin. Once all artefacts are found, the game continues in a combat against an evil wizard utilizing VR headsets. The ultimate reward is a virtual exploration with a VR headset of a nearby fortress that is currently closed for renovation. The first trial for UC12 was on checking the load on the 5G network of the most critical component, that is the VR part of the game. The conclusion of the first measurements in the lab indicates that the aggregated downlink and uplink loads could be managed by the current 5G network.

Main KPIs

KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per user	10-<40Mbps	30Mbps	5
	Uplink throughput per user	10-<40Mbps	2Mbps	5
	Downlink aggregate throughput	10-<40Mbps	120Mbps	5
	Uplink aggregate throughput	10-<40Mbps	8Mbps	5
Latency	Application one-way lattency			5

- **UC13 "Extended XR Museum experience" (Turin):** The goal of this use case is to create a metaverse platform for visiting museums in Turin through portable devices. Users will be able to visit collections with friends and family in remote locations and/or in presence in selected locations. A captivating narrative is also developed to make the experience more engaging, interactive, and informative. The first trial for UC13 dealt with checking the load on the 5G network of the most critical component, that is the VR part of the experience in the metaverse. The AR step has not been tested. The preliminary tests that have been carried out focused on the application side. The results of the first measurements indicate that 5G network capacity and application roundtrip delay were sufficient to satisfy the requirements of such test setup.



KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per user	8Mbps	6,25Mbps	5
	Uplink throughput per user	2Mbps	2Mbps	5
	Downlink aggregate throughput			5
Latency	Application one-way lattency			4
	Application round trip lattency	15ms	<15ms	5

Horizon-JU-SNS-2022
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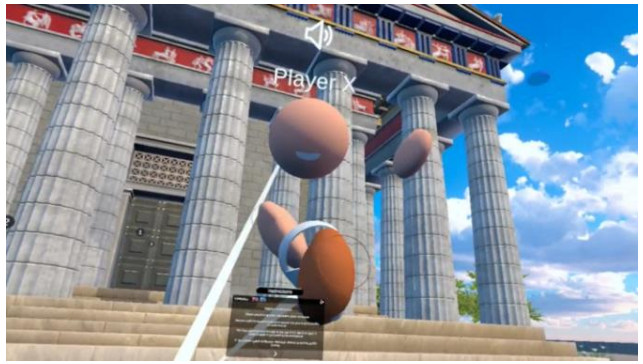
Use Cases and KPIs for CTE domain (3/3)

Use case implementation status and Requirements

- **UC13 "Extended XR Museum experience" (Athens):** AR-based technologies are used to leverage on content that elaborates on culture/historic aspects. In addition, scope itineraries optimization, to enhance the user experience (and safety when needed), are implemented. Lab tests have been conducted using an experimental network. The tests successfully demonstrated the main capabilities of the application, showing the capability of downloading the Asset Bundles that comprise the content of both the AR and VR applications on demand. The main conclusions of the first measurements indicate that 5G network capacity and one-way delay are sufficient to satisfy the requirements of the use case. Regarding the round-trip time latency, it was insufficient but this was due to the file size of the individual asset bundles (some of them were more than 225 MB).

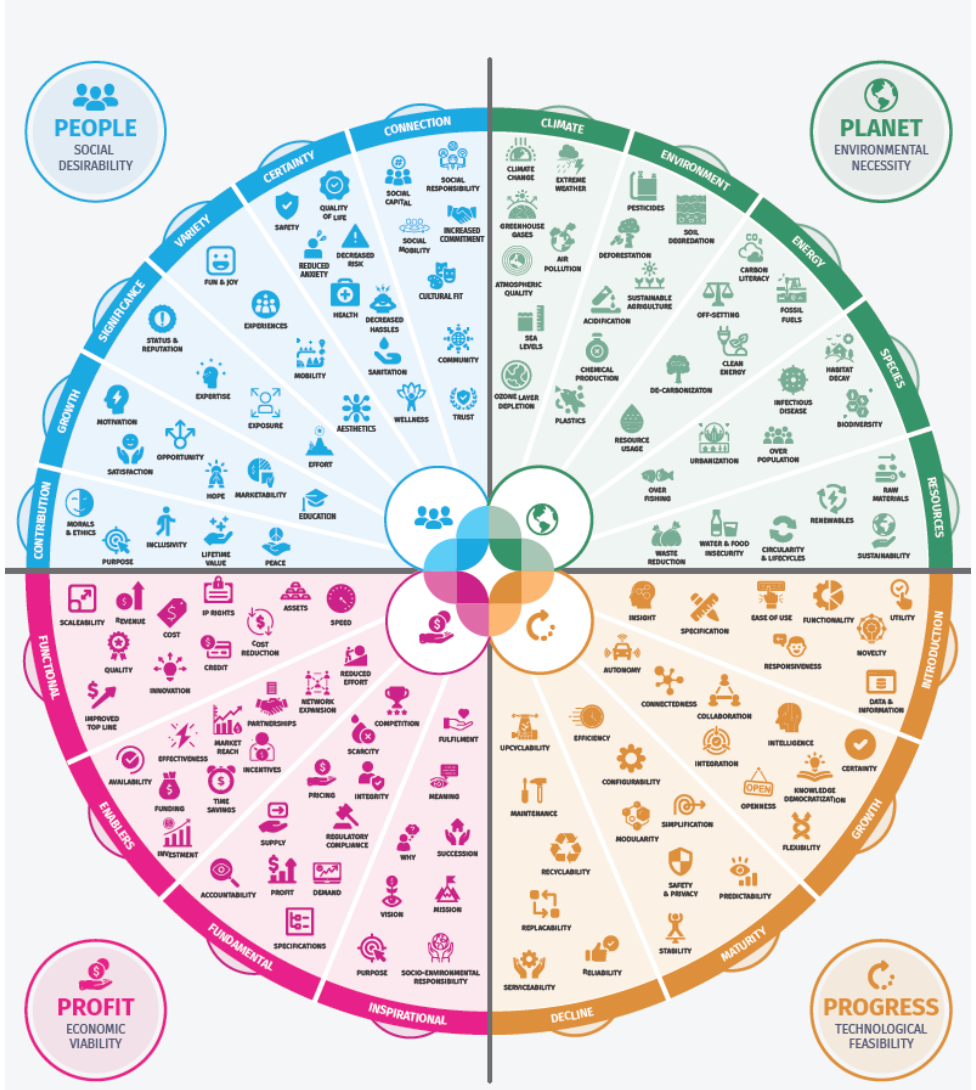


Main KPIs

KPI/Project		Target Range	Preliminary results	Relevance
Capacity	Downlink throughput per user	50 Mbps	150Mbps	5
	Uplink throughput per user			5
	Downlink aggregate throughput			5
Latency	Application one-way lattency	50ms	30ms	5
	Application round trip lattency	80-10ms	20s	5

Introducing the KVIs: the value type wheel

- Over 130 values are shown in the Figure to the right.
- In [1] these values are divided into 4 categories:
  - People: Social
  - Planet: Environmental
  - Profit: Economic viability
  - Progress: Technological feasibility



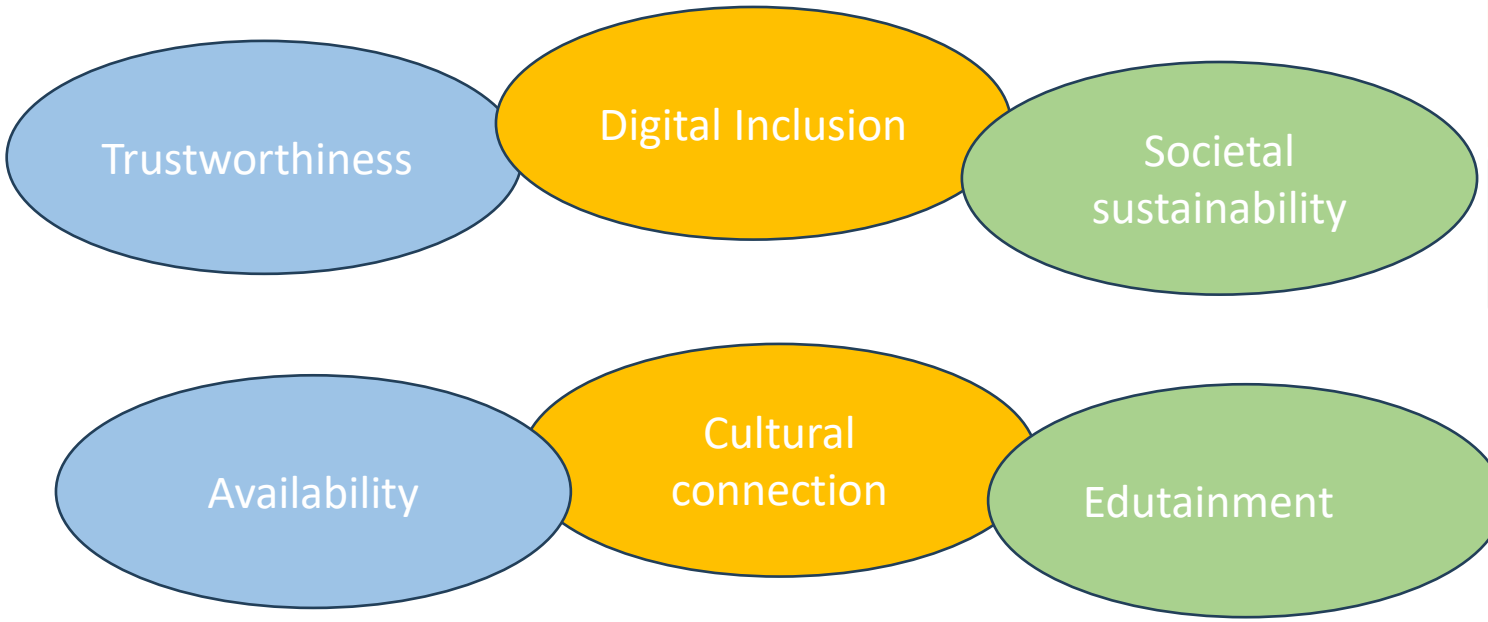
[1] https://www.explorerlabs.co/thinking/130-value-types-wheel-for-sustainabiltity-business-innovation

Roadmap: KPIs' vs. Key Value [6G-IA]

Key Value (KV)	*What are the values that we care about? What are the values that hold significance for us?*
Key Value Indicator (KVI)	*What are the key indicators of those values? How could we measure or assess those values?*
Enablers	*What factors contribute to the promotion of those values? what are the factors that make those values possible? e.g. 6G features, low latency, reliability, etc ..*
KPIs	*What are the technical impacts of those values? e.g. coverage, capacity, energy efficiency, device access density and localization accuracy*

KVs considered in TrialsNet

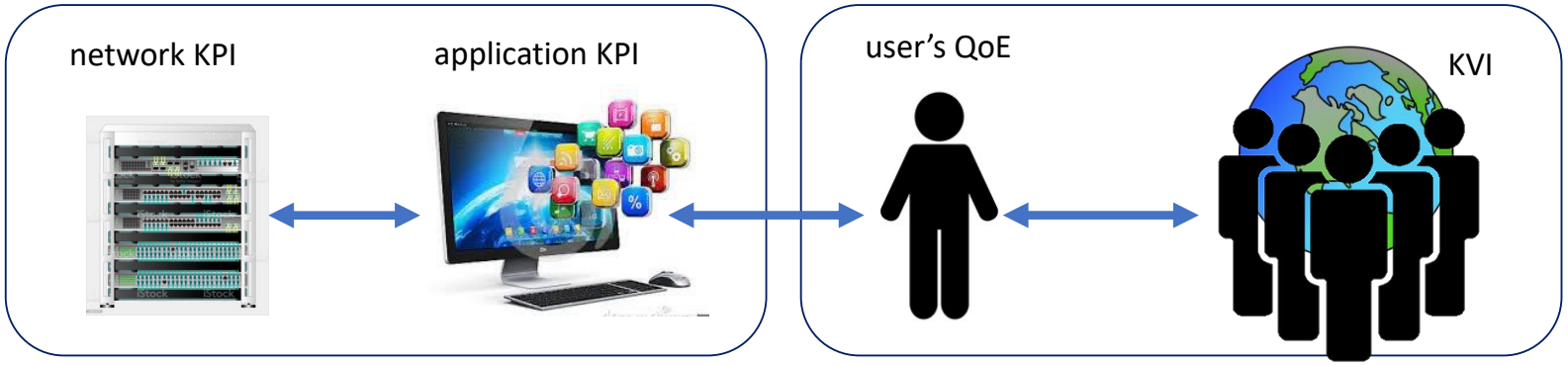
- Evaluating various Key Performance Indicators (KPIs) to measure progress towards “valued” objectives, such as Sustainable Development Goals (SDGs) or societal requirements, results in the identification of KVIs



THE 17 GOALS | Sustainable Development (un.org)

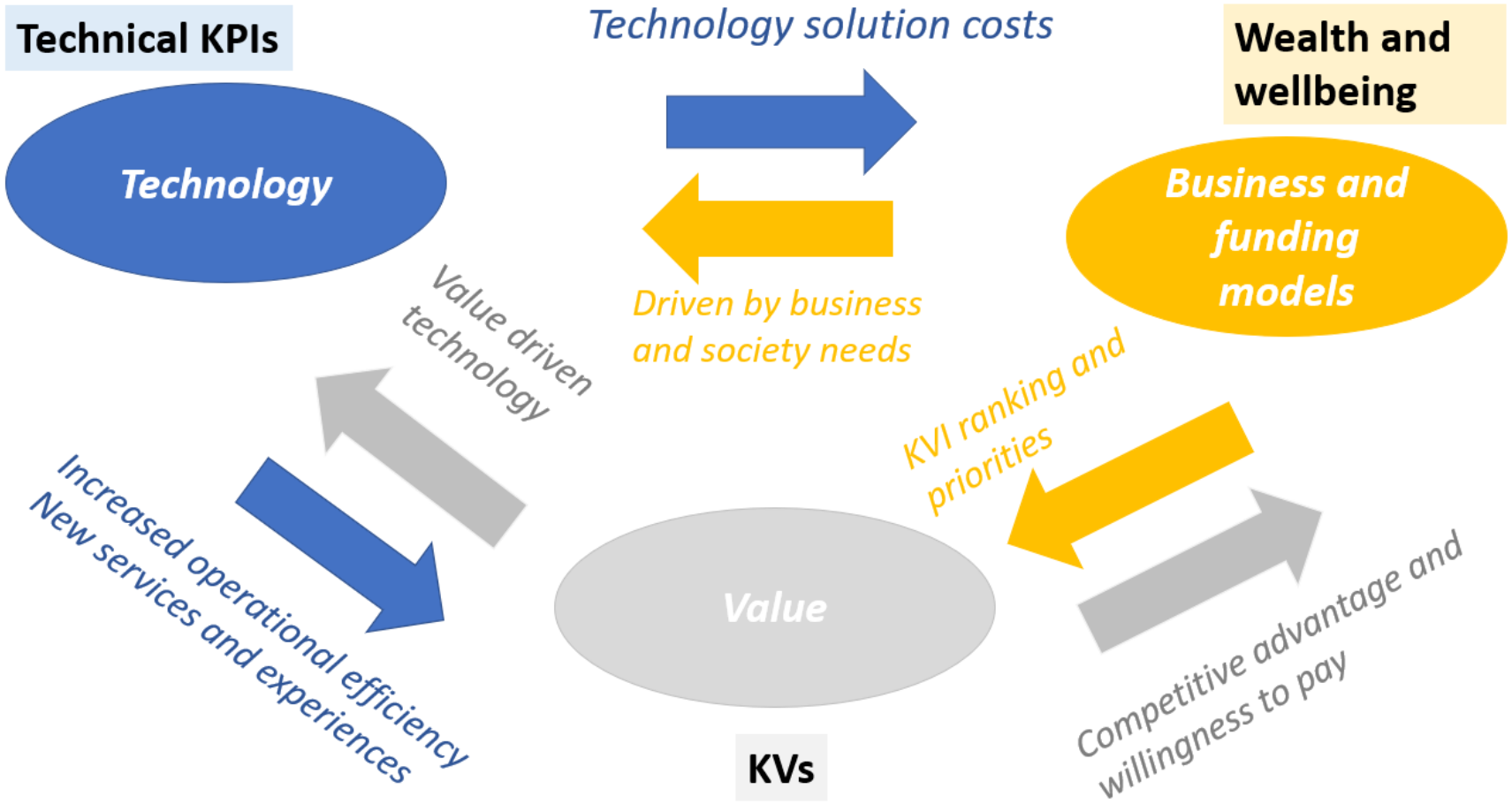
KVs, KVIs and KPIs

- Example of KVIs vs. KPIs :
  - **KV**: Environmental sustainability
  - **KVIs**: CO_2 reduction
  - **KPIs**: Lower Energy Consumption
  - **QoE**: maintain the same QoE perceived by the end user



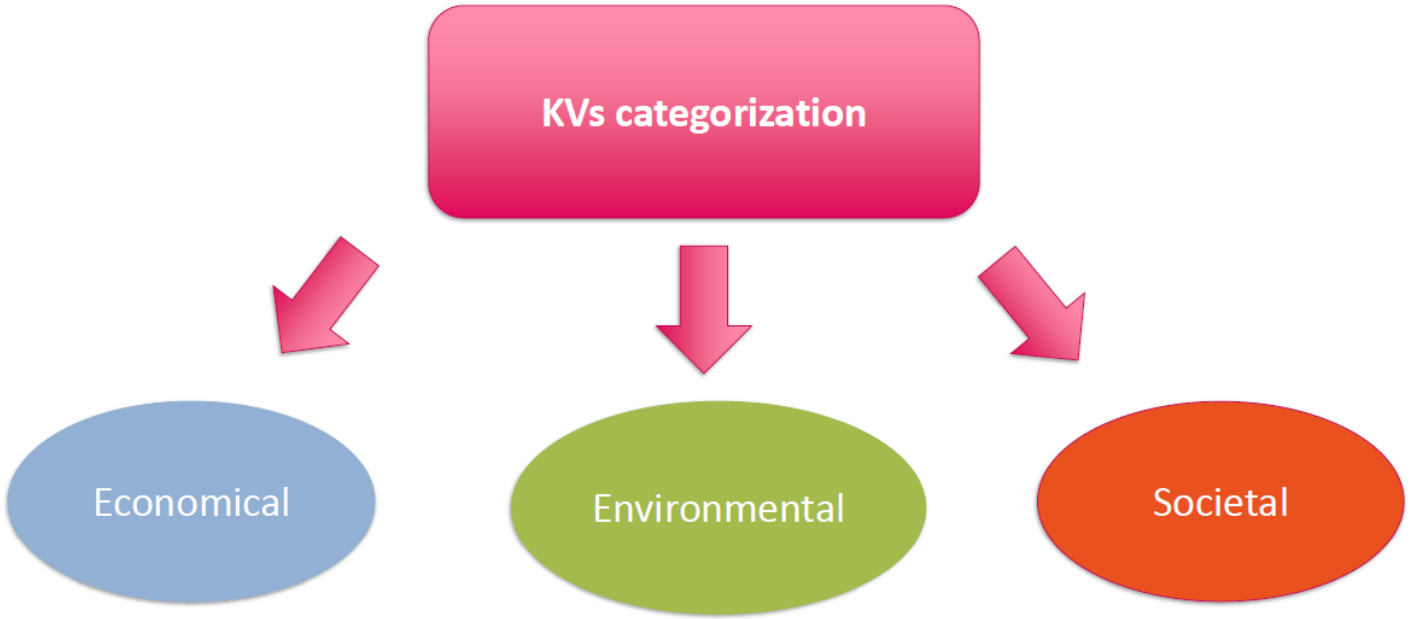
- Assessment of KVs in TrialsNet:
  - Questionnaires
  - Methodology to combine several KVs into the targeted KV

A value-driven business model



TrialsNet focus

- We propose to categorize the values as illustrated in the Figure to the right,
  - Economical
  - Environmental
  - Societal
- This categorization will ideally help with the prioritization of KVs for each use case depending on the direction of the business and funding model.



Example of KVIs measurement: UC10

- Least squares structural equation model methodology for calculating KVI has been used. A pre-test analysis with students was conducted at laboratory premises to carry out a qualitative analysis and measure the initial reaction of viewers while viewing the Euroleague basketball final four 360° immersive video streaming.
- The users took part on two different scenarios: i) Scenario A, using VR headsets and ii) Scenario B, using mobile application. Following the test, a QR code linked to an online survey using Qualtrics, Net Promoters Score, was displayed so that the users could respond. The following table reports the KVIs results for the pre-test

KVI name	Description/KVI definition	Value
User experience In-venue and at-home	Perceived easiness, enjoyment, and emotional quality of the experience in the venue	67% positive effect on user experience
Acceptability	Perceived acceptability, ease of use and comfort of the experience	77% positive effect on how users accept this technology

Conclusions and next steps

- Preliminary measurements activity has been performed for almost all the use cases depending on their level of maturity and in different contexts (e.g. laboratory, experimental and commercial networks)
- From the current KPIs results, it emerges that the main limitation of 5G might be related to uplink performances and in some cases to latency (depending also on the applications)
- The trials in the second phase of the project (including 24 new use cases from the Open Call) will allow to collect a relevant amount of data in terms of network performances as well as feedbacks from real users
- Such data will be therefore analyzed and evaluated, on one side, to further elaborate on the potential limitations of the current network technologies and, on the other side, to understand the level of acceptance of the proposed applications from the user's perspective

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Thank you

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