Trials Supported By Smart Networks Beyond 5G: the TrialsNet Approach

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***Abstract*—TrialsNet is a project focused on improving European urban ecosystems through 13 innovative use cases in the three representative domains of Infrastructure, Transportation, Security and Safety; eHealth and Emergency; and Culture, Tourism, and Entertainment. These use cases will be implemented across different clusters in Italy, Spain, Greece, and Romania, involving real users. This paper provides an overview of the various use cases that will be trialled in different contexts through the platform and network solutions that will be deployed by the project based on advanced functionalities such as dynamic slicing management, NFV, MEC, AI/ML, and others. To this end, TrialsNet will develop assessment frameworks to measure the impact of use cases on a technical, socio-economic, and societal level through the definition and measurement of proper Key Performance Indicators (KPIs) and Key Value Indicators (KVIs). The project seeks to identify network limitations, optimize infrastructure, and define new requirements for next-generation mobile networks. Ultimately, TrialsNet aims to enhance livability in urban environments by driving advancements in various domains.**

***Index Terms*—6G, Use Cases, Large Scale Trials.**

I. Introduction

During the development of 5G technology, significant attention has been given to defining the KPIs of the network infrastructure. Unlike previous generations of mobile networks, 5G was designed to support a wide range of network services from the outset. This means that instead of solely relying on an Over-The-Top architecture, 5G can natively support various services through technologies such as network slicing and Service Based Architecture 5G Core.

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While initial developments have shown promise, the full benefits of 5G are yet to be realized by society at large. Commercial deployments and trials conducted by projects like the 5G-PPP ones [1] have demonstrated the versatility and readiness of the technology to meet the KPIs required for challenging applications. However, the impact of 5G on human society and its potential to create a deeper impact compared to previous generations of networks is still to be witnessed.

To evaluate how 5G and future technologies may improve people's quality of life, the United Nations' Sustainable Development Goal 11 (UN-SDG11) [2] is used as a benchmark. UN-SDG11 focuses on the need for inclusive, safe, resilient, and sustainable cities. With over half of the world's population currently residing in cities and projections indicating that this number will reach 68% by 2050 [3], cities will have a significant impact on economic, social, environmental, and global aspects. To accommodate population growth, infrastructure investment will need to double by 2040 [4].

Efforts are being made to ensure that cities are safe, affordable, and sustainable for everyone, in order to avoid negative consequences such as congestion, sprawl, pollution, and inequality. The concept of Digital or Smart Cities has gained attention, and although progress has been made in addressing issues like environmental degradation, traffic congestion, inadequate urban infrastructure, and essential services, there is still more work to be done to adequately address UN-SDG11. Cities should be seen as urban ecosystems, encompassing human populations, their characteristics, and the biological and physical components within them. Achieving SDG-11 requires optimizing all aspects of the urban ecosystem in an interconnected manner, while simultaneously achieving economic growth and benefiting both inhabitants and businesses.

Sustainable cities following the "liveability" model require advanced infrastructures, applications, and services to monitor and achieve their goals. Although the full potential of 5G is yet to be realized, stakeholders are already envisioning the architecture and features of 6G networks [5]. 6G aims to further connect and intertwine the biological, physical, and digital worlds. It is driven by the goal of supporting social values such as sustainability, resilience, inclusion, trust, and security, particularly in the context of Smart Cities. Advanced use cases based on massive twinning, Internet of Senses, cobots, and XR are among the potential applications of 6G that directly impact UN-SDG11.

The TrialsNet project[1] aims to enable the realization of societal values by implementing 5G and beyond applications that empower 13 different Use Cases (UC) that are proxies towards the 6G ecosystem. The UCs serve as a bridge between the digital and physical worlds, through large-scale trials in the domains of infrastructure, transportation, security and safety, eHealth and emergency services, and culture, tourism, and entertainment. By connecting the digital, physical, and natural worlds, TrialsNet paves the way for the transition towards the next generation of mobile networks.

This paper is structured as follows: Section II introduces the 13 selected use cases that will be implemented in TrialsNet as forerunner for the 6G activities. Then, in Section III, we present the methodology and the platform and network solutions that will be deployed by TrialsNet to support the trials of the UCs. In Section IV we discuss the expected impact in terms of KPIs and KVIs, before concluding in Section V

II. TrialsNet Use Cases

The UCs envisioned by the TrialsNet project are addressing three main domains, as discussed next.

A. Infrastructure, Transportation, Security & Safety

Infrastructure, Transportation and Security & Safety (ITSS) represent one of the key domains of the urban ecosystems in Europe. ITSS use cases target improving the "liveability" of the urban environment by decreasing the negative effects (congestion, sprawl, pollution, inequality, etc.) of collapsing metropolises, as it is of utmost importance to ensure that cities are safe, affordable, and sustainable for all. In this context, five different UCs have been designed, as described in the following.

UC1: Smart Crowd Monitoring - This use case will be carried out in (i) sports or spectacles venue in Madrid for the Spanish cluster, and in (ii) large public area in Iasi, for the Romanian cluster. The high concentration of people and the social impact of sport and spectacle events, as well as of key metropolitan events, make security a crucial issue in specific areas, including stadiums and sports facilities. To mitigate the security risks that occur during events with participation of a large number of people, the UC focuses on building an application and infrastructure environment to test and detect abnormal situations such us crowds preventing the uncontrolled access to the facility when not open-access, violent activity such as people fighting or riots, vandalism, weapons, suspicious activity such as loitering, or person running and abandoned bags. The use case focuses on the use of B5G/6G applications to enable situation awareness to key end-users, by bringing disparate data streams into a common operational picture for real-time data-driven insights and actionable intelligence. The new platform ingests available data from arrays of sensors and cameras deployed in the area/through the city, communicating over reliable B5G and Wi-Fi networks and output insights and actionable intelligence on public safety monitoring system. The use case focuses on public events by managing people counting, density, and dynamics of large numbers of persons (flow directions, spread, speed), as well as on detecting special situations during normal traffic scenarios.

[1]https://www.trialsnet.eu

Fig. 1. Example of platform interface for the Autonomous APRON (UC3).

UC2: Public Infrastructure Assets Management - This use case offers a solution to improve the management and maintenance of infrastructure assets in Athens International Airport and DAEM's public infrastructure in Athens. The solution utilizes advanced technologies such as Artificial Intelligence (AI)-powered algorithms and unmanned vehicles to enhance the effectiveness of data collection and assessment of infrastructure assets. AI techniques will analyze data from multiple sources to evaluate infrastructure assets, generate alerts and recommendations for maintenance tasks, improve worker safety, while unmanned vehicles will assist with the necessary maintenance operations. Augmented Reality (AR) will be used to provide on-site views of assets' blueprints and live communications with remote experts. In addition, Digital Twins (DT) of public construction sites will be created, allowing for validation of technical plans and real-time monitoring.

UC3: Autonomous APRON - This use case demonstrates how autonomous and smart systems can perform ground handling operations at the airport APRON, such as aircraft catering replenishment and baggage handling, using unmanned vehicles and collaborative robots. The development of DTs will enable real-time monitoring and remote control of vehicles, ensuring safer and more efficient operations. AI techniques will be used to analyze data from sensors and cameras, generating alerts and suggestions for improving operations. The integration of a Network Monitoring System (NMS) will enable continuous monitoring and automated mitigation of network anomalies. This UC will be demonstrated in the Athens International Airport. An example of platform interface for the Autonomous APRON is reported in Figure 1.

UC4: Smart Traffic Management - This use case will be piloted in the Podu Roș Intersection Area (Iasi city, Romania) with a focus on traffic comfort and safety functions. From a comfort perspective, the traffic flow will be monitored to create predictive models and suggest intersection rules adaptation to reduce congestion. Safety will be increased especially by protecting the Vulnerable Road Users (VRUs) by creating a digital traffic model, capable of identifying hazardous traffic situations. Based on the same infrastructure of the UC1 developed in Iasi, the new platform will ingest available data from arrays of sensors and cameras deployed throughout the city, communicating over reliable B5G and Wi-Fi networks and output insights and actionable intelligence on traffic monitoring system.

UC5: Control Room in Metaverse - The purpose of this use case is to employ Extended Reality (XR), Metaverse, Digital Twin and IoT technologies for remote, multi-agency and environment tailored XR training and real-time visualization of behavioral anomalies and crowd movement patterns. UC5 enhances the management of large events and situations of panic by contributing to improved decision-making and reduced intervention times in the event of an emergency on the side of emergency responders. The target environment is the events area at Valentino Park (Turin, Italy).

B. eHealth & Emergency

eHealth is certainly one of the most promising fields in which new technologies will play a fundamental role. In particular, SNS and future network technologies can benefit (i) telemedicine, allowing to transmit data about a patient's health to healthcare professionals in real time, even in mobility situations, permitting pre-hospital identification of the correct diagnosis, (ii) remote monitoring, allowing even in areas not equipped with departments for certain medical specializations, to be assisted by the specialised medical doctors', especially in the surgical field, (iii) control of prostheses, allowing to connect a prosthetic device control system with AI technologies for reducing the need for explicit control by the user and thus their cognitive load for driving it, and making the movements of the wearer more natural, and (iv) emergency, allowing flexibility to address different dynamic plans and guidelines over standard predefined Emergency Action Plans. In this context, four different UCs have been designed, as described in the following.

UC6: Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area - UC6 aims to offer cutting-edge technological solutions for the most effective coordination for first-case responders in the context of i) 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 ii) an emergency evacuation in the context of a crowded sporting or cultural event. This UC has the ambition to demonstrate the viability of a coordinated response in densely populated areas (Athens and Madrid) as well as more effective and digitally traceable pre-hospital care by first responders in the event of MCI. Through this use case, innovative technologies will be shown off in a large-scale field exercise for more effective first responder communication, quicker and more efficient triage, and pre-hospital treatment, and they will be compared to the baseline approach using conventional approaches.

UC7: Remote Proctoring - This use case 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. UC7 will be deployed by connecting two sites at a geographical distance, via a dedicated Virtual Private Network (VPN), and equipping with tailored 5G coverage the site where the proctor is located. This allows increasing the number of remote hospitals that can leverage the support of remote experts and improve the entire eHealth workflow of interventional cardiology. This UC will be demonstrated in Pisa, Italy.

UC8: Smart Ambulance - This UC proposes a 5G-connected smart ambulance operating outdoor in mobility, in Pisa, Italy. The use case develops an infrastructure that will enable ambulances (or small emergency centres) to share diagnostic information with the main centre. The proposed infrastructure will be designed and implemented to equip the ambulance with i) new audio/video communication tools (Augmented Reality – AR - and virtual reality - VR - headsets) between operators on the ambulance and supporting experts in the hospital, ii) diagnostic tools for cardiological pathology and ii) devices to guarantee an efficient and fast 5G connection in remote locations and mobility conditions, including emergency high-speed travel through congested urban areas. This UC demonstrates the possibility of sending real-time information to local operators to maximize early intervention and sending information and large data batches (like real-time video and 3D imaging) to a central hub with low latency.

UC9: Adaptive Control of Hannes Prosthetic Device - This UC focuses on designing advanced control capabilities for prostheses using AI methods. This UC will use the Hannes prosthetic hand developed by Istituto Italiano di Tecnologia [6]. Sensory information from the prostheses will be processed off-board to compute the control signals that will be then sent back as input to the motors. The main aim of UC9 is to leverage radio 5G connectivity to provide sufficient computing power to the prosthesis to deploy AI methods with high reliability and minimal latency. This UC will be demonstrated in Pisa, Italy. The architecture in the solution application is reported in Figure 2.

C. Culture, Tourism & Entertainment

Trials in this domain will be based on various 6G candidate technologies such as robots, metaverse, advanced sensors and cameras, focusing on the Culture, Tourism and Entertainment aspects. In this context, four UCs have been designed, as described in the following.

UC10: Immersive Fan Engagement - This use case aims to improve the engagement of fans during sports events. Two applications will be developed, using new 5G features in the area of Madrid; the first one is for home use, bringing the spectator to the game with Virtual Reality (VR) and immersive video on VR headsets and smartphones; the second one, live in

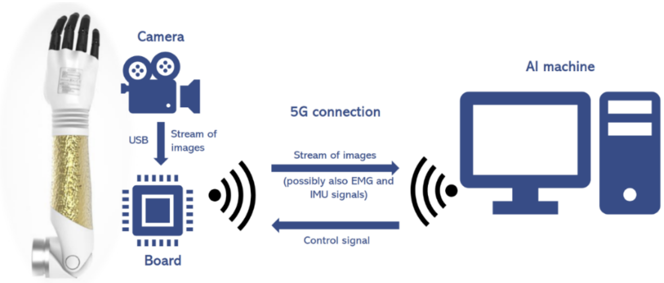

Fig. 2. Architecture of the application for the adaptive control of Hannes Prosthetic Device.

Fig. 3. Example of camera selection interface in the immersive fan engagement UC.

the stadium, bringing the action to fans on their smartphones regardless wherever the fans are seated (which often offers a partial or limited view of the field and players). With a low-latency multi-screen application, fans can follow all the details of the match on their tablet or smartphone. Some preliminary solutions have been identified for both applications, along with the appropriate equipment (cameras, servers, VR, and smartphones) capable of transmitting high-quality, and low-latency visualizations. An example of the camera selection interface for UC is shown in Figure 3.

UC11: Service Robots for Enhanced Passenger's Experience - This use case aims at improving passengers' comfort at AIA, particularly during congested situations. With the use of sensors, cameras and AI-powered algorithms, the passenger flow would become smoother by reducing waiting times and queues, which frequently form in different areas of the airport, such as for baggage drop-off and reclaim, security screening, passport control areas. A solution will be developed to aggregate and analyse the passenger data (e.g., location, flight details, e-ticket, etc.). These will be collected from various applications, based on which AI-enabled robots will assist/inform passengers during their permanence at the airport. With the help of cameras and sensors installed in different areas of the airport, it will be also possible to detect critical situations or issues (e.g., disturbance in normal passenger flow, litter accumulation, etc.) and promptly alert the Terminal Operator Supervisor (T0S).

UC12: City Parks in Metaverse - This use case develops around the social metaverse concept, centred on the idea of creating a virtual world where people can interact with each other, form social connections and participate in a variety of activities. It will take place in the Borgo Medievale, one of the main attractions of the Valentino Park of Turin, reproducing a village of ancient Piedmont. During its closure for renovation from 2024 to 2026, the use case intends offering, as alternative to the tourists arriving to the gate of the Borgo, a virtual visit enriched with a layer for gaming along with the possibility for multiple persons to join the visit with their avatars.

UC13: Extended Reality (XR) Museum Experience - The goal of this use case is to create a modular metaverse platform for visiting museums in Turin through portable devices, as well as an AR application covering Athens archaeological sites such as the Acropolis. The use case entails creating new interactive experiences in collaboration with museums and sites, exploiting two different metaverse platforms. Users will be able to visit collections with friends and family in remote locations and/or in presence in selected locations. A captivating narrative will also be developed to make the experience more engaging, interactive, and informative by reusing part of the results of the previous project 5G-TOURS [2].

III. TrialsNet Technology

The implementation UCs described above will be supported by TrialsNet using an iterative methodology, that will leveraged on a set of platform and network solutions deployed in different clusters, as discussed next.

A. *TrialsNet Methodology*

The TrialsNet methodology reported in Figure 4 starts from the assessment of the capabilities of the current mobile network solutions, and will iteratively perform the four main phases of Deployment, Trials, Evaluation, and Optimize described in the following:

- **Deployment**: This phase deploys network infrastructures based on defined UCs and their requirements. It utilizes the capabilities of different clusters' platform and network solutions (see Section III-B).
- **Execution**: During this phase, UCs challenge cluster infrastructures and both KPIs and user feedback are collected to assess the Quality of Experience (QoE).
- **Evaluation**: Data from the execution phase is analyzed to identify strengths, weaknesses, and areas of improvement on the baseline platform and network solutions.
- **Optimization**: The platform and network solutions are optimized based on the evaluation outcomes, including the addition of new network functions, spectrum resources, parameter tuning, and integration of innovative functionalities from TrialsNet research activities.

TrialsNet aims to complete at least one full iteration of these four phases. However, the possibility of conducting multiple iterations during the project's lifespan remains open and it will strictly depend on the progress of the activities for

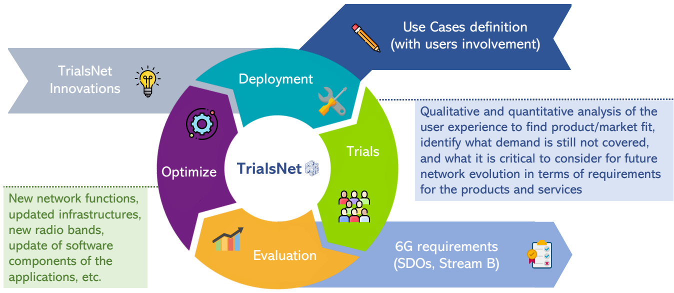

Fig. 4. TrialsNet methodology.

each single UC. This iterative approach allows for continuous improvement and optimization, enabling TrialsNet to stay at the forefront of innovation throughout its duration. It has to be highlighted that the insights gained through this methodology will be not only limited to TrialsNet but they will also contribute as input in terms of new 6G requirements to the other ongoing 6G research projects, as well as the main Standards Development Organizations (SDOs), thus fostering a broader understanding of the subject matter related to the definition of the next generation of mobile networks.

B. TrialsNet Clusters Overview

TrialsNet will conduct large-scale trials by implementing the 13 representative UCs described in Sec. II across four clusters in Italy, Spain, Romania, and Greece. The development and implementation of these UCs will follow the progression of technology based on different releases of the 5G standard. This approach ensures a comprehensive and diverse set of capabilities and features at the project level.

Alignment between advanced technologies and corresponding 5G standards is crucial for the successful deployment and operation of the UCs. By synchronizing these elements, cutting-edge features and functionalities can be integrated, maximizing performance and capabilities.

While most UCs benefit from shared technologies, certain advancements may be limited to specific clusters or sites due to factors like research focus, infrastructure availability, or regulations. This means that some UCs may have access to additional or unique technologies specific to their clusters. These specialized technologies offer advantages such as ultra-low latency communication, advanced network slicing capabilities, and tailored solutions. Leveraging these technologies enables UCs to explore new opportunities, conduct in-depth experiments, and facilitate innovative applications beyond what standard technologies allow.

Ongoing collaboration and knowledge sharing among UCs and clusters are vital as the TrialsNet project progresses. This fosters a dynamic environment where the benefits of unique technologies can be shared and replicated, contributing to the overall advancement of the project.

TrialsNet has established a comprehensive terminology to differentiate and categorize the various phases of network development. This terminology distinguishes TrialsNet technology deployments from the work conducted by the relevant SDOs. By creating this categorization, TrialsNet can focus on its specific solutions and innovations while maintaining awareness of broader advancements in 5G technology.

TrialsNet technology deployments involve cutting-edge hardware and software components tailored to the project's objectives. These deployments leverage the latest advancements in 5G technology, ensuring alignment with project goals. In contrast, SDOs play a significant role in shaping the future of telecommunications by establishing industry standards and guidelines. With the introduction of Release 18, SDOs have designated related technologies as 5G Advanced, emphasizing their enhanced capabilities. TrialsNet recognizes the contributions of SDOs to 5G technology development while concentrating on its unique requirements and deployments.

So, TrialsNet's large-scale trials aim to implement representative UCs across multiple clusters, leveraging advancements in 5G technology. Specialized technologies offer specific advantages to UCs, fostering innovation and exploration. Collaboration and knowledge sharing are crucial, and TrialsNet distinguishes its technology deployments from broader 5G developments by SDOs. By aligning technology and objectives, TrialsNet remains at the forefront of 5G advancements while recognizing the contributions of the broader telecommunications industry.

TrialsNet has defined two distinct sets of technologies for its platform and network solutions, depicted in Figure 5: **TrialsNet Baseline 5G Technology (Bs5G)** and **TrialsNet Advanced 5G Technology (A5G)**. Bs5G represents the initial capabilities available at the project's start, serving as a reference point for measuring the initial Key Performance Indicators (KPIs) during UCs development. A5G, on the other hand, represents enhanced capabilities that will be available across clusters by the project's end.

The improvement work for A5G involves enhancing existing technology within each cluster and incorporating evaluation results from initial UCs deployments. By monitoring and analyzing these results, TrialsNet identifies areas for improvement and optimizes the technology to achieve more advanced capabilities and better performance. A5G represents the collective knowledge and advancements gained throughout the UC implementation phases, refining and enhancing network capabilities beyond the baseline technology.

The distinction between Bs5G and A5G provides a framework for UC development in TrialsNet. Bs5G sets the initial reference point for performance evaluation, while A5G represents progressive improvements based on planned enhancements and results from initial UC deployments. This approach enables continuous refinement and optimization, leading to more advanced and capable 5G technology within TrialsNet's platform and network solutions.

TrialsNet categorizes technology into two main groups: those from SDOs and those specifically required to support UC applications. Bs5G combines Rel-15/Rel-16 network solutions, edge and orchestration functionalities, and serves as a starting point and reference for measuring initial KPIs. A5G goes

	3GPP Releases, Edge and Orchestration		Additional functionalities	
	Per site Bs5G	Per site A5G	Per site Bs5G	Per site A5G
Italian (Turin)	Rel-15 + Edge			
Italian (Pisa)	Rel-15 + Edge	E2E Orchestration	AIaaS	
Spanish	Rel-16 + Edge	Rel-17		AIaaS, DTs, TSN
Romanian	Rel-16	Edge, E2E Orchestration		AIaaS, AI Orchestration
Greek	Rel-15			AIaaS*, AI Orchestration*

Fig. 5. TrialsNet components and functionalities in the different sites (* means at service level only).

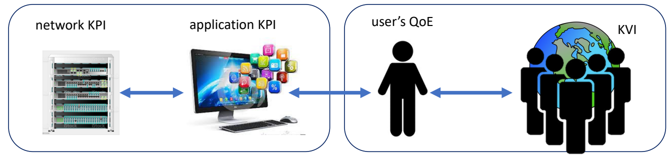

Fig. 6. TrialsNet KPIs and KVIs.

beyond the baseline and includes additional elements such as AI-based orchestration, AI as a Service (AIaaS), Digital Twinning, and Time Sensitive Networking (TSN). These advanced functionalities enhance network capabilities and enable UCs to leverage AI, digital twinning, and time-critical communication for improved operations and applications.

Incorporating these advanced functionalities into TrialsNet's network solutions enhances its capabilities and enables new implementation possibilities for UCs. A5G represents planned improvements and insights gained from initial UC deployments, ensuring the network evolves to meet the unique needs of each UC and cluster.

Overall, TrialsNet's technology framework provides a foundation for UC development, with Bs5G as the starting point and A5G representing advancements based on evaluations and requirements specific to each cluster. The project aims to refine and enhance network capabilities, contributing to the definition of requirements for future mobile networks through the definition of a compelling evaluation methodology as discussed next.

IV. TrialsNet validation: from KPIs to KVIs

Validating the use cases requires a rigorous approach, in order to keep the evaluation fair and objective. TrialsNet adopts an integrated approach in which both KPIs and KVIs are evaluated. In Sec. IV-A the methodology to define KPIs and their measurement is described, whereas in Sec. IV-B the methodology to define and validate the KVIs is introduced.

A. KPI definition and validation

Both KPIs and KVIs are defined and measured to validate the proposed use cases. As shown in Figure 6, KPIs enable a quantitative analysis at network level and at application level, in order to assess the achieved level of QoS and thus validate the use case. Notably, application KPIs are collected at the user's equipment and typically cannot be inferred directly from the network KPIs. For example, when evaluating the user experienced latency when interacting with a trial application, the latency must be evaluated at application layer, taking into account also the effects of the different levels of resource virtualization that the hosting machine provides to run the application. This effect is especially exacerbated for low-latency applications.

KPIs affect the perceived QoE by each user, which can be evaluated in a quantitative way by leveraging the user's feedback (e.g., through surveys and interviews on a statistically meaningful population). The actual impact of each use case on the society, the environment and the economy is evaluated through specific KVIs, as detailed in Sec. IV-B.

The definition of measurable KPIs plays a crucial role since it enables the validation of the proposed experimental methodology. The definition regards not only each specific KPI term, but also the methodology to measure it.

TrialsNet provides a synoptic view of the different KPIs that have been defined in the different use cases. To harmonise the definition of the different KPIs, TrialsNet adopts an iterative methodology, mixing a bottom-up with a top-down approach. Each use case initially defines the relevant KPIs, based on its own specific requirements in terms of QoE and validation (i.e., following a bottom-up approach). Then, by collecting the list of the KPIs across all the use cases, each KPI is classified either as "generic KPI" or "use case specific KPI". In the case of conflicting or incoherent definitions, 5G PPP reference documents, as [7], are adopted to properly define the KPIs and merge equivalent definitions. At the end, starting from a list of almost one hundred KPIs defined across the 13 use cases, the KPI revision process identifies a list of reference KPIs, which is shared to all the use cases managers and researchers, in order to adapt to the identified reference KPIs (i.e., following top-down approach). The procedure iterates multiple times, also due to the "circular" methodology of use case design and development, as shown in Figure 4, allowing to achieve a refined version of definition for all the KPIs.

Finally, as mentioned before, the definition of "measurable" KPIs highlights the fundamental role of the adopted methodology to measure the KPIs, both in terms of scenarios and of tools. Also in this case, 5G PPP reference documents, as [7], are guiding the choice of measurement tools and the validation process, favoring open source tools.

B. KVI definition and validation

TrialsNet acknowledges the intricate relationship between enabled business models and societal benefits, which influences technology acceptance models by taking into consideration the environmental impacts. The use cases identified and described in this paper have a socio-technical and environmental effects. TrialsNet aims to establish a strong connection between technology and its positive impact on society, environment and economy. The project focuses on developing assessment frameworks that enable the evaluation of use case dynamics for societal and environmental acceptance, specifically in the context of 6G solutions. Hence the concept of key value (KV) is analysed across the UCs in the project, this increased visibility not only benefits the wireless industry but also aids non-technical adopters, such as users in the public or environmental sectors, in understanding the advantages. In the 6G context, the concept of KV and key value indicator (KVI) were recently introduced in the several research works [8] and [9]. According to 6G-IA, the utilization of KVIs in the development of 6G serves two main purposes: first, to demonstrate and validate that 6G can effectively address societal needs, and second, to steer technology development towards directions that yield value-driven benefits. It's important to note that KVIs differ from KPIs as they provide deeper insights into factors related to human experiences and may require open conversations and creative thinking for their emergence. The work proposed in [9] provides a clear definition of the following new concepts in the technology sector:

1) KV: What is the value that we care about?
2) KVI: How do assess those values?
3) Enablers: what factors contribute to those values? How do we make those values happen?
4) KPIs: What are the technical impacts of the those values?

For example, if we take into consideration the case of environmental sustainability as a KV, KVI could be assessed by measuring the CO_2 emissions of a mobile network. The enablers of such KV would be developing a more efficient radio network and the impacted KPIs are received bits/Joule. In the previous deliverables of the project, a list of KVs were provided for each use case. The total number KVs defined in TrialsNet is close to 50 and these are distributed across 13 UCs. Note that same KVs may be present in several UCs.

In the framework proposed in TrialsNet, we propose to categorize the values as illustrated in Figure 7, being the resulting categories:

1) Economical
2) Environmental
3) Societal

Some values may belong to one category, two categories or even three categories. Some KVs have an economical value by generating business benefits and at the same time have societal value by contributing to the well-being of the society. For example, the KV "business effectiveness" belongs principally to the economical category as businesses are more efficient and productive, hence eventually a higher growth and profit occurs. However, this KV has also a positive effect on the well-being and development of the society, a lower unemployment rate is recorded when businesses grow.

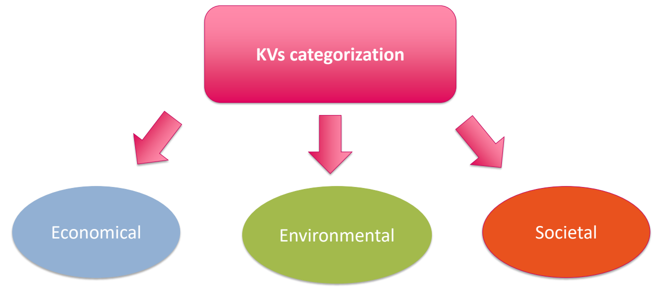

Fig. 7. Categories of KVs.

V. Conclusion

This paper introduced the TrialsNet project, which aims to enhance societal values through the implementation of 13 innovative use cases over a 5G and beyond network infrastructures. The paper explored how these UCs contribute to the improvement of the state of the art and presented the methodology adopted by the project, including platform and network solutions deployment and the validation of KPIs and KVIs as result of the trial activities.

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References

[1] A. Gavras, O. Bulakci, M. Gramaglia, M. Iordache, M. Ghoraishi, A. Garcia, T. Cogalan, J. Gutiérrez, A. Tzanakaki, D. Warren, and et al., "5G PPP Architecture Working Group - View on 5G Architecture, Version 4.0," Oct 2021.
[2] "Goal 11 — Department of Economic and Social Affairs — sdgs.un.org," https://sdgs.un.org/goals/goal11, [Accessed 11-Jul-2023].
[3] "Urbanisation worldwide — Knowledge for policy — knowledge4policy.ec.europa.eu," https://knowledge4policy.ec.europa.eu/foresight/topic/continuing-urbanisation/urbanisation-worldwide_en, [Accessed 11-Jul-2023].
[4] "Global Infrastructure Outlook - A G20 INITIATIVE — outlook.gihub.org," https://outlook.gihub.org/, [Accessed 11-Jul-2023].
[5] Ömer Bulakçı, X. Li, M. Gramaglia, A. Gavras, M. Uusitalo, P. Rugeland, and M. Boldi, Eds., *Towards Sustainable and Trustworthy 6G: Challenges, Enablers, and Architectural Design*. Now Publishers, 2023. [Online]. Available: https://doi.org/10.1561/9781638282396
[6] M. Laffranchi, N. Boccardo, S. Traverso, L. Lombardi, M. Canepa, A. Lince, M. Semprini, J. A. Saglia, A. Naceri, R. Sacchetti, E. Gruppioni, and L. D. Michieli, "The hannes hand prosthesis replicates the key biological properties of the human hand," *Science Robotics*, vol. 5, no. 46, p. eabb0467, 2020. [Online]. Available: https://www.science.org/doi/abs/10.1126/scirobotics.abb0467
[7] L. Valcarenghi, D. Amadou Kountché, M. Dieudonne, A. Gavras, M. Gramaglia, E. Kosmatos, L. Nielsen, I. Patsouras, A. Sgambelluri, J. Sterle, and et al., "KPIs Measurement Tools - From KPI definition to KPI validation enablement," Mar 2023.
[8] M. A. Uusitalo, P. Rugeland, M. R. Boldi, E. C. Strinati, P. Demestichas, M. Ericson, G. P. Fettweis, M. C. Filippou, A. Gati, M.-H. Hamon, M. Hoffmann, M. Latva-Aho, A. Pärssinen, B. Richerzhagen, H. Schotten, T. Svensson, G. Wikström, H. Wymeersch, V. Ziegler, and Y. Zou, "6G Vision, Value, Use Cases and Technologies From European 6G Flagship Project Hexa-X," *IEEE Access*, vol. 9, pp. 160 004–160 020, 2021.
[9] G. Wikström, A. Schuler Scott, I. Mesogiti, R.-A. Stoica, G. Georgiev, S. Barmpounakis, A. Gavras, P. Demestichas, M.-H. Hamon, H.-S. Hallingby, and D. Lund, "What societal values will 6G address?, societal key values and key value indicators analysed through 6G use cases," *6G IA SNVC-SG*, May 2022.