TrialsNet: TRials Supported By Smart Networks Beyond 5G

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***Abstract*—This paper provides an overview of the TrialsNet project. The project focuses on the deployment of large-scale trials supported by smart networks beyond 5G. The paper elaborates on the methodology and advanced technologies brought by the project as well as on the high-level presentation of the use cases, focusing on the preliminary measurements results, that are under development and will be implemented in the context of the four clusters located in Italy, Spain, Romania, and Greece. The use cases cover the three main domains of the European urban ecosystem of (i) Infrastructure, Transportation, Security & Safety - ITSS, (ii) eHealth and Emergency - eHE, and (iii) Culture, Tourism, and Entertainment - CTE. The paper also provides an overview of the trials and related validation plans of the project.**

Keywords - Large-scale trials, B5G technology, 6G applications, use case, urband ecosystem, measurementes, validation, KPIs, KVIs

I. INTRODUCTION

TrialsNet targets a set of technical, performance and productivity objectives which impact the current 5G ecosystem substantially, effectively leading the B5G technology wave by drawing compelling requirements towards the next generation of mobile networks. The main objectives of the project are the following: a) Trialing of 6G Applications, b) Enhance B5G networks to support 6G applications, c) Introduce societal benefits in different areas, thanks to 6G Apps, d) Large scale deployment of B5G Networks, e) Achieve Industrial Impact, f) Achieve Scientific and Standardization Impact, and g) Create an ecosystem of verticals and technology providers in the trial sites and beyond.

To achieve these objectives, TrialsNet is implementing 13 innovative core Use Cases (UCs) covering three relevant domains of the urban ecosystems in Europe identified as a) Infrastructure, Transportation, Security and Safety - ITSS, b) eHealth and Emergency - eHE; and c) Culture, Tourism, and Entertainment - CTE. The use cases will be trialed over wide coverage areas with the involvement of extended sets of real users in four geographical clusters (Italy, Spain, Greece, and Romania) on the platforms and network solutions with advanced functionalities such as dynamic slicing management, End-to-End (E2E) orchestration solutions, Network Function Virtualization (NFV), Mobile Edge Computing (MEC), and Artificial Intelligence and Machine Learning (AI/ML) properly designed and deployed in the context of the project. Sustainability and affordability aspects are also considered in both design and operational phases of the TrialsNet's solutions. To evaluate the results of its trials activities, TrialsNet develops an assessment framework 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) targeting to identify network limitations, optimize infrastructures, and define the new requirements for next-generation mobile networks.

In Section 2, the paper elaborates on the project's methodology and technologies, while Sections 3, 4, and 5 reports on the use cases under development and the related preliminary test results according to the three domains ITSS, eHE, and CTE. Finally, Section 6 discusses aspects on trials and validation as well as next steps for the second half of the project and Section 7 concludes the paper. Further details can be found in the public deliverables available in the related page of the project website [1] and that are properly referenced in each section.

II. METHODOLOGY AND TECHNOLOGIES [2][3]

The TrialsNet methodology reported in Figure 1 is based on an iterative approach that, starting from the assessment of the capabilities of the current mobile network solutions, will iteratively perform the four main phases of Deployment, Trials, Evaluation and Optimize described in the following:

- **Deployment:** This initial phase is based on WP3, WP4, and WP5 input that defines the UCs (in certain cases also with the users involvement) and the related network requirements that need to be fulfilled to support their implementation. Based on such requirements and on the capabilities

offered by the platform and network solutions of the different clusters, the network infrastructures can be deployed as the base for the following phase related to the trials execution.

- **Execution:** During the trials execution phase, some of the UCs are expected to challenge the capabilities provided by the infrastructures of the related cluster. In order to evaluate in which measure the capabilities and the current resources available in each cluster may differentiate, during the execution phase, proper KPIs as well as feedbacks from the users involved in the trials in terms of questionnaires aimed at assessing the perceived Quality of Experience (QoE) and the related KVIs, will be collected.
- **Evaluation:** In this phase, the data collected during the trials execution will be analysed with the objective to understand where the baseline platform and network solutions could be enhanced. Through the evaluation phase, it will therefore be possible to identify strengths, weaknesses, and potential areas of improvement.
- **Optimization:** Based on the outcomes of the evaluation phase, the platform and network solutions can be accordingly optimized by different means such as the enablement of new network functions (NF)s, the addition of spectrum resources (i.e., radio bands), the tuning of proper parameters, etc. Additionally, the optimization phase can take advantage of the TrialsNet research-oriented activities through which innovative functionalities can be provided and integrated in the current setup. As a result of this phase, TrialsNet will provide a updated and optimized infrastructure deployments relying on higher performances, reliability, and efficiency.

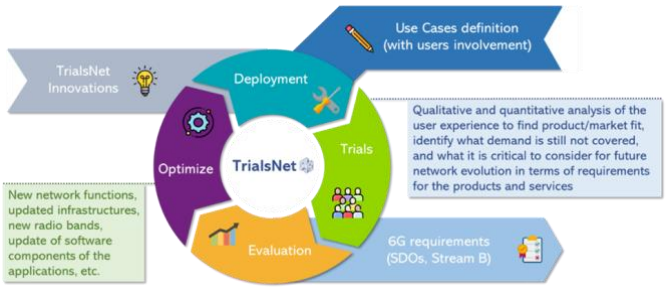

Fig. 1. TrialsNet methodology.

On the context of WP2, TrialsNet clusters will develop platform and network solutions providing performances and functionalities tailored to the specific needs of the UCs, ensuring a diverse and comprehensive technology portfolio at the project level. The alignment between the deployment of advanced technologies and 5G standards is vital for maximizing the performances of the UCs, with clusters potentially accessing unique technological advancements due to various factors, such as infrastructure availability or regulatory constraints. These improvements offer specialized benefits, like ultra-low latency or advanced network slicing, fostering innovation and experimentation within the UCs.

TrialsNet distinguishes between two sets of technologies for its network solutions (see Figure 2): TrialsNet Baseline 5G Technology (Bs5G) and TrialsNet Advanced 5G Technology (A5G). The former sets the foundation for initial UCs implementation, while the latter represents the enhancements aimed at improving network capabilities based on the outcomes from such early UCs deployments.

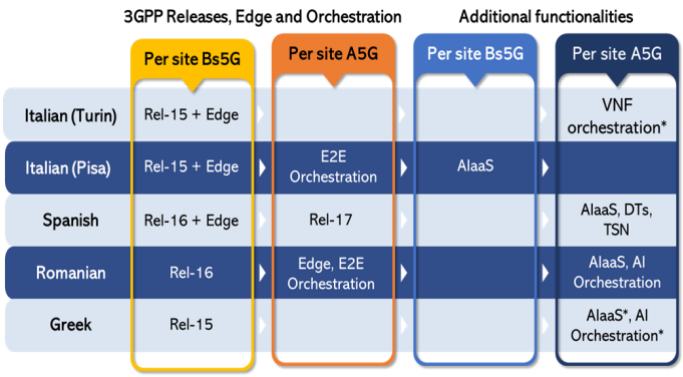

Fig. 2. TrialsNet advancements.

This differentiation enables TrialsNet to continuously refine and optimize its network solutions, leveraging advancements and insights from its deployments to evolve its technology beyond the baseline, incorporating innovative solutions development in the context of the project such as AI-based orchestration and Digital Twinning. This approach ensures that TrialsNet not only meets the current technological needs but also contributes to defining future mobile network requirements.

III. USE CASES FOR INFRASTRUCTURE, TRANSPORTATION, AND SECURITY & SAFETY [4][5]

Initial version of the applications, related devices and 5G infrastructure have been integrated for the preliminary measurement activity of the use cases. The firsts achieved results for UC1-UC5 are summarized hereafter.

UC1 "Smart Crowd Monitoring" (Madrid): This use case 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.

UC1 "Smart Crowd Monitoring" (Iasi): The use case focuses on outdoor public events by managing people counting, density, and dynamics of large numbers of persons and detecting special situations during normal traffic scenarios. Preparatory activities were done such as installation of cameras and 5G Customer Premises Equipment (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.

UC2 "Public Infrastructure Assets Management" (Athens): This use case 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.

UC4 "Smart Traffic Management" (Iasi): This use case 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.

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.

IV. USE CASES FOR EHEALTH AND EMERGENCY [6][7]

Preliminary testing activities related to the eHE use cases have been mainly performed in laboratory context which results are summarized hereafter. For U7-UC9 in Pisa, is should be highlighted that a dedicated experimental network is under deployment that has been designed based on the very demanding requirements coming from the use cases. The experimental network will also implement an advanced orchestration solution providing efficient slicing management mechanisms.

UC6 "Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area" (Athens/Madrid): This use case aims to offer cutting-edge technological solutions 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.

The evacuation part of the use case is going to be implemented both in Athens and in Spain sites with the use of a different 5G infrastructures. In Athens site, two main scenarios have been identified and tested:

- Both on the patient profile creation and the device assignment to obtain the vital signs measurements.
- A new patient profile has been created and gets simulated vital signs for the triaging and a batch patient is created accordingly.

The first results are encouraging and satisfying, in particular for what concern the recall indicator (i.e., how often the algorithm correctly predicts a positive outcome

out of all the actual positive outcomes) that is expected as the most critical KPI. The UC6 in Madrid has gone through a laboratory testing phase to obtain preliminary KPI measurements (throughput in particular) and assess behavior in a controlled environment.

UC7 "Remote Proctoring" (Pisa): 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 (Pisa and Massa). It is going to be deployed by connecting two sites at a geographical distance. The initial laboratory experiments were conducted in April 2023, while field tests have been done in December 2023. These tests mainly aimed to assess the influence of the proposed technological innovations on the psychophysiological states, 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.

UC8 "Smart Ambulance" (Pisa): The use case proposes a 5G-connected smart ambulance operating outdoor in mobility. The use case is going to develop an infrastructure enabling ambulances to share diagnostic information with the main centre. The infrastructure will be designed and implemented to equip the ambulance with new audio/video communication tools adopting Augmented Reality (AR) and Virtual Reality (VR), diagnostic tools for cardiological pathology and devices to guarantee an efficient and fast 5G connection in remote locations and mobility conditions. The laboratory tests tested the XR devices that will also be used in the context of the smart ambulance, albeit in a mobility scenario. The requirements that such devices demand from the network are the same as those for the UC7 scenario.

UC9 "Adaptive Control of Hannes Prosthetic Device" (Pisa): This use case focuses on designing advanced control capabilities for prostheses using Artificial Intelligence (AI) methods and deployment on the Hannes arm. The main aim of UC9 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 minimal latency. In this first phase the goal has been the assessment of the developed prototypes and their integration until an advanced level of readiness of the system is achieved. A set of tests have been already carried out to define the network performance baselines.

V. USE CASES FOR CULTURE, TOURISM, AND ENTERTAINMENT [8][9]

The activities implemented in the context of the CTE domain have been centred around the implementation of the defined use cases and the execution of initial tests in order to identify current network technology limits. This effort aims to define new requirements for future evolutions for all use cases and early gauge user satisfaction with the developed applications for UC10. For each use case, some initial conclusions derived from the preliminary test activities are reported hereafter.

UC10 "Immersive fan engagement": The goal of this use case is to explore the capabilities and limitations of the current 5G implementation for the immersive video streaming workflow, and to determine where it is possible to replace fiber with 5G connectivity to gain flexibility and versatility in venue deployments. Preliminary testing of 5G testbed in 5TONIC laboratory has revealed uplink challenges prompting the need for network optimization to get improved throughput (especially on the uplink) and jitter for video contributions.

UC11 "Service Robots for Enhanced Passengers' Experience": This use case aims to create a connected airport ecosystem utilizing AI algorithms and data from diverse sources to optimize passenger flows and improve the overall experience supported by the use of service robots. Successful tests have been performed and validated the application´s diverse capabilities, paving the way for potential system expansion.

UC12 "City Parks in Metaverse": This use case seeks to showcase the capabilities of B5G technologies in enhancing the visitor experience at cultural and public heritage sites such as public parks, with a focus on edutainment and gamification-oriented applications. Initial laboratory measurements of the aggregated downlink and uplink loads, conducted with a VR headset connected to a PC via Ethernet, indicate that they can be adequately managed by the local 5G network. However, one critical parameter that warrants attention is latency, which will have to be measured while considering the various system components in series.

UC13 "Extended XR museum experience (Turin)": This use case aims to enhance the appeal of four museums realities in Turin by developing immersive experiences based on AR and VR based applications. Preliminary measurements for a metaverse platform connected to a 5G network indicate that the capacity and roundtrip delay meet the requirements for the use case. Nonetheless, further field tests are necessary to validate these findings.

UC13 "Extended XR museum experience (Athens)": The aim of this use case is to develop AR and VR digital applications aimed at showcasing the content and historical significance of various cultural sites in Athens, thereby enhancing the visitor experience and providing access to those unable to physically visit these locations. Successful tests confirmed the application´s on-demand asset bundle download capability for the various contents, revealing manageable 5G capacity with minor latency issues due to large file sizes, to be addressed in the upcoming retesting and field trials.

VI. KPIs and KVIs Framework Definition, Trials and Validation [10]

In the context of its trial activities, TrialsNet project aims to obtain measurable results of the 6G applications in terms of both KPIs and KVIs targeting various contexts and scenarios, including different network infrastructures and related deployments. The collected results will be used to perform a quantitative and qualitative analysis to understand what is critical to consider for the future network evolution in terms of requirements as well as to find products and market fits, and what demand from the users is still not covered by the current services. On such basis, in strict collaboration with the other WPs, the WP6 started to work on the definition of a proper KPIs and KVIs framework (see Figure 3) and the corresponding assessment methodologies for the use cases, including also specific metrics related to the platform and network solutions that will be deployed in the different clusters.

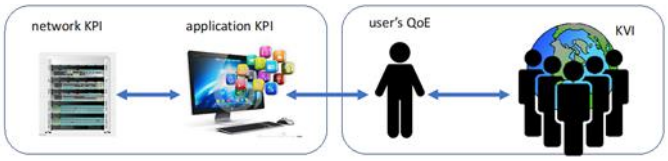

Fig. 3. TrialsNet KPIs and KVIs high-level framework.

In the context of the activities related to the technical definition and assessment methods for the KPIs, WP6 analyzed all the KPIs defined in the different use cases to define a common terminology to use as a reference for the next phases of the project's activities. As a result, a set of 18 different KPIs has been identified and divided in categories of i) capacity, ii) latency, iii) compute, iv) availability/reliability, and v) localization, in line with the 6G-IA overall framework. Concerning the activities on KVIs, a common framework for their definition and analysis has been defined in order to share a coherent validation approach in the whole project. The framework is going to be adopted by each use case to define KVs, the corresponding KVIs, and related (technological) enablers. The relevant domains for KVs have been identified according to the Sustainable Development Goal (SDG) societal, economical, and environmental areas, under the common umbrella of sustainability.

During the second half of the project, the implementation of the use cases will be finalized as well as the deployment of the cluster's infrastructures will be completed. The following trial phase (which will include also the trials activities of the use cases onboarded through the Open Call) will permit to collect a relevant amount of data in terms of network performances and feedback from the users. Such data will be therefore analyzed and evaluated to identify, on one side, 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. The results of such analysis will be used to consolidate the outcomes and findings of the project which will be used as input to contribute towards the definition of the 6G ecosystem.

VII. Conclusions

This paper presented an overview of TrialsNet project. The project works on use cases covering three relevant domains of the urban ecosystems in Europe identified as i) Infrastructure, Transportation, Security & Safety, ii) eHealth and Emergency, and iii) Culture, Tourism, and Entertainment. The use cases will be trialed over wide coverage areas with the involvement of extended sets of real users in the four project's clusters located in Italy, Spain, Greece, and Romania. Trials will run until the end of the project which is scheduled for December 2025.

Acknowledgment

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