MISSION 4
EDUCATION
RESEARCH

PROJECT TITLE: EXTENDABLE - NETWORK OF EXTENDED REALITY-ENABLED LABORATORIES FOR REMOTE PRACTICAL TRAINING

SCIENTIFIC REPORT

TIMEFRAME 01/04/2024 - 31/07/2024

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

Table of Contents

NATIONAL RECOVERY AND RESILIENCE PLAN (NRRP) – MISSION 4 COMPONENT 2 INVESTMENT 1.1 – "Fund for the National Research Program and for Projects of National Interest (NRP)"

Project: P2022L2KTA CUP: E53D23014680001

Project Title: EXTENDABLE - network of EXTENDed reAlity-enaBLEd laboratories for remote practical training

Principal Investigator: Prof. Annalisa Liccardo

Timeframe: 01/04/2024 – 31/07/2024

1. SECTION 1 – GENERAL TRENDS OF THE PROJECT

With regard to the specific timeframe, it is below provided:

a) a brief summary of the project;

Practical exercises are crucial in STEM education, providing hands-on experience to reinforce theoretical knowledge. Access to laboratories is vital at all educational levels, but challenges like overcrowded classrooms or movement restrictions during pandemics have highlighted the need for remote solutions. A research team from the University of Naples Federico II, Sannio, and Calabria proposes a network of laboratories utilizing extended reality to enable remote execution of lab activities. This system allows students to conduct experiments from home using real devices, ensuring immersive and responsive interactions. Key tasks include scanning, reconstructing, and functionalizing lab instruments, as well as managing complex operations and communication interfaces to minimize delays. The prototype will initially focus on measuring instruments, a common subject in metrology courses, and set up specific experiments for engineering students at different locations. This initiative aims to validate the system and maintain high-quality practical training, ensuring that students can continue their education effectively, even remotely.

b) names of the operational units involved in the implementation of the project;

Research Unit (RU) University of Naples Federico II – led by the PI, Prof. Annalisa Liccardo

RU University of Calabria – led by Prof. Francesco Lamonaca

RU University of Sannio – led by Prof. Luca de Vito

c) description of the achievement of the objectives connected to the project and related outcomes;

From one side, project activities in the considered timeframe were mainly focused on the completion of the study of the state-of-the-art about the different topics associated with the research units; on the

other side, research activities associated with WP2 started in the considered timeframe. The outcome consists of a deep analysis of available solutions both in the scientific literature and commercial devices; the results of the analysis are presented in the deliverable D1, a unique technical report containing the contributions of all research Units.

d) description of the carried out activities which are in compliance with the *DNSH, Open Access* principles as well as with *gender*, *generational* principles and with those of *Equal opportunities*

The project activities of the considered timeframe were mainly related to the completion of the study of the state-of-the-art of the different topics associated with the operational units. This way, no specific compliance with the DNSH, Open Access principles as well as with gender, generational principles and with those of Equal opportunities has been experienced. Nevertheless, all the objectives in terms of discrimination reduction presented in the project proposal remain.

e) description of the actions aimed at informing and disseminating knowledge

One of the main actions performed in the considered timeframe has involved the update of the website of the project, that can be freely accessed at the link:

extendable.dieti.unina.it

In the homepage, a new image demonstrating the last project achievement has been added.

Figure 1. New homepage of the project website

Prof. Lamonaca in April 21-25,2024 was invited by Prof. Alessio Carullo to Polytechnic of Turin to present the EXTENDABLE project in order to evaluate the possibility to create a node of the Extended Reality Laboratory also in the Polytechnic of Turin.

Francesco Lamonaca <f.lamonaca@dimes.unical.it>

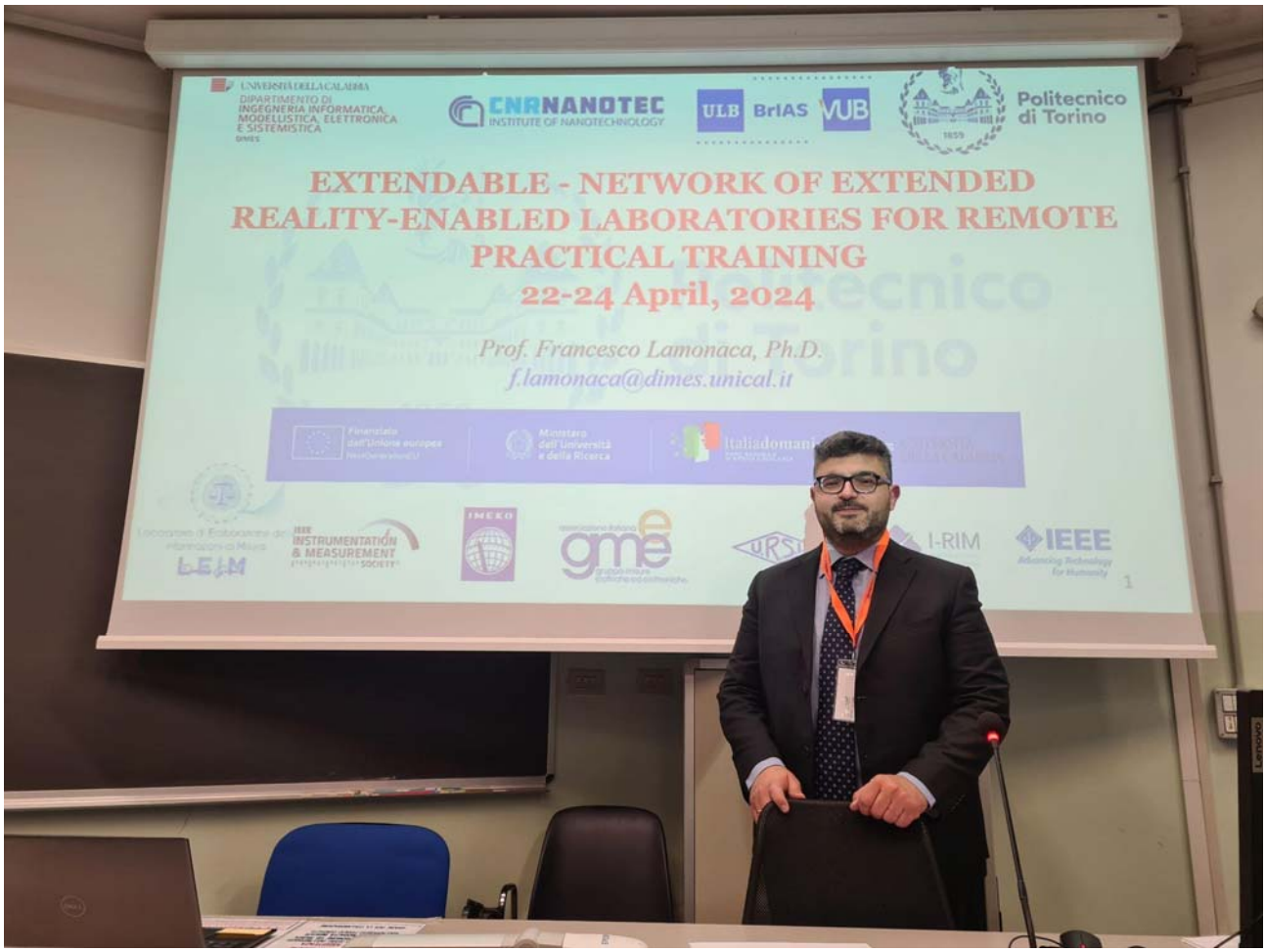
Invito per progetto laboratorio remoto
1 messaggio

Alessio Carullo <alessio.carullo@polito.it> 2 aprile 2024 alle ore 18:24
A: Francesco Lamonaca <f.lamonaca@dimes.unical.it>

Gentile prof. Lamonaca,
la invito presso il Politecnico di Torino nel periodo 22-24 aprile 2024 per una serie di incontri di studio per la divulgazione del progetto EXTENDABLE - network of EXTENDed reAlity-enaBLEd laboratories for remote practical training, CUP H53D23007360001 e per valutare la possibilità di creare un nodo del laboratorio remoto nella sede del Politecnico di Torino inerente gli strumenti elettronici di misura utilizzati, anche, per le scienze animali e veterinarie.

In attesa di un suo riscontro, porgo cordiali saluti
Alessio Carullo

Figure 2. Invitation Letter of Prof. Alessio Carullo to Prof. Francesco Lamonaca




CNRNANOTEC
INSTITUTE OF NANOTECHNOLOGY
ULB
BrIAS
VUB
Politecnico di Torino
Let's introduce my self
Outline
EXTENDABLE - network of EXTENDed reAlity-enaBLEd laboratories for remote practical training
Project Development
Case Studies
Invitation to join: what we can do toget
LEIM

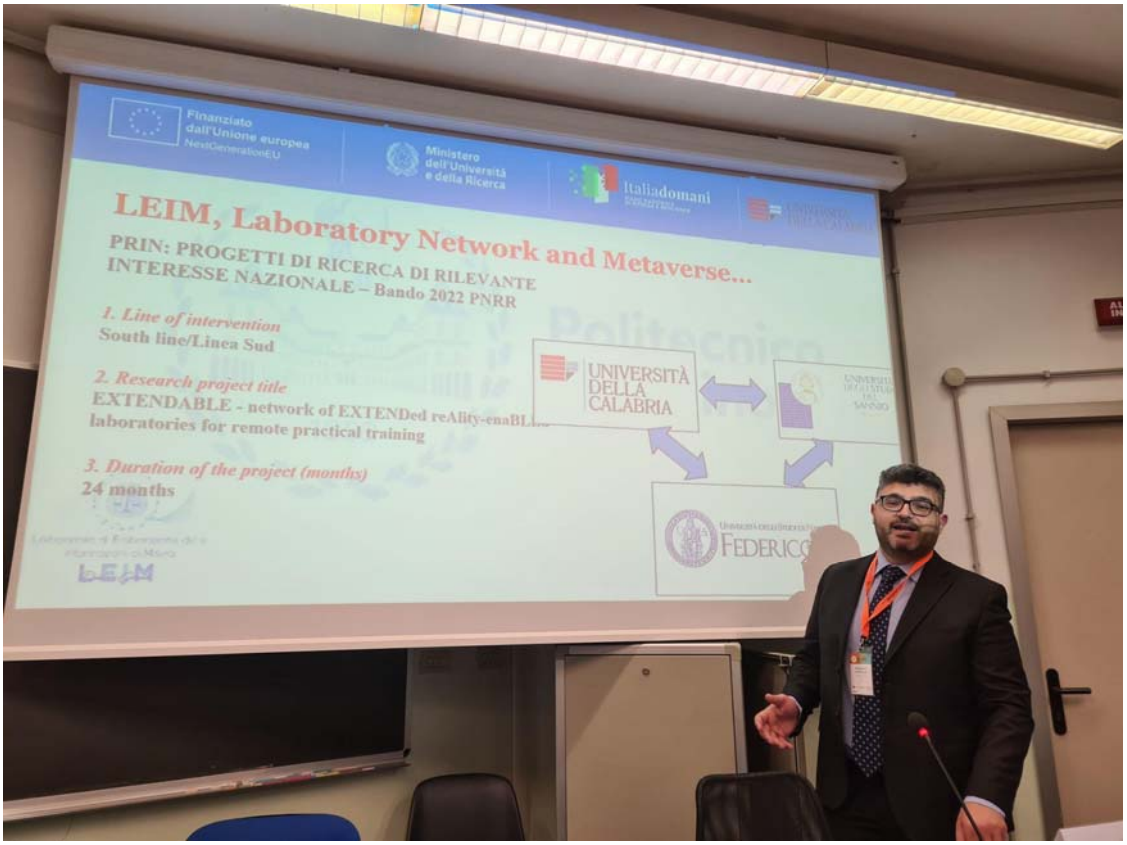

Finanziato dall'Unione europea
NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani
LEIM, Laboratory Network and Metaverse...
PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2022 PNRR
1. Line of intervention
South line/Linea Sud
2. Research project title
EXTENDABLE - network of EXTENDed reAlity-enaBL
laboratories for remote practical training
3. Duration of the project (months)
24 months
UNIVERSITÀ DELLA CALABRIA
FEDERICO
LEIM

Figure 3. Pictures of Prof. Francesco Lamonaca at Polytechnic of Tourin presenting EXTENDABLE Project.

Furthermore, the dissemination section has been enriched, by inserting the publication list and the news about group meeting and presentation at conference of the project activities.

Moreover, the following papers, concerning the project activities have been published:

1) *F. Lamonaca, A. Liccardo, D.L. Carnì, E. Bilotta, A.M. Palermo, G. Spadafora , "Network of Extended Reality Laboratory for Remote Practical Training. Didactic between Virtual and Real Living Environments", IEEE Workshop on Metrology for Living Environment, June 2024*

The integration of extended reality (XR) technologies in remote practical training offers immersive learning experiences through virtual simulations. In this paper, the first step to offer a new virtual living environment implementing a measurement laboratory is proposed. Differently from a pure simulative environment, the proposal goes further allowing the design of a real didactic experience by using real measurement instruments. The proposed XR-enabled measurement laboratory provides a blend of virtual and real-world environments, fostering practical skills and critical thinking abilities that can be acquired only with "first hand" experiences. Despite technical obstacles, and open

didactical questions, XR presents opportunities for innovation and collaborative learning experiences. Enhancing interactivity through multiplayer and social engagement features, the proposed laboratory will foster a sense of community among learners and researchers.

1) *A.F. Gentile, D.Macrì, F.Lamonaca, "Safeguarding Sensitive Data in the Era of IoT: A Study on Security Protocols for Distributed Measurement Systems", IEEE Workshop on Metrology for Living Environment, June 2024*

IoT devices have led to the development of Distributed Measurement Systems (DMS). However, cyber-attacks have increased, making it crucial to implement security protocols without reducing network throughput. Open firmware on constrained devices offers another layer of customization, essential for the flexibility required in DMS. This allows software updates and modifications in real-time, which is crucial for adapting to evolving cybersecurity threats and managing device functionality. The objective is to identify algorithms that ensure optimal data transmission and encryption ratios and maximum compatibility with existing infrastructures and commercial hardware that support MQTT technology. This approach utilizes local MQTT brokers and TLS tunnels to secure local sensor data transmissions. This design enhances security and maintains the efficiency of data flow across the network. The primary objective moving forward is to refine and identify algorithms that ensure optimal data transmission and encryption ratios and uphold maximum compatibility with existing infrastructures that support MQTT technology. This is critical as MQTT is a standard protocol for IoT communications.

2. SECTION 2 – PROGRESS OF ACTIVITIES

With regard to the specific timeframe (bi-monthly/end of project activities), it is below provided:

a) detailed description of activities carried out by each operational unit with a focus on the timeframe for their implementation

According to the presented project GANTT, activities of the RU University of Naples Federico II were mainly mandated to 1) Study of the communications solutions for remote control of instruments and devices. 2) Study of literature solutions for reconfigurable circuits implementation and 3) Definition and design of innovative scan and reconstruction methods for 3D modeling of devices and instruments.
As for Item 2), the research activity aimed to identify and analyze the most efficient technologies for real-time data transmission, ensuring reliability, security, and scalability. Various communication platforms have been examined, including wireless networks (Wi-Fi, LTE, 5G), wired solutions (Ethernet, fiber optics), and emerging technologies such as IoT and LPWAN networks (LoRaWAN, Sigfox). Special attention was given to the integration of specific communication protocols to ensure low latency and high availability, such as MQTT and OPC UA. The study also considered aspects related to cybersecurity and data protection, which are critical in remote control scenarios.
Regarding Item 2), the research activities aimed to explore existing approaches and technologies for designing circuits that can adapt their functionality dynamically. Various architectures and design methodologies have been reviewed, focusing on tunable components, such as variable resistors,

capacitors, and inductors, as well as programmable analog arrays (FPAA). The study also examines the use of MEMS technology and voltage-controlled elements to achieve real-time reconfigurability. Key challenges, including linearity, power consumption, and noise performance, were identified and analyzed. Furthermore, potential applications in signal processing, communications, and sensor networks were evaluated.
In the current timeframe, research related to WP2 started with the activities related to Item 3); in particular, the research aims to develop advanced techniques to capture detailed geometric data, optimizing both accuracy and efficiency. New algorithms for point cloud generation, surface reconstruction, and texture mapping are being explored, with a focus on improving speed, precision, and compatibility with various materials and shapes.

At University of Calabria the investigation about the didactical implication of the extended reality are strongly boosted. The results of these investigations are presented in 2 scientific papers. A first one is published in an international conference proceedings of the IEEE International Workshop on Metrology for Living Environment. In this paper the Metaverse is considered like a living environment and the effect of this holistic and immersive environment on students is investigated, also presenting some practical activities that include real measurement instruments. The second paper will be presented in September in the most important conference for the metrologist in Italy: the VIII Forum delle Misure, that will be held in San Vincenzo (Li).
Moreover the investigation about the time characterization of the system is further ameliorated by taking into account the possibility to use the dark web as further shield to protect sensitive data. This aspect is crucial for industries, militar, and all the didactic scenarios where sensitive data and strategies are exchanged. This paper will be published in a first quartile journal. For the other Activities in collaboration with University of Naples the aforementioned considerations will be.

The activities at the RU of the University of Sannio were concentrated on the following tasks:

- The analysis of state-of-the-art technologies allowing access to different types of systems has been continued and completed. It has been observed that different instruments and laboratory resources have different operating systems and remote access technologies. Most recent and high-end instrumentation is often equipped with a general-purpose operating system based on either MS Windows or Linux, while low-end or older instrumentation requires to be interfaced with an external computer, by means of an instrumentation bus, such as USB, GPIB, or LXI. As a result of the analysis, it has been found that remote access technology is suitable for providing most of the functionalities offered by high-end instrumentation remotely. In particular, it has been observed that many recent implementations of remote laboratories exploit the remote access features offered by the Apache Guacamole framework. Compared with other solutions, it is clientless, i.e. it does not require specific software on the client side, but it runs on a browser supporting HTML5.
  Moreover, an analysis of current technologies to get the internal state of the controlled instrumentation has been carried out by paying attention to the integration of heterogeneous sources of data.
- An evaluation of the Guacamole-lite framework has been started to verify its capability to provide remote access to electronic instrumentation and the possible integration with other remote control technologies.

b) description of potential changes to what has been originally approved mentioning the impacts on the aim of the intervention, on the achievement of intermediate and long- term goals, on the proposed actions for improvement;

Stemming from the deep analysis of the state-of-the-art about distance learning, the research units are going to enrich the number of possible solutions by focusing the attention towards metaverse-based approaches, capable of assuring more engaging, interactive and immersive environments for students, trainees, teachers and trainers.

c) description of potential challenges encountered and of the proposed actions for improvement;

The research activities carried out during the reporting period did not present any specific challenges requiring further analysis and definition of appropriate solutions.

d) brief description of potential publications.

Publications are expected in the successive bimester,

A. Liccardo, F. Lamonaca, L. De Vito, "Progetto PRIN PNRR 2022 EXTENDABLE - network of EXTENDed reAlity-enaBLEd laboratories for remote practical training", VII Forum delle Misure, Settembre 2024

Il Progetto "EXTENDABLE - network of EXTENDed reAlity-enaBLEd laboratories for remote practical training" (CUP E53D23014680001) ha ricevuto il finanziamento dall'Unione Europea nel piano NextGenerationEU attraverso il "Bando Prin 2022 - D.D. 1409 del 14-09-2022" del Ministero dell'Universita e della Ricerca. Il progetto ` e iniziato il 30 novembre 2023, ha durata biennale e prevede il coinvolgimento di tre Unita di Ricerca, rispettivamente presso l'Università di Napoli Federico II, l'Universita del Sannio e l'Università della Calabria.

A.F. Gentile, D. Macrì, D.L. Carnì, E. Greco, F. Lamonaca, "A Network Performance Analysis of MQTT Security Protocols with Constrained Hardware in the Dark Net for DMS", Applied Science, 2024.

In the context of the internet of things, and particularly within distributed measurement systems that are subject to high privacy risks, it is essential to emphasize the need for increasingly effective privacy protections. The idea presented in this work involves managing critical traffic through an architectural proposal aimed at solving the problem of communications between nodes by optimizing both the confidentiality to be guaranteed to the payload and the transmission speed. Specifically, data such as a typical sensor on/off signal could be sent via a standard encrypted channel, while a sensitive aggregate could be transmitted through a dedicated private channel. Additionally, this work emphasizes the critical importance of optimizing message sizes to 5 k-bytes (small payload messages)

for transmission over the reserve channel, enhancing both privacy and system responsiveness, a mandatory requirement in distributed measurement systems. By focusing on small, encrypted payloads, the study facilitates secure, timely updates and summaries of network conditions, maintaining the integrity and privacy of communications in even the most challenging and privacy-sensitive environments. This study provides a comprehensive performance analysis of IoT networks using Dark Net technologies and MQTT protocols, with a focus on privacy and anonymity. It highlights the trade-offs between enhanced security and performance, noting increased latency, reduced bandwidth, and network instability when using TOR, particularly with cipher suites like AES256-GCM-SHA384 and DHE-RSA-CHACHA20-POLY1305. The research emphasizes the need for further exploration of alternative protocols like LWM2M in secure IoT environments and calls for optimization to balance privacy with performance in Dark-Net-based IoT deployments.

3. SECTION 3 – COMMON INDICATORS

Below the updates on the indicator RRFCI 8 – "*Number of researchers who work in research centres which are recipients of financial support (women; men; non-binary)*" – as per the description in the guidelines included in the n.34 MEF notification from the 17th of October 2022.

Common indicators (University of Naples)	*Planned value*	*Implemented value*
Researchers who work in research centers which are recipients of financial support (women)	0,31	0,292
Researchers who work in research centers which are recipients of financial support (men)	0	0
Researchers who work in research centers which are recipients of financial support (non-binary)	0	0

Common indicators (University of Calabria)	*Planned value*	*Implemented value*
Researchers who work in research centers which are recipients of financial support (women)	0,033	0,074
Researchers who work in research centers which are recipients of financial support (men)	0,393	0,894
Researchers who work in research centers which are recipients of financial support (non-binary)	0	0

Common indicators (University of Sannio)	*Planned value*	*Implemented value*

Researchers who work in research centers which are recipients of financial support (women)	0	0
Researchers who work in research centers which are recipients of financial support (men)	0,336	0,360
Researchers who work in research centers which are recipients of financial support (non-binary)	0	0

4. SECTION 4 – PREDICTIVE ANALYSIS AND FINAL COMMENTS

Below it is provided a description of the forecast scenario on the development of the project, any potential change which is deemed necessary for the future as well as comments on the document.

1) Predictive analysis

The preliminary stage mandated to in-depth analyze the state of the art has been completed during the considered timeframe, highlighting viable paths for the successive steps. Successively, research activities of WP2 started during reporting period accordingly to the original Gantt. Stemming from that analysis, the research units will start defining and developing suitable solutions to fulfill the project objectives.

2) Final comments

Operational units are carrying out their activities according to the predicted timelines. At the moment, no specific concerns have been highlighted. Activities more related to active research started in the last bimester, according to the project schedule.

Principal Investigator

(digital signature)

Firmato digitalmente da
Annalisa Liccardo
CN = liccardo Annalisa
O = Universita' degli Studi Federico II
Data e ora della firma: 31/10/2024 12:09:38

5. SECTION 5 – ATTACHMENT

The below documents are also attached to the technical – scientific report:

Att.1 – Declaration of compliance with DNSH principle and compliance with other principles as per the Environment code;