MISSION 4
EDUCATION
RESEARCH

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

SCIENTIFIC REPORT

TIMEFRAME 30/11/2023 - 31/03/2024

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

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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: 30/11/2023 – 31/03/2024

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;

The project activities of the considered timeframe were mainly related to the study of the state-of-the-art of the different topics associated with the operational units. This way, no specific outcome has been generated, since the corresponding deliverable is expected at the end of the third bimester.

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 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 gender and/or geographical discrimination reduction presented in the project proposal remain. In a similar way, DNSH and Open Access will be the driving force of the successive research activities.

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

The most important action performed in the considered timeframe has been the implementation and deployment of the website of the project, which can be freely accessed at the link

extendable.dieti.unina.it

whose home page is given in the following figure

Figure 1. Homepage of the project website

The web site consists of static pages (describing the proposal, research team and project objectives) and dynamic pages (that are periodically filled with news corresponding to obtained results or dissemination activities).

As a further dissemination activity, Professor Francesco Lamonaca presented the Extendable project in an invited talk at the University of Venice Ca' Foscari on February the 1st, 2024 and to the Board of Directors of the Italian Electrical and Electronic Measurements Group (Consiglio Direttivo del Gruppo Italiano di Misure Elettriche ed Elettroniche) March the 22nd, 2024.

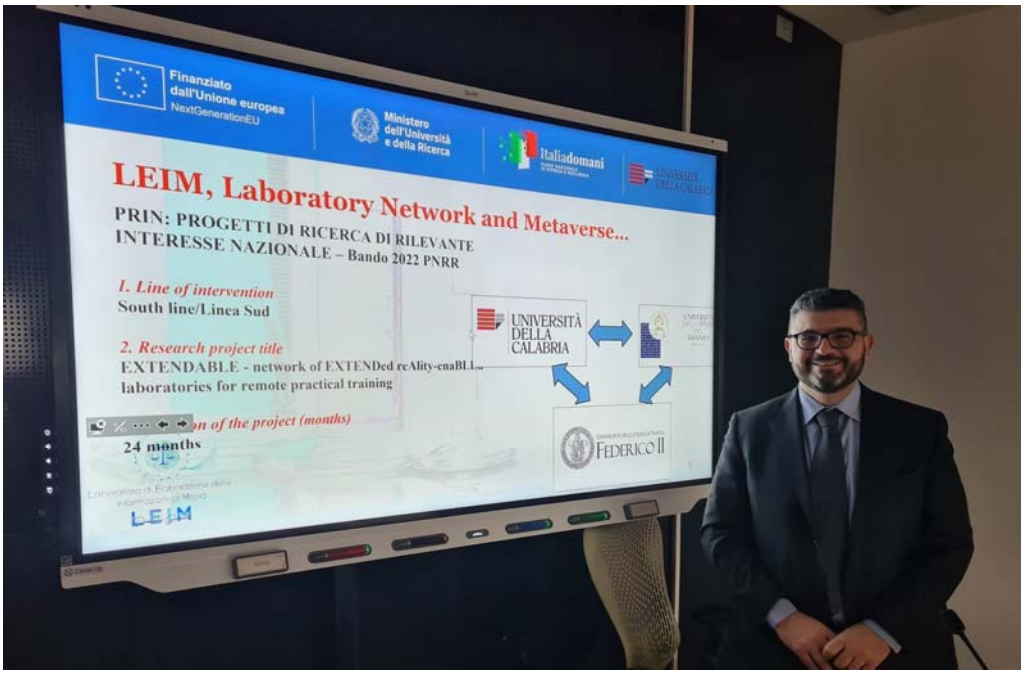

Figure 2. Prof. Lamonaca presenting the project at the University of Venice Ca' Foscari

2. SECTION 2 – PROGRESS OF ACTIVITIES

With regard to the specific timeframe, 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 adopted AR, VR, XR solutions for distance learning, 2) Study of the communications solutions for remote control of instruments and devices and 3) Study of literature solutions for reconfigurable circuits implementation.

As for the first item (the only one that ended in the considered timeframe), the current literature has highlighted the integration of augmented reality (AR) to enable remote control and interaction with laboratory measurement instruments, aiming to mitigate the impact of pandemic restrictions. The pandemic necessitated innovative solutions to continue practical education, and AR provides a promising approach to bridge the gap created by the lack of physical access to laboratories. Distance

learning platforms were effective for theoretical knowledge but inadequate for hands-on laboratory experiences. The use of AR involves developing software and 3D models of instruments, integrating them into a virtual environment. Lightweight communication protocols ensure that user commands in the AR environment are executed by actual laboratory instruments. The system translates user actions into commands for real instruments, maintaining consistency and functionality. Enhancements in the virtual environment, such as realistic animations and interactive features, improve user experience.AR technology aims to enhance remote learning by providing virtual access to laboratory instruments. AR technology is seen as a sustainable solution for remote practical education. The integration of IoT and AR can potentially revolutionize how laboratory education is conducted, ensuring that students can continue to gain practical skills regardless of physical access limitations. This introduction sets the stage for discussing the development and implementation of AR solutions to facilitate remote laboratory education, emphasizing the need for innovative approaches in response to global challenges like the COVID-19 pandemic.

The other two items are currently in progress; as for item 2), the study of communication solutions for remote control of instruments and devices focuses on enabling seamless interaction between users and laboratory equipment from a distance. This involves developing robust communication protocols like MQTT, which ensures reliable data transmission and command execution. Key aspects include latency reduction, data integrity, and real-time feedback, essential for maintaining the functionality and accuracy of remote operations. Integrating IoT technologies enhances connectivity, allowing devices to be controlled and monitored via the internet. This research is critical in creating efficient, user-friendly systems that ensure continuity in practical education and professional applications, especially under restrictions like those seen during the COVID-19 pandemic.

Regarding Item 3), the study of literature solutions for analog reconfigurable circuits implementation examines various methodologies and technologies used to design and create adaptable analog circuits. Key areas include the use of Field-Programmable Analog Arrays (FPAAs), which allow for dynamic reconfiguration of circuit components, and the development of mixed-signal integrated circuits that combine analog and digital functionalities. Research also focuses on adaptive control algorithms, which enable real-time adjustments to circuit parameters to optimize performance. Advanced materials and fabrication techniques are explored to enhance the flexibility and scalability of reconfigurable circuits. This field is crucial for applications requiring versatile and efficient analog signal processing, such as telecommunications, medical devices, and sensor networks.

As concerned with the University of Calabria, the foreseen tasks are: (i) the study of the communications solutions for remote control of instruments and devices, (ii) the study of literature solutions for reconfigurable circuits implementation and (iii) the performance assessment of the communication system delay. The task (i) and (ii) were developed together with the University of Naples Federico II and all the previous considerations and activities description are valid. As concern with the third task, an extensive analysis of the delay in the sending and receiving communication messages in the network with different constraints of security and quality of services is carried out. In particular, in the research activity, the communication network is seen as a critical infrastructure retrieving sensitive data. We proposed a security oriented VLAN testbed deployed with open source firmware and constrained hardware to address this issue. The approach uses local MQTT brokers, TLS tunnels for local sensor data, and an SSL tunnel to transmit encrypted data to a cloud based central broker. The proposal evaluates critical metrics such as Total Ratio, Total Runtime, Average Runtime, Message time, Average Bandwidth, and Total Bandwidth to predict the minimum network throughput for the selected QoS and security. The research evaluates the network performance of commonly used methods applicable to captive and commercial hardware. The proposal considers a

security focused VLAN approach, along with targeted solutions for hardware constraints. Given the nature of the worst case, this allows for broad application of the results obtained. Our study marks the initial phase of a larger and more extensive research effort. Specifically, we used commercial hardware such as the Raspberry Pi 4. Our goal is to extend the scope of the research and delve into more complex and detailed questions. The primary objective is to identify algorithms that ensure optimal data transmission and encryption ratios and explore algorithms that ensure maximum compatibility with existing infrastructures supporting MQTT technology and will facilitate secure connections for geographically dispersed Virtual Laboratory Node.

The project activities of the RU at the University of Sannio have been concentrated on the analysis of state-of-the-art technologies allowing access to different types of systems. A key requirement of remote laboratories is the capability of providing access to instrumentation with different sofware and operating systems. Such access must be ensured without reducing the functionalities provided by the instrumentation.

As a result of this analysis, it has been observed that the technologies based on remote desktop are able to satisfy the above-mentioned requirements.

In particular, the literature offers several implementations of remote laboratories based on remote desktop connections, where the most recent ones exploit the dynamic features offered by HTML5.

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;

Currently no potential changes to what has been originally approved were required except:

- the anticipation of some dissemination activities to catch the opportunity to present EXTENDABLE and potentially extend the network of laboratories to Venezia Ca'Foscari and to the Italian Group of Electric and Electronic Measurements GMEE.
- the definition and design of method for performance assessment of the communication system delay in order to experimentally validate the available solutions to guarantee security and quality of service in the MQTT communication.

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

The preliminary stage mandated to in-depth analyze the state of the art as well as the current main guidelines about the project topics is currently ongoing and will be terminated in the next bimesters. Stemming from that analysis, the operational units will start defining and developing the suitable solutions to fulfill the project objectives.

d) brief description of potential publications.

Publications are expected in the successive bimester,

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.

2) *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 Dis tributed Measurement Systems (DMS). However, cyber-attacks have increased, making it crucial to implement security protocols without reducing network throughput. Open firmware on con strained 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 transmis sions. 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.

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	0,25
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	0,076
Researchers who work in research centers which are recipients of financial support (men)	0,393	0,442
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	0,336
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 as well as the current main guidelines about the project topics is currently ongoing and will be terminated in the next bimesters.

Stemming from that analysis, the operational 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. No specific concerns have been highlighted at the moment. Activities more related to active research will start in the next bimesters.

Principal Investigator

(digital signature)

Firmato digitalmente da
Annalisa Liccardo
CN = Liccardo Annalisa
O = Universita di Napoli Federico II
C = IT
Data e ora della firma: 08/05/2024 10:16:24

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.