Rural Environmental Monitoring via ultra wide-ARea networKs And distriButed federated LEarning

First Progress Report

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Authors of the document

Name/Beneficiary	Position/Title	Date
Paolo Calciati / PDM	Project coordinator	01-03-2024

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
João Carvalho / ULHT	Professor	28-05-2024
Nuno Pedrosa / PDM	Senior Software Architect	29-05-2024

Approved for submission to the REA by - representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Luis Miguel Campos / PDM	Project coordinator	04-06-2024

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Name/Beneficiary	Position/Title	Date

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1. Abstract

This document reports on progress on the REMARKABLE project at the end of the first year of the project. Specifically, the report reports the performed secondments, reviews the secondments conducted this year against the secondments approved at the project start, and proposes some changes to the secondment plan proposed in the GA. The report also summarises the results in the mark of the different Work Packages of the project, presenting research and training activities that have been performed. Finally, the last section reports the advancements with respect to deliverables submitted against what was agreed in the GA.

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2. Introduction

This document presents the REMARKABLE's major achievements during the first year of the project, as specified in the Grant Agreement, Annex 1 - DoA) [1].

The document is divided into two main parts. The first part of the document presents the progress with the planification of the secondments, together with a summary of the work done in each of them and an update of the secondment plan for the remaining part of the project. The second part focuses on the project activities and contains a summary of the work done in the Work Packages and active tasks.

2.1. Applicable Reference Material

[1] Grant Agreement Number: 101086387 — REMARKABLE — HORIZON-MSCA-2021-SE-01.

2.2. List of Acronyms

Acronym	Definition
AI	Artificial Intelligence
CN	Communications and Networking
DoA	Description of Action
FL	Federated Learning
HAP	High-altitude Platform
IoT	Internet of Things
ICT	Information and Communication Technologies
LoRa	Long Range
ML	Machine Learning
NB	Narrow Band
LEO	Low-Earth Orbit
NSS	Networked Sensing Systems
LP-WAN	Low-power Wide-area Network
LR-UWAN	Low-power Ultra-wide-area Network
LR-PAN	Low-rate Personal Area Network
TinyML	A kind of embedded ML
UAV	Unmanned Aerial Vehicle
UC	Use Case

Table 1. List of acronyms.

1. Project Introduction

2.3. The REMARKABLE project

Internet of Things (IoT) technology combined with complementary support for data analytics is the cornerstone of today's digital transformation. The societal and economic impact of IoT/machine learning (ML) systems in urban and suburban areas significantly outpaces the one in rural areas due to a limited reach of connectivity infrastructure. IoT technologies have a huge potential for improving the economy and quality of life in rural areas, both in developed and developing countries. For instance, about 30.6% of the EU population lives in rural areas, which cover over 83% of the total EU area. Nonetheless, the average GDP per capita in rural EU areas is only 75% of the EU average [5]. Moreover, even though mobile networks cover more than 99% of the population in some European countries (such as the UK), they cover only about 79% of their landmass, thus leaving more than 20% of deep rural country areas without signal coverage [6]. To reverse further widening of the urban-rural gap, one needs to bring efficient and affordable IoT/ML solutions to deep rural areas, reaching out to applications and use cases ranging from wildlife management, rural tourism, livestock monitoring, water and air pollution control, and others.

REMARKABLE is an interdisciplinary project comprising experts from computer science, communication engineering, life sciences, environment and management. These experts come from diverse organisations in the UK, Europe and Africa. The project’s vision is to bring IoT/ML systems a step closer to seamless, energy efficient and secure deployment targeting use cases in deep rural areas. This will be done by identifying main gaps in connectivity and affordable data analytics and through interleaved research, development and validation in a real-world setting. The project is centred on an IoT/ML-based technological platform that will be adapted and demonstrated in the context of use cases applied in environmental monitoring, management, and conservation.

In short, the REMARKABLE project emphasises a necessity of bringing rural areas into the reach of IoT/ML technologies. Its ultimate goal is to facilitate a reduction of urban-rural gap which is currently increasing. Making advanced information and communication technologies (ICT) such as IoT/ML systems a rural commodity will play a crucial role in reversing the rural depopulation trends due to an expanded range of economic opportunities through empowering and modernising traditional rural ecosystems. The added value of deploying IoT/ML in deep rural areas is in reaching out to new streams of data sources that could prove invaluable in tackling and better understanding the growing environmental concerns, ranging from local and regional (such as pollution monitoring) to global ones (such as climate change).

REMARKABLE considers several objectives in terms of research and innovation that will also have a large environmental and societal impact, summarised in Table 2.

	Objective	Outcome	WP-M	Deliverable	Respons. Partner
Research and Innovation Objectives	Secure and Trustworthy Sensing, Localisation and Digital Twins	Design of robust, secure, trustworthy, and traceable IoT platform suitable for deep rural applications	M44	D.1.1-D.1.4	ULHT
	Connecting the Unconnected – Ultra Wide-Area IoT Networks	Provide a solution for connectivity of IoT devices deployed in deep rural areas beyond the reach of current wireless cellular network infrastructure	M44	D.2.1-D.2.4	UNS-FTN
	Secure and Frugal Distributed Data Analytics for Rural IoT	Develop a novel data analytics platform based on privacy-preserving distributed ML methods that are frugal secure and scalable	M44	D.3.1-D.3.4	MMU
	Demonstration, Validation and Assessment	Demonstrate, validate, and assess developed solutions in uses cases in real-life conditions, across European and African countries	M48	D.4.1-D.4.4	UA
Environmental and Societal Impact	Health and vitality monitoring of livestock in real-time	Enable quick animal treatment and prevent spreading illness, increase food production, track animals, identify grazing patterns, prevent desertification			
	Wildlife monitoring	Support tracking of endangered animals, reduce their poaching, improve tourist experiences in wildlife parks and reservations			
	Soil and agronomic management	Support automated irrigation and increase all-season production of food products			
	River pollution and air quality monitoring	Prevent health risk to humans, protect aquatic ecosystems from collapse and prevent the proliferation of phytoplankton			

Table 2. Summary of REMARKABLE project objectives.

2.4. Project key messages

REMARKABLE offers at least four main high-level messages that are foreseen for the principal findings produced by the project, which are focused on the following concepts:

- The REMARKABLE project is centred on developing an IoT/ML-based technological platform that will be adapted and demonstrated in the context of use cases applied to environmental monitoring, management, and conservation.
- REMARKABLE uses and assesses innovative methodologies based on statistical data processing and decentralised federated learning methods specifically designed for different use case implementations and demonstrations.
- The REMARKABLE project places a specific focus on rural environments and, in particular, on the African continent due to the huge potential of the number of IoT applications in Africa and the lack of traditional connectivity options.
- REMARKABLE strives at developing various added-value services ranging from wildlife management, rural tourism, livestock monitoring, water and air pollution control and others.

2.5. Keywords

Distributed federated learning, Internet of Things, Rural environmental monitoring, Statistical data processing, Ultra-wide area networks.

3. Progress with respect to the Secondment Plan

3.1. First year progress against secondment plan

Figure 1 shows the planed secondments according to the Grant Agreement (GA) for the first period, which includes the first two years of the project – 2023 and 2024.

Year 1-2	MMU	FTN-UNS	UPV	ULHT	ICTP	UA	DNET	PDMFC	ZOE	TKC	BV	UR	SU	FUT	LBS	UEMF
Office on the web Frame																
MMU (UK)		0	0	0	0	0	2	2	1	0	3	3	2	3	2	2
FTN-UNS (RS)	0		1	0	1	1	0	3	0	2	4	3	4	0	0	2
UPV (ES)	0	0		0	2	0	2	0	0	3	4	0	1	0	0	0
ULHT (PT)	2	2	0		1	0	3	0	1	3	0	1	3	0	0	1
ICTP (IT)	0	0	1	0		1	1	0	0	0	0	4	1	0	0	0
UA (ES)	1	1	0	0	0		4	1	0	3	2	0	3	0	0	2
Non-academic																
DNET (RS)	0	0	3	2	3	0		0	1	0	1	1	1	0	0	0
PDM (PT)	0	1	0	0	0	1	0		0	1	0	0	1	1	1	0
IURC (EL)	1	0	0	0	0	0	0	0		0	1	1	0	1	0	0
TKC (UK)	0	0	0	1	0	0	0	1	0		0	0	0	2	2	0
BEV (PT)	0	1	1	0	1	1	0	0	1	1		1	1	1	1	1
Associated Partners																
UR (RW)	1	1	0	1	1	1	1	0	0	0	2					
STU (ZA)	1	2	0	0	0	2	0	2	0	0	1					
FUT (NG)	2	0	0	0	0	0	0	1	0	0	1					
LBS (NG)	1	0	1	0	0	0	0	0	0	1	0					
UEMF (MA)	0	0	0	0	0	0	1	1	0	0	1					

Figure 1. Planned secondment according to the GA

Out of the 160 secondment-months foreseen for the first period the first two years of the project) 41.83 have been already realized or planned, as shown in Table 3, where for each row it shows for each partners the planned outgoing secondment for the first two years of the project, together with the actual secondments performed.

The table is also considering secondments between extra-EU partners (e.g., African partners and UK partners). Those are being tracked in the project, and amount to 32 secondment-months in the first period, which leaves a target total of 128 secondment-months for EU-related secondments.

Partner	Planned P1	Actual
MMU (UK)	20	2.25
FTN-UNS (RS)	21	8.03
UPV (ES)	12	5
ULHT (PT)	17	7.53
ICTP (IT)	8	0
UA (ES)	17	7.7
DNET (RS)	12	1
PDM (PT)	6	0
IURC (EL)	4	0
TKC (UK)	6	0
BEV (PT)	11	2.03
UR (RW)	8	2.97
STU (ZA)	8	4.57

FUT (NG)	4	0
LBS (NG)	3	0.75
UEMF (MA)	3	0
Total	160	41.83

Table 3. Actual secondments

As it can be seen from the table, the project is currently behind schedule with respect to the secondment plan. This was partially expected for the first year of the project, as it requires time for partners to organize the trips and to clearly define the objectives of both the project and the secondments. The goal would be to recover during the second year of the project, realistically without reaching the previously planned goal of 160 secondment months, but getting much closer to it than what the current numbers suggest. It is worth noting that during the summer of 2024 a high number of secondments is scheduled due to the project meeting organized in July: partners will take part in the meeting and extend their stay for performing secondments, taking advantage being already travelling.

3.2. Secondment reporting and outcome summary

Table 4 reports the secondments that already took place, specifying sending and receiving organizations.

Sending	**Receiving**	**Start Date**	**High level description**
STU	BEV	17/03/23	Smart agriculture through IoT in greenhouses
UA	BEV	20/06/23	Development of cutting-edge Computer Vision algorithms for UAV position estimation in GPS-denied environments
UA	DNET	18/05/23	Development TinyML algorithms to identify and track animals in farms
UA	MMU	01/10/23	Development of Machine Learning algorithms to classify an track crops origin
ULHT	DNET	08/07/23	Defining a Secure and Trustworthy ML-based IoT Platform Architecture
STU	UA	21/05/23	Study and development of IoT devices connected by LoRA WAN to monitorize natural parks
ULHT	UPV	15/07/23	Defining Sustainable Ultra-Wide Area IoT Network Architecture
ULHT	DNET	30/09/23	Secure and Trustworthy Design of IoT Platforms for Rural Areas and Ultra Wide-Area IoT Networks
ULHT	FTN-UNS	15/10/23	Development of a Novel Federated Learning Algorithm to Aggregate the Trainable parameters
ULHT	FTN-UNS	30/11/23	Providing a Solution for Multi-modal Device Localisation
STU	ULHT	07/01/24	Design of Secure IoT Device Localisation Methods for GPS-Denied Rural Areas

ULHT	DNET	23/03/24	Development of Frugal and Secure Localisation Algorithms
ULHT	ICTP	01/04/24	Extending Rural IoT Connectivity via UAV-based Network Coverage Extension
ULHT	STU	29/04/24	Developing Internet of Underwater Things (IoUT) and Communication Technologies for Rural Deployment
ULHT	UPV	15/07/24	Studying Solutions for Cooperative Device Localisation and Navigation
FTN-UNS	BEV	09/03/23	Extending Rural IoT Connectivity via UAV-based Network Coverage Extension
FTN-UNS	BEV	18/07/23	Extending Rural IoT Connectivity via UAV-based Network Coverage Extension
STU	MMU	13/09/23	Smart agriculture in greenhouse tunnels with climate-resilient bambara nuts
FTN-UNS	TWK	15/09/23	Remote connectivity of UAVs via 5G Networks
STU	MMU	23/09/23	Smart agriculture in greenhouse tunnels
FTN-UNS	UoR	04/08/23	IoT solutions for Deep Rural Environments. Resource Management in 5G networks.
FTN-UNS	BEV	18/07/23	IoT and 5G connectivity and positioning involving UAVs
FTN-UNS	PDM	01/07/23	Environmental monitoring, water quality monitoring, sensing and analytics for water quality monitoring
FTN-UNS	PDM	01/07/23	Environmental monitoring, water quality monitoring, sensing and analytics for water quality monitoring
FTN-UNS	UPV	06/07/23	Integration of optical and RF wireless, hybrid OWC/RF IoT networks and random access protocols
FTN-UNS	BEV	12/08/23	Massive IoT design and capacity analysis. Integration of UAVs in massive IoT networks.
FTN-UNS	BEV	29/07/23	Reliable and resilient UAV to infrastructure communications
FTN-UNS	ICTP	20/01/24	Distributed learning in IoT networks. Design of communication-aware split learning.
DNET	ULHT	16/11/23	Learning about the specifics of the Marie Curie program from the administrative perspective. Defining KPIs for the REMARKABLE evaluation and impact assessment in technical, economic, environmental and societal terms. Investigation of applicable business models.
UPV	BEV	1/10/23	Orchestrate and implement a future multi-UAV survey mission
STU	ULHT	5/01/24	Smart agriculture through LoraWAN in forests with dendrometers
UPV	ICTP	6/5/24	Bridging theoretical advances with practical implementations in combining ML and IoT
UR	UNS-FTN	03/06/23	Research in IoT networking

UR	UNS-FTN	31/01/24	Machine learning in IoT
BEV	FUT	28/10/23	Identification of research and development topics
BEV	FUT	15/10/23	Research in Network and recognition of research and development areas
BEV	STU	25/11/23	Beyond Vision UAV platforms and communication focused on solar panel inspection, wildlife preservation and mine surveillance
MMU	STU	19/07/23	Deep learning in smart agriculture using sensor data from Greenhouse Tunnel
MMU	DNET	19/08/23	Research in distributed smart farming using drones and communication technology
MMU	FUT	27/08/23	Deep learning for intrusion detection in Internet of Things network
MMU	FUT	14/04/24	Federated learning for privacy preservation in Internet of Things applications

Table 4. Secondment description

3.3. Summary of changes to original Secondment Plan

	MMU	FTN-UNS	UPV	ULHT	ICTP	UA	DNET	PDM	IURC	TKC	BV	UR	STU	FUT	LBS	UEMF
Academic																
MMU (UK)		1	0	0	1	0	5	5	3	0	5	6	4	7	4	4
FTN-UNS (RS)	0		2	0	2	2	0	5	0	5	6	6	7	0	0	3
UPV (ES)	0	0		0	4	0	3	0	0	6	6	1	4	0	0	0
ULHT (PT)	2	4	2		2	0	6	0	2	6	0	2	6	2	0	2
ICTP (IT)	0	0	2	0		2	2	0	0	0	0	9	2	0	0	0
UA (ES)	2	2	0	0	0		8	2	2	6	4	0	6	0	0	3
Non-academic																
DNET (RS)	0	0	6	4	6	0		0	2	0	2	2	2	0	0	0
PDM (PT)	0	1	0	0	1	0	0		2	1	0	0	2	1	0	1
IURC (EL)	1	1	1	0	0	0	0	2		0	1	0	1	0	0	1
TKC (UK)	0	0	0	2	0	0	0	2	0		0	0	0	4	4	0
BEV (PT)	0	2	1	0	1	2	0	0	1	1		2	2	1	1	1
Associated Partners																
UR (RW)	1	3	0	1	3	2	1	2	0	0	2					
STU (ZA)	3	3	0	2	2	3	1	3	0	0	2					
FUT (NG)	3	0	0	0	0	1	1	2	1	1	1					
LBS (NG)	2	0	1	0	0	1	0	0	1	1	0					
UEMF (MA)	1	0	0	1	0	0	1	1	0	0	1					

Figure 2. Updated secondment plan

Figure 2 shows the updated secondment plan. With respect to the original secondment plan the following changes were implemented:

1. ULHT removed one secondment from both MMU and STU and added 2 secondments to UPV

2. UA removed two secondments from UEMF and added two secondments to IURC
3. PDM removed one secondment from both FTN-UNS, UA and LBS and added two secondments to IURC and one to ICTP
4. IURC removed one secondment from each of TKC, BV and UR, and removed two secondments from FUT; they added 2 secondments to both FTN-UNS and PDM, and one secondment to STU

Changes applied to the secondment plan do not modify the total number of secondments nor the project budget.

4. Progress with respect to project activities

4.1. WP1 - Secure and Trustworthy design of IoT platforms for Rural Areas (ULHT)

Task 1.1: Define a secure and trustworthy ML-based IoT platform architecture – M1-18 ULHT

In this task, the main contributors (ULHT, MMU, UNS-FTN, UPV, ICTP, UA, DNET, UR, STU), with assistance from the remaining partners, worked on defining a resilient ML-based IoT platform architecture for different rural use cases. The contributors identified that the main IoT platform requirements for IoT devices deployed in rural use cases include the following.

- The developed platform must be constantly available and highly scalable: Platform's constant availability (with minimal downtime) is crucial for the majority of stakeholders that should always be able to access and benefit from the platform. Moreover, the platform should be scalable in the sense that one can add more devices and/or payloads from existing devices that automatically scale with every device/payload.
- Substantial consideration must be given to flexibility, resilience and security of the developed platform: Network evolution, reflected in the augmented levels of connectivity and automation, poses several challenges that need to be addressed, together with the growing dependence on poorly inter-operable proprietary technologies that may pose risk to people and surrounding environment. We foresee that platform's versatility could be maximized by UAV assistance in many rural use cases.
- Secure connectivity extension is crucial for the developed platform: The platform should enable connecting currently unconnected remote rural areas in a reliable and sustainable manner. This could be achieved by designing a solution for ultra-wide area IoT networks, by possible considering hardware improvements at both the IoT device and the network side, exploiting High-Altitude Platforms, Low Earth orbit satellites, as well as using UAVs to provide aerial data links beyond the coverage edges.
- The developed platform must be energy-efficient: The platform will aggregate enormous collection of heterogeneous coming from multiple IoT sensors. It is therefore paramount to extract relevant features from the (unstructured) data and enable the platform to learn from it (and adapt according to it) in a frugal (in the sense of resource and data requirements) manner.

Task 1.2: Design of lightweight ML-based algorithms for rural IoT – M6-44 UA

Several algorithms have been developed by UA in collaboration with MMU, SU and NSU during the development of secondments and contributing to different challenges in sites in Serbia and Spain. Applications for birds' identification of natural parks [1], [2], required deployments on edge devices with very limited computational resources and the lack of power supply and internet connectivity required the design of tinyML solutions. Other scenarios like chicken farms have been also monitored and edge solutions that include both, reidentification and tracking of animals have been developed in collaboration with DuvaNET [3].

Publications/submissions relevant to the task:

[1] D. Teterja, J. Garcia-Rodriguez, J. Azorin-Lopez, E. Sebastian-Gonzalez, R. E. van der Walt, M. J. Booysen, "An Image Mosaicing-Based Method for Bird Identification on Edge Computing Devices", in 18th International Conference on Soft Computing Models in Industrial and

Environmental Applications (SOCO 2023). SOCO 2023. Lecture Notes in Networks and Systems, vol 750. Springer, Cham. https://doi.org/10.1007/978-3-031-42536-3_21

[2] Teterja, D. et al. (2023). A Performance Evaluation of Lightweight Deep Learning Approaches for Bird Recognition. In: Rojas, I., Joya, G., Catala, A. (eds) Advances in Computational Intelligence. IWANN 2023. Lecture Notes in Computer Science, vol 14134. Springer, Cham. https://doi.org/10.1007/978-3-031-43085-5_26

[3] Dmitrij Teterja, Jose Garcia-Rodriguez, Jorge Azorin-Lopez Esther Sebastian- Gonzalez, Daliborka Nedic, Dalibor Lekovic, Petar Knezevic, Dejan Drajic , and Dejan Vukobratovic, "A Video Mosaicing-Based Method for Chicken Behavior Recognition on Edge Computing Devices", submitted to Sensors, 2024.

Task 1.3: Design of secure IoT device localization methods for GPS-denied rural areas – M6-44 ULHT

The task contributors made significant progress in designing secure IoT-device localisation methods in GPS-denied environments. More precisely, the contributors already developed a couple of frugal and trustworthy model-based localisation algorithms, robust to hardware malfunctions and specifically designed for GPS-denied environments, together with a couple of semi-autonomous UAV navigation algorithm based on machine learning that might be particularly useful for some of the considered use cases. The fruit of this work is published/submitted in some of the leading international journals and conferences, listed below. Nevertheless, there is still much work to be done regarding the task, and all contributors are working hard and together to meet the expectations put forth in the project proposal.

Publications/submissions relevant to the task:

[1] S. Tomic, M. Beko, "A Min-max Optimization-based Approach for Secure Localization in Wireless Networks," IEEE Transactions on Vehicular Technology, vol. 73, no. 3, 4151—4161, March 2024. https://doi.org/10.1109/TVT.2023.3325063

[2] S. Tomic, M. Beko, "Trustworthy Target Localization via ADMM in the Presence of Malicious Nodes", to appear in IEEE Transactions on Vehicular Technology, December 2023. https://doi.org/10.1109/TVT.2023.3346476

[3] R. Santos, J. P. Matos-Carvalho, S. Tomic, M. Beko, and S. D. Correia, "A Hybrid LSTM-based Neural Network for Satellite-less UAV Navigation", 6th Conference on Cloud and Internet of Things (CIoT), Lisbon, Portugal, March 20-22, 2023. https://doi.org/10.1109/CIoT57267.2023.10084873

[4] R. Santos, J. P. Matos-Carvalho, S. Tomic, M. Beko and C. T. Calafate, "Convolutional Neural Networks for autonomous UAV Navigation in GPS-denied Environments", to appear in 'Human-Centric Systems', 15th Doctoral Conference on Computing, Electrical and Industrial Systems (DoCEIS'24), Caparica, Portugal, July 03-05, 2024.

Task 1.4: Design of Digital Twin models for rural IoT devices – M18-36 UPV

This task will start in M18 of the project.

4.2. WP2 - Ultra Wide-Area IoT Networks (UNS-FTN)

Task 2.1: Establish the limits of existing LP-WAN technologies for wide-area IoT – M1-18 ICTP

In this task, researchers have investigated the coverage limits of existing LP WAN technologies. We identified and precisely characterised configurations and possible hardware improvements at both the IoT device and the network side capable of providing extreme coverage for the main LP WAN technologies such as LoRa, SigFox and 3GPP NB-IoT/LTE-M. We identified rural IoT scenarios investigated in REMARKABLE project. ICTP and UPV have focussed on the development of a LoRaWAN range extender, capable of connecting standard LoRaWAN end devices to standard LoRaWAN gateways. The device has been developed, tested in the lab and deployed in the field. The presentation at Globecom 2023 has gained a lot of interest to test the solution with UAVs.

From UPV side the works continued to extend the LoRa based protocol and a possible application using ML at the edge to determine the presence of water using an energy aware architecture. ICTP and UPV will continue in this line through one of the active secondments

Publications/submissions relevant to the task:

- Altayeb, Moez, Marco Zennaro, Ermanno Pietrosemoli, and Pietro Manzoni. "Optimizing the Performance of LoRaWAN Range Extenders in Sparse and Unconventional Contexts." In 2023 IEEE Globecom Workshops (GC Wkshps), pp. 714-719. IEEE, 2023.
- Altayeb, Moez, Marco Zennaro, Ermanno Pietrosemoli, Pietro Manzoni, and Rosdiadee Nordin. "A LoRaWAN Uplink Range-Extender (LURE) for Extended and Energy-Efficient Wireless IoT Communications." In ICC 2023-IEEE International Conference on Communications, pp. 6151-6156. IEEE, 2023.
- Arratia-Uribe, Benjamín Andrés, Rosas-Olivos, Erika Susana, Tavares De Araujo Cesariny Calafate, Carlos Miguel, Cano, Juan-Carlos, Cecilia-Canales, José María, Manzoni, Pietro, “AlLoRa: Empowering environmental intelligence through an advanced LoRa-based IoT solution, submitted to Computer Communication https://doi.org/10.1016/j.comcom.2024.02.014
- Arratia-Uribe, Benjamín Andrés, Prades, Javier, Peña-Haro, Salvador, Cecilia-Canales, José María, Manzoni, Pietro, “BODOQUE: An Energy-Efficient Flow Monitoring System for Ephemeral Streams”, 24th ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc 2023)

Task 2.2: Extend rural IoT connectivity via UAV-based network coverage extension – M6-44 UNS-FTN

In this task, the researchers explored the use of unmanned aerial vehicles (UAVs) or drones for rural connectivity. UNS-FTN and ULHT researchers are working to evolve the UAV platform for NB-IoT and LoRa rural connectivity reported at CIoT 2023 conference [1]. UNS-FTN signed a contract with national Telekom (Telekom MTS) provider to use their LoRa/NB-IoT infrastructure free of charge for research purposes (similar contract is established before the project with A1 Serbia, a mobile operator in Serbia, for their NB-IoT network). UNS-FTN is now working on remote connectivity and control of drones through 5G network, sharing experience with BEV. UNS-FTN plans several real-world measurement campaigns during summer 2024 for the purpose of rural water (river, lakes) quality monitoring, while testing the network connectivity in deep rural environments. This context is explored in complex communication scenario involving underwater sensors, floating water buoys, drones and cellular network. Initial results are reported at two conferences (CNSDSP 2024 and BalkanCom 2024) [2]-[4]. IURC explored path planning for a fleet of drones. Path optimisation for multi-drone missions is explored in [5] improving the total path distance between 4-22%.

Publications/submissions relevant to the task:

[1] S. Sobot, M. Lukic, D. Bortnik, V. Nikic, B. Lima, M. Beko, D. Vukobratovic, "Two-Tier UAV-based Low Power Wide Area Networks: A Testbed and Experimentation Study," 6th Conference on Cloud and Internet of Things (CIoT), Lisbon (Portugal), March 2023.

[2] T. Devaja, S. Sobot, M. Petkovic, M. Beko, D. Vukobratovic, "Relay-Aided Slotted Aloha for UAV-Assisted Mixed UOWC-RF Systems," accepted, Int'l Symp. on Communication Systems, Networks and Digital Signal Processing - CSNDSP 2024, Rome, July 2024.

[3] M. Petkovic, A-M. Vegni, E. Hernandez-Orallo, P. Manzoni, D. Vukobratovic, "Novel Design of Two-Tier Slotted-ALOHA OWC/RF IoT Networks with Adaptive Control," accepted, Int'l Symp. on Communication Systems, Networks and Digital Signal Processing - CSNDSP 2024, Rome, July 2024.

[4] A-M. Vegni, P. Manzoni, M. Petkovic, "IRON: an Integrated RF-OWC System for Interoperability in IoT Systems," accepted, 2024 7th International Balkan Conference on Communications and Networking (BalkanCom), Ljubljana, Slovenia, June 2024.

[5] Gasteratos, G., Karydis, I.: "Path planning optimisation for multiple drones: Repositioning the Starting Point", 20th International Conference on Artificial Intelligence Applications and Innovations (AIAI2024), to appear, 2024.

Task 2.3: Design Deep Rural IoT Connectivity Solution using High-Altitude Platforms and LEO Satellites – M18-36 BEV

This task will start in M18 of the project.

Task 2.4: Define Sustainable Ultra-Wide Area IoT Network Architecture – M6-44 UNS-FTN

In this task, the partners are collaborating to propose (towards the end of the project) a REMARKABLE ultra-wide area IoT network architecture. It will address different obstacles in rural deployments from the perspective of communication (coverage and node placement), data flows (data from IoT nodes), energy (energy harvesting and renewable power sources), and computation constraints (location and performance of edge, fog and cloud computing nodes). The task is still work in progress and collect different inputs from other tasks towards defining initial REMARKABLE architecture proposal.

4.3. WP3 - Secure and Frugal Distributed Data Analytics for Rural IoT (UA)

Task 3.1: Develop feature extraction and dimensionality reduction methods for heterogeneous data from multiple sources – M1-24 UA

In some application related with natural parks it is important to provide compact and multimodal solutions. In the case of birds identification, the monitoring using cameras is not always possible since birds are occluded or hided which make necessary the use or other sources like audio systems to identify the species based on the analysis of the singing. The development of multimodal solutions including different modalities is challenging and the deployment onto edge devices needs to reduce the data dimensionality and to reduce the number of features employed. In our works we have developed some algorithms and strategies to reduce data and implementations.

Task 3.2: Develop frugal ML architectures for edge/fog-based model development – M1-36 MMU

This task investigates the development of machine learning, deep learning and federated learning architectures for edge-based model development. Specifically, for memory constraint IoT devices and frugal environments. Such as in a limited amount of IoT sensor data to ensure data privacy, promote frugal data usage and reduce computation complexity. MMU worked with STU to develop deep learning models for temperature simulation of Greenhouse Tunnel farming based on limited data [1]. In addition, a federated learning model was developed for intrusion detection in consumer IoT devices [2].

Publications/ submissions relevant to the task:

[1] Jogunola, O., KJ, H., Mabitsela, M. M., Phiri, E. E., Adebisi, B., & Booysen, M. J. (2023). Deep Learning-Enabled Temperature Simulation of a Greenhouse Tunnel. IWACP, https://scholar.sun.ac.za/handle/10019.1/129193.

[2] Popoola, S. I., Imoize, A. L., Hammoudeh, M., Adebisi, B., Jogunola, O., & Aibinu, A. M. (2023). Federated Deep Learning for Intrusion Detection in Consumer-Centric Internet of Things. *IEEE Transactions on Consumer Electronics*, 10.1109/TCE.2023.3347170.

Task 3.3: Design Secure Federated Learning Methods for Distributed Model Parameter Aggregation – M1-44 ULHT

The contributors of this task made very good progress towards designing federated learning methods for distributed model parameter aggregation. The contributors designed a novel approach to empower cellular-connected UAVs in predicting signal quality. The developed prediction model leverages data collected by the UAVs, addressing privacy concerns, and ensuring effectiveness, while taking into account the constraints imposed from the UAVs' side. This work resulted in one journal submission and a few conferences/workshops, listed below.

Publications/submissions relevant to the task:

[1] I. Mouhamad, D. N. K. Jayakody, and D. Vukobratovic, "Cost-Effective Federated Learning-Based Approach for SINR Prediction in Cellular-Connected UAVs," submitted to Journal of Communications and Information Networks.

[2] S. Sabapathy, J. S. Prabhu, S. Maruthu, and D. N. K. Jayakody, "Profuse Channel Estimation and Signal Detection Techniques for Orthogonal Time Frequency Space in 6G Epoch: A Survey," IEEE Access, vol. 11, pp. 129963-129993, 2023, https://doi.org/10.1109/ACCESS.2023.3333428

[3] C. Basnayaka, D. N. K. Jayakody, and M. Beko, "Semantics-Empowered UAV-assisted Wireless Communication System for Wildfire Detection," IEEE International Workshop on Computer Aided Modeling and Design of Communication Links and Networks, Edinburgh, UK, 6–8 November 2023. https://doi.org/10.1109/CAMAD59638.2023.10478404

[4] S. S. Morapitiya, T. W. W. Leelarathna, and D. N. K. Jayakody, "BER Analysis in PS-SLIPT Architecture Using Different Modulation Schemes," 3rd International Research Conference, Dec 2023, Colombo, Sri Lanka.

[5] V. P. Sooriarachchi and D. N. K. Jayakody, "Model for Advanced Sensor Placement in Wildfire Detection Systems", to appear in IEEE Wireless Communications and Networking Conference, 21–24 April 2024, Dubai, United Arab Emirates.

Task 3.4: Define Secure, Frugal and Decentralised REMARKABLE Learning Architecture – M1-44 UNS-FTN

In this task, the partners are investigating distributed learning architecture capable of providing necessary scalability, reduced complexity, frugal data and computation IoT node design (developed in WP1), sporadic and versatile IoT communication links (developed in WP2), secure and decentralised federated learning principles (developed in WP3), to support smart applications in infrastructure-limited rural areas. The work between UNS-FTN and ICTP focused on efficient communication-aware distributed learning methods. In particular, the focus is on efficient techniques for split learning, where part of the learning process is implemented in edge IoT devices and more involved part at the edge or cloud server. Preliminary results are submitted to a conference and a renowned IEEE journal [1], [2].

Publications/submissions relevant to the task:

[1] V. Ninkovic, D. Miskovic, D. Vukobratovic: "UAV-assisted Distributed Learning for Environmental Monitoring in Rural Environments," submitted, BalkanCom 2024, Ljubljana (Slovenia), June 2024.
[2] V. Ninkovic, D. Vukobratovic, D. Miskovic, M. Zennaro: "COMSPLIT: A Communication-Aware Split Learning Design for Heterogeneous IoT Platforms," submitted, IEEE Internet of Things Journal, March 2024.

4.4. WP4 - Demonstrating, Validating and Assessing REMARKABLE Solutions (UA)

Task 4.1 Pilot Sites Continuous Management and Evaluation Planning – M1-48 UA

The development of secondments has permitted the collaboration and knowledge of the different pilot sites, with important advances in Spain (x,y), Serbia (z) and South Africa. In Spain there have been installed some IoT sensors to monitor the lagoon. In Serbia, several observation sites have been installed the park. In South Africa there have been develop different devices to monitor air quality, wells water levels and many other utilities. Work in the other African sites is under development and results are expected in the next months.

Task 4.2 Pre-Pilot Activities and Validation of REMARKABLE Solutions - M1-48 BEV

This task is still starting with some activities focusing on simulation and testing setups for the drones' submodules. This activity included some of the secondments hosted by BV.

Task 4.3 Inter-Disciplinary Research and Implementation of REMARKABLE Use Cases – M1-48 UNS-FTN

This task, which is still in its early stages, targets implementation of WP1-3 solutions in real-life environments in order to assess, validate and evaluate their impacts. The task involves interaction between ICT-related and non-ICT related researchers (e.g., field biologists, environmental engineers, livestock managers, agri-food and forestry experts, etc.). It will include deployment of sensors and IoT platforms where they are not available to serve multiple monitoring operation needs of the defined environments. Drone-based IoT testbeds are in preparation by multiple partners (e.g., UNS-FTN, BEV, STU) jointly with edge/fog/cloud computing facilities in order to demonstrate end-to-end system operation and measure its performance.

Task 4.4 Evaluation and User's Acceptance - M1-48 DNET

Evaluation of the pilot deployments will be done once pilot solutions are deployed and ready for technical, business and end users' evaluation. In order to prepare the activities, the approach to deploying pilots/living labs and their evaluation/validation adopted by two projects were analysed leveraging DNET's involvement in these projects: H2020 DEMETER which ran over 20 smart agriculture pilots, and the Horizon Europe COMMECT project (Home - Commect (horizoneurope-commect.eu)) which deployed living labs in five European rural regions. Both projects analyzed deployed solutions from multiple angles and with extensive participation of end users. These activities and the adopted evaluation/validation approaches were presented to and discussed with the REMARKABLE researchers visiting DNET as an introduction to the topic and as a preparation for the execution of this task.

Task 4.5 Planning, preparation and publishing of openly accessible data sets - M1-48 IURC

This task is still in its early stages. The task will include the following steps: (1) Ask partners who of them has / will have openly accessible datasets; (2) When will they have them ready (so we can plan); (3) Verify with coordinator / consortium if they want us to create a separate web-platform for the publishment / dissemination of the datasets or we're going with the existing (website?) of the project (and accordingly, either create the new platform or acquire appropriate access in the existing); (4) Verify (according to plan of #2 and/or periodically) partners and (declared contributors) for their dataset + related metadata (sizes, contents, descriptions, images, etc); (5) Homogenise the collected datasets; and (5) Publish the data.

4.5. WP5 - Knowledge Sharing, Training and Networking (UPV)

Task 5.1: Organising and overseeing the execution of the exchange plan – M1-48 PDM

PDM has been keeping track of the status of the secondments organized during the project. This was achieved by organizing a shared repository to keep all project's documentation available to all partners of the consortium and by coordinating parting in updating the provided information at regular intervals.

All partners participated in this task agreed to register all secondments both in SyGMA on the EU portal, and in one Excel file in the project repository to keep track of the progression.

Task 5.2: Monitoring the quality of the knowledge sharing – M1-48 UPV

Effective monitoring of knowledge-sharing quality has been ensured through diligent monitoring of activities related to personnel exchanges. Systematic tracking of these activities leverages a centralized repository to maintain comprehensive, accessible documentation for all partners involved in the consortium. This strategic approach facilitates regular updates and enhances collaborative engagement in managing shared knowledge. Furthermore, all involved partners have committed to documenting details of these personnel exchanges in a designated online system and a unified spreadsheet within the project repository, ensuring transparent and current progress tracking.

Task 5.3: Organisation of the project's training and networking events – M1-48 UNS-FTN

This task is devoted to organisation of training events (summer schools, training and demo events) as well as networking events (workshops, special sessions). This includes organisation of the kick-off workshop, two training and demo events and two project summer schools. Project kick-off event as well as workshop is organised from 20-22. March 2023 (M3 of the project, as planned) and it was collocated with 6th Int'l Conf on Cloud and Internet of Things (CIoT) 2023 organised by ULHT. The project will organise two special sessions during 2024: 1) special session on AI/ML Empowered IoT Connectivity in Rural Environments at BalkanCom 2024, Ljubljana, Slovenia, June 2024, and 2) Special track on AIoT for Rural Environmental Monitoring (REMARK) at ACM International Conference on Information Technology for Social Good (GoodIT 2024). The project workshop will be organised in July 2024 in Porto.

4.6. WP6 - Coordination, Dissemination, Communication and Management (PDM)

Task 6.1 Communication, dissemination and planning – M1-48 PDM

The first version of the Dissemination and Communication Plan was created, defining strategy and activities for the project's dissemination, designing responsibilities for each activity. Moreover, a PowerPoint template was created and is available on the project repository on SharePoint for preparing presentations.

Task 6.2 Project Web-site and maintenance/ Social Media – M1-48 ULHT

In constant communication and consultation with other partners, ULHT set up the project website in May 2023 (it can be accessed through: https://remarkable.ulusofona.pt/), alongside with social media profiles (Facebook, LinkedIn and Twitter (X)). The maintenance and contents updates are constantly being performed by ULHT and in communication with other partners (that are communicating all relevant information, such as findings, publications, secondment and other stories pertinent for sharing on social media/website). These activities are summarized in Table 5 below. Moreover, in the same period, ULHT proposed the first draft of the project logo, which after a few minor adjustments was approved by the Consortium and has been in function since then.

Date	Channel	Description	Views	Likes	Shares	Link
01/08/23	Facebook	About project	16			https://www.facebook.com/photo?fbid=110685225449204&set=a.110685402115853
04/08/23	LinkedIn	About project	50	3		https://www.linkedin.com/feed/update/urn:li:activity:7093229614914793472
04/09/23	Twitter	CIoT'23 Portugal	139	2	1	https://twitter.com/remarkable_iot/status/1698724696827527409
04/09/23	Facebook	CIoT'23 Portugal	21			https://www.facebook.com/remarkable.iot/posts/pfbid0wXxdTD2jvFbZZNdNbLhjinuyyHYVoxTC8nWCEFJybGvpLuX5b9g8KQdDBc2pH4mQl
04/09/23	LinkedIn	CIoT'23 Portugal	258	17	2	https://www.linkedin.com/feed/update/urn:li:activity:7104491081198661632
10/10/23	LinkedIn	About team	537	21	1	https://www.linkedin.com/feed/update/urn:li:activity:7117470340087230465
10/10/23	Facebook	About team	10	1		https://www.facebook.com/photo/?fbid=156517714199288&set=a.110685402115853

10/10/23	Twitter	About team	76	4		https://twitter.com/remarkable_iot/status/1711693758104838184/photo/1
18/10/23	LinkedIn	About team	1322	48	1	https://www.linkedin.com/feed/update/urn:li:activity:7120361124004315138
18/10/23	Facebook	About team	16	4		https://www.facebook.com/photo?fbid=161871890330537&set=a.110685402115853
18/10/23	Twitter	About team	734	8	3	https://twitter.com/remarkable_iot/status/1714596622812741736/photo/1
19/10/23	Twitter	Secondment ULHT/DNET	45	1	1	https://x.com/DunavNET/status/1714931400422392309?s=20
19/10/23	LinkedIn	Secondment UA/DNET	69	2	1	https://www.linkedin.com/posts/remarkable%2Eiot_mosaicbasedmethod-birdrecognition-poultryfarming-activity-7120712342048284673-GxSQ?utm_source=share&utm_medium=member_desktop
23/10/23	Facebook	Secondment DNET	13	4		https://www.facebook.com/photo/?fbid=165174593333600&set=a.110685402115853
03/11/23	Twitter	Secondment DNET/FTN	110	3	1	https://x.com/remarkable_iot/status/1720397014880383447?s=20
03/11/23	LinkedIn	Secondment DNET/FTN	485	14	2	https://www.linkedin.com/feed/update/urn:li:activity:7126159860731105280
03/11/23	Facebook	Secondment DNET/FTN	17	5		https://www.facebook.com/remarkable.iot/posts/pfbid0swP6nQKKkzCZXcgh4Rbx6nbq5MyofJL5GXVEz7ZswD9dVmFAiPG8WnKMgwLbMYo8l
07/11/23	LinkedIn	Secondment ULHT/FTN	1531	22		https://www.linkedin.com/feed/update/urn:li:activity:7127693383271079936
08/11/23	Facebook	Secondment ULHT/FTN	13	3	1	https://www.facebook.com/remarkable.iot/posts/pfbid08qZkRyupFncipHy8MT6GNkUqG5W36m3CxtasifCbUtnYbNsBSCVVf7TpTafXQYtPl
08/11/23	Twitter	Secondment ULHT/FTN	29	3		https://twitter.com/remarkable_iot/status/1722275980629458986/photo/1
17/11/23	Twitter	About team (UA)	41	3	1	https://twitter.com/remarkable_iot/status/1725492234420682985/photo/1
17/11/23	LinkedIn	About team (UA)	540	16	1	https://www.linkedin.com/feed/update/urn:li:activity:7131254485116489728
17/11/23	Facebook	About team (UA)	26	2		https://www.facebook.com/photo/?fbid=179752228542503&set=a.110685402115853

27/11/23	Twitter	About team (FTN)	63	2	1	https://x.com/remarkable_iot/status/1729096469527838936?s=20
27/11/23	LinkedIn	About team (FTN)	401	32		https://www.linkedin.com/feed/update/urn:li:activity:7134863334826258432
27/11/23	Facebook	About team (FTN)	20	4		https://www.facebook.com/photo/?fbid=185249531326106&set=a.110685402115853
11/12/23	Facebook	Secondment UPV/BV	6	6		https://www.facebook.com/remarkable.iot/posts/pfbid034L2KPG2b3eaGWcuvZ8DD38vxztSA2Su68KThTy8UGsgXgzh4rKQrFhZTzDfVeuR9l
11/12/23	Twitter	Secondment UPV/BV	71	3	2	https://x.com/remarkable_iot/status/1734221057106518252?s=20
11/12/23	LinkedIn	Secondment UPV/BV	43	43	2	https://www.linkedin.com/feed/update/urn:li:activity:7139987981708308480
20/12/23	Facebook	Secondment UA/MMU	3	3		https://www.facebook.com/photo/?fbid=199045779946481&set=a.110685402115853
20/12/23	Twitter	Secondment UA/MMU	50	2		https://x.com/remarkable_iot/status/1737504147413295447?s=20
20/12/23	LinkedIn	Secondment UA/MMU	11	11		https://www.linkedin.com/feed/update/urn:li:activity:7143261656507228160

Table 5. Summary of social media posts

Task 6.3 Workshop and Special Sessions Organization – M1-48 UNS-FTN

In this task, we are working towards organising networking and demonstration events in the form of project workshops and special sessions, typically collocated with major conferences in the field. The project will organise two special sessions during 2024: 1) special session on AI/ML Empowered IoT Connectivity in Rural Environments at BalkanCom 2024, Ljubljana, Slovenia, June 2024, and 2) Special track on AIoT for Rural Environmental Monitoring (REMARK) at ACM International Conference on Information Technology for Social Good (GoodIT 2024). The project workshop will be organised in July 2024 in Porto.

Task 6.4 IPR handling and innovation management – M1-48 PDM

During the first year of the project the focus has been on defining the specific technological contributions of the different partners, and defining how those can help create innovation in the use cases sites.

No work has been done yet on IPR.

Task 6.5 Administrative consortium management – M1-48 PDM

PDM has been leading this task by working on different fronts:

- Ensuring administrative and contractual relationships,
- Leading the generation of a consortium agreement, and its subsequent signature from all consortium members.

- Overseeing the preparation and submission of project deliverables.
- Creating a SharePoint for the project, which hosts all project's documentation and deliverables
- Contacting the Project Officer (PO) for important matters.
- Preparing and proposing an amendment to the original GA, which included the removal of ZOE and the addition of IURC to the consortium.
- Managing the project's cashflow

Task 6.6 Scientific coordination – M1-48 UNS-FTN

UNS-FTN is working in tight coordination with the project coordinator PDMFC and all the partners to coordinate research activities at different participating organizations, manage conflict resolution, and perform research misconduct investigation. Research activities are currently evolving according to the plan and are (re)evaluated at each consortium online meeting. There have been no reported conflicts or research misconducts.

Task 6.7 Risk management and Quality assurance – M1-48 UPV

Throughout the project, we have incorporated the necessary action to coordinate the continual assessment and evaluation of potential risks, ensuring that any technological shifts or developments are promptly addressed. To manage these changes, specific work package (WP) leaders explore developments and recommend necessary actions to the Board. Regular project meetings are also convened at key milestones, including project reviews and audits. These meetings are crucial for monitoring the project's progress and adherence to established quality standards.

Moreover, at the commencement of each WP, all project partners thoroughly analyze the project's goals and objectives. This systematic approach helps identify critical requirements and determine the measures needed to meet them effectively. Several internal quality checks are conducted regularly to further support the project's integrity and success. These checks are essential to ensure that all partners fulfil their responsibilities and comply with the project directives, thereby maintaining the high standards required for success.

4.7. WP7 - Ethics Requirements (PDM)

No tasks have been carried out during the first reporting period.

4.8. Deliverables (PDM)

Four Deliverables were planned to be submitted during the first year of the project: D5.1, D6.1, D6.2, and D7.1. Table 6 shows the status of these deliverables: the first three have been submitted, while for the latter (D7.1) the consortium is currently investigating whether the deliverable is required, as the Ethics Work Package (WP7) was not initially contemplated in the Grant Agreement.

Deliverable	Deliverable name	Due date	Status
D5.1	Organisation of project's knowledge sharing, networking and training events and dissemination opportunities	31/12/23	Submitted
D6.1	Dissemination Exploitation and Communication Plan	30/06/23	Submitted
D6.2	Data Management Plan	30/06/23	Submitted

D7.1	OEI – Requirement No. 1	31/01/23	Pending

Table 6. Deliverable status

Despite having submitted some deliverables with a slight delay, the project is now correctly on time with respect to the original deliverable planning.

5. Conclusions

During the first year of the project, there have been some delays with respect to deliverable submission and carrying out the secondment plan. Nevertheless, the majority of these issues have already been addressed, and currently the deliverable submission is on par with what originally proposed in the GA. Regarding the secondment plan, it was expected that there would be a lower number of secondments during the first year of the project, which is growing at the beginning of the second year of the project. This should be adequately overseen during the next months to ensure that enough secondments are scheduled during the second year of the project to prevent creating delays that cannot be overcome in the future.