D7.17 Annual Report on Collaboration - Year 4

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Abstract	This annual report on collaboration activities performed under the umbrella of the OFERA project and in relation to the micro-ROS platform.

Abbreviations

Term	Definition
DDS	Data Distribution Service
DDS XRCE	DDS for extremely resource-constrained environments
IMU	inertial measurement unit
MCU	microcontroller
rcl	ROS 2 client support library
rmw	ROS 2 middleware interface
ROS	Robot Operating System
RTOS	real-time operating system

1 Introduction

This document reports on additional collaboration activities which are linked to the 1-year extension of the OFERA project. In the same line of previous reports, the collaboration activities in OFERA have created and strengthened the synergies between micro-ROS and the communities behind ROS, FIWARE and related EU funded Projects (e.g., DIH^2 or ALMA). Besides these traditional collaboration lines, it is important to mention that the maturity of the micro-ROS technology as well as of the internal relationships within the micro-ROS community itself have led to a series of collaborations which are not strictly linked to the aforementioned lines. A dedicated Section in this document elaborates on them.

Regarding ROS, the close relationship between micro-ROS and the ROS community is continuously growing and most of the collaboration activities are coordinated under the umbrella of official ROS initiatives. Two partners from the OFERA consortium, Bosch and eProsima, are active part of the ROS Technical Steering Committee which gives great visibility to OFERA results and is key to the interests of micro-ROS beyond the project life. On its turn, the official ROS Embedded Working Group (WG) is one of the more dynamic and effective collaboration mechanisms, the activities of this WG started in 2018 with the formation of an Embedded Special Interest Group (SIG) during the ROSCon event and nowadays the community behind this WG participates in regular meetings and actively collaborates in a number of joint initiatives. A partner from OFERA, eProsima, plays the coordination role of this WG since its creation time and Bosch is also one of its main caretakers. In addition, the active participation of Bosch in the ROS 2 Real-Time WG increases even more the number of opportunities for collaboration and the visibility of OFERA results within the ROS community. Some bilateral cooperations with organizations like Robotis and RENESAS already exist and new promising ones are emerging from the intensive OFERA activities carried out in this reporting period.

On the side of FIWARE, the progress of the DDS related Generic Enablers (GEs) continues according to the objectives set by the FIWARE's Robotics Roadmap. Mature components like Fast DDS and Micro XRCE-DDS were already part of the FIWARE GE Catalogue incubated FIWARE GE and, in 2021, two results from the OFERA project the SOSS-FIWARE and the entire micro-ROS framework itself have increased the list of FIWARE enablers which gravitate around the DDS and ROS2 standards. This means that all the aforementioned components regularly report on their current status, achievements, and technical roadmap at the level of the FIWARE Technical Steering Committee (TSC). Since the overall technical direction of the FIWARE Open Source Community is driven there, new opportunities for collaboration are always emerging. Last but not least, since micro-ROS is one of the pillars within the framework of FIWARE Technical Roadmap activities in robotics, which accounts for a specific working group with monthly meetings. The OFERA members, FIWARE and eProsima, work in continuous collaboration with members from other organizations like Atos, Fraunhofer, NEC, Engineering, and the Japanese TIS Inc.

In regard to collaboration activities with EU projects, the ones to be highlighted in this reporting period are mostly connected to the DIH^2 and ALMA projects. In DIH^2, the results from OFERA are enabling the creation of a reference open platform for SMEs which aim to implement agile production concepts through the use of advanced robotics solutions. In ALMA, the outputs from OFERA are playing a major role in the materialization of a novel technology framework which integrates Algebraic machine learning, a relatively new machine learning technique based on algebraic representations of data.

2 Collaboration with the ROS Community

The ROS ecosystem undoubtedly defines the most strategic axis for establishing collaborations around the micro-ROS framework. Since the beginning of the project, the OFERA consortium has worked very hard for micro-ROS to find its place in this ecosystem. Today, different lines of collaboration can be considered established and opportunities to create new ones emerge every month. The following subsections summarize the main collaboration activities around the ROS ecosystem during 2021.

2.1 Contributions to ROS 2 Core Packages

eProsima contributes to rclc and the rclc package is feature-complete now (compared with the C++ client library rclcpp) and rclc is actively maintained by OFERA members from eProsima and Bosch.

After open-source contributions regarding execution management for the ROS 2 Foxy release in June 2020, OFERA members from Bosch also contributed to the ROS 2 Galactic release in May 2021: The release included the Callback-group-level Executor from the first year of OFERA, which can be described as a refinement of the Executor API in the C++ client library rclcpp. To demonstrate the use of the refined API, Bosch also open-sourced a corresponding demo for the ROS 2 Examples repository[1] and created a general documentation page on execution management for docs.ros.org.[2]

OFERA members from Bosch have also developed the ROS 2 diagnostics package further. The micro-ROS diagnostics has been integrated with standard ROS 2 diagnostics by a bridge so that micro-ROS diagnostics information from microcontrollers can be processed on larger processors and developer machines using standard mechanisms and tools.

2.2 Interaction with ROS Developers

The vibrant community of developers that is behind ROS is one of the main pillars of this open source framework for robotics developments. Thus, a good interaction between the OFERA consortium and the community of ROS developers plays a vital role in the success of micro-ROS as well as in its sustainability after the project. The OFERA consortium interacts directly with ROS developers in different ways:

A. OFERA members are active in existing ROS developers oriented communication channels including ROS Discourse and ROS Answers in particular.
B. OFERA consortium members are also active contributors to ROS GitHub repositories. This collaboration is done via pull request and issues in which discussions and design are open to the community, including OFERA members.
C. Aside from the previous “official” ROS channels, OFERA has launched a micro-ROS dedicated Slack workspace: https://micro-ros.slack.com/.
D. A fourth way of interaction with the community of ROS developers is the participance of Consortium members in community oriented events like: ROSCon, ROS-Industrial Conferences and Workshops… more detail can be found in D7.16 Annual Report on Communication and Dissemination - Year 4.

[1] The source code of this package *examples_rclcpp_cbg_executor* can be found at https://github.com/ros2/examples/tree/master/rclcpp/executors/cbg_executor.
[2] See https://docs.ros.org/en/galactic/Concepts/About-Executors.html.

2.3 ROS 2 Technical Steering Committee

The ROS 2 Technical Steering Committee (TSC), initiated by the Open Source Robotics Foundation (OSRF) in September 2018, is in charge of broadening the participation to accelerate ROS 2 delivery. It defines the ROS 2 development roadmap and its members contribute to the development of ROS 2 core libraries and tools. The OFERA consortium accounts for two members of the ROS 2 TSC Bosch (one of the ROS 2 TSC founders) and eProsima. Other TSC members are Amazon, Apex.AI, Canonical, Intel, LG Electronics, Microsoft, ROBOTIS, Samsung, GVSC, Tier IV, the Toyota Research Institute and Wind River. The exhaustive list of ROS 2 TSC members is provided at https://index.ros.org/doc/ros2/Governance/.

The TSC membership of Bosch and eProsima allows to align the micro-ROS developments well with the roadmap for each ROS 2 release. In addition, it is a great opportunity to stay at the forefront in technical discussions about the ROS 2 core layers. Besides, since the ROS 2 TSC aims at conducting its technical discussions as publicly as possible, it makes it possible to establish Working Groups (WG) as collaborative spaces in which specific topics can be discussed in greater detail. The list of ROS 2 WGs is also provided at https://index.ros.org/doc/ros2/Governance/, just below the list of TSC members. The ROS 2 WGs in which the OFERA consortium is involved are mainly two: i) the Embedded Systems WG which is leaded by eProsima and accounts for the regular participation of the OFERA consortium and ii) the Real-time WG and the Middleware WG in which Bosch is an active participant.

2.4 ROS 2 Embedded Working Group

In July 2020, the OFERA consortium decided to retake the effort to organize a ROS Working Group dedicated to the embedded world with 4-week periodicity. Starting on July the 22th, Embedded Working Group (EWG) meetings have been organized and held every four Tuesdays at 5 pm CET, with the exceptions of holidays (e.g, the August/December meeting were skipped due to the fact that most of the organizers and many participants were unavailable due to vacations). During 2021 the persons in charge of the organization have been members of eProsima, with strong support from the Bosch partner and PIAP, offering regular short presentations focused on their role in the OFERA project.

The iter followed for each meeting has been the following. About one week early, the agenda is prepared and released, together with a post on the ROS discourse as part of a dedicated thread. At the same time, a public announcement is made on the micro-ROS Slack channel and a mail to a list of interested members of the community is sent. The 60 minutes agenda consisted of three differentiated sections:

- A space of ~ 30-40 minutes was dedicated to presentations given by external participants from industrial companies or members of the ROS Community that are using micro-ROS in their use case, including professional close-to-market prototypes.
- Discussion about new features, recent developments and technical advancements of the project that happened during the 4 weeks preceding the meeting.
- Finally, a Miscellaneous section is dedicated to opening the debate to the community and/or discussing less technical aspects of the project (e.g., advertise conferences or demos) or, finally, to comment on some open issue or Pull Request on GitHub.

Monthly meetings in 2021 happened on Google Meet and the number of participants oscillated between 17 and 23. This is quite a good result for this kind of meetings, especially if compared with the rest of ROS working groups. There have been 11 EWG meetings[3].

[3] The latest 6 are available at ROS discourse: https://discourse.ros.org/t/ros-2-embedded-wg-meetings/15460 .

2.5 ROS 2 Real-time Working Group and Middleware Working Group

The Real-time Working Group was founded in May 2019 and the Middleware Working Group one year later in June 2020. Members of the OFERA project (in particular from Bosch) are participating actively in both working groups since their beginnings. In general, there is a large overlap in the participants of the two working groups, which is a consequence of the fact that execution management and communication are closely connected. In the current design of the ROS 2 stack - and the micro-ROS stack - the decision on the processing order of messages and other events is distributed to the middleware layer and the client library, as explained in a comprehensive talk by Ralph Lange (Bosch) at the ROS-Industrial Conference in December 2020.[4]

A focus of the Real-time Working Group is to improve this design to better meet the requirements for processing with bounded latencies and determinism. An important contribution from OFERA members from Bosch was the Callback-level-group Executor, which was released with ROS 2 Galactic in May 2021, as explained in Section 2.1.

OFERA members from Bosch were also involved in the organization of the workshop "ROS 2 Executor: How to make it efficient, real-time and deterministic?" at ROS World in October 2021. Jan Staschulat (Bosch) dedicated a separate talk to the micro-ROS rclc executor.[5] In preparation of the workshop, members of the Real-Time Working Group created an elaborate reference system[6] to compare the different concepts and mechanisms for execution management. Both, the Callback-group-level Executor and the micro-ROS rclc Executor, have been integrated with this system.

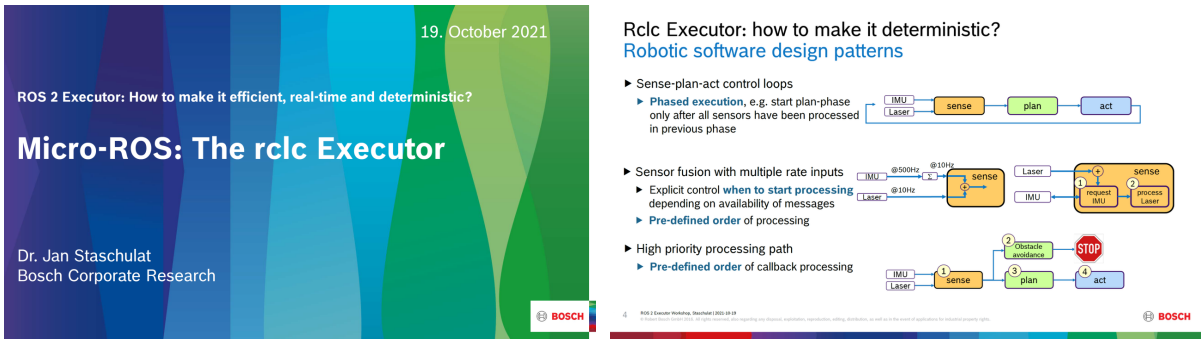

Figure 2.5.1: Two slides from the talk on the rclc Executor at the workshop on execution management at ROS World 2021.

[4] See: *Ralph Lange: "Advanced Execution Management with ROS 2." in ROS Industrial Conference. Virtual event. December 2020.* https://youtu.be/Sz-nllmtcc8?t=109.

[5] The workshop webpage can be found at https://www.apex.ai/roscon-21. A video recording of the talk by Jan Staschulat (Bosch) on the micro-ROS rclc Executor is available at https://youtu.be/lazrPF3RN1U.

[6] The source code of the reference system can be found at https://github.com/ros-realtime/reference-system.

3 Collaboration with the FIWARE Community

FIWARE brings a curated framework of open source software platform components (referred to as FIWARE Generic Enablers - GEs) which can be assembled together as well as with other third-party components to build platforms that support the development of Smart Solutions faster, easier and cheaper. More technical descriptions of FIWARE can be found on the FIWARE website or GitHub.

The FIWARE NGSI API provides a simple yet powerful API for solving a basic need in any smart solution: how to gather, manage and provide access to context information. There is a core Context Broker component in every "Powered by FIWARE" platform which supports this API and enables the integration of the rest of platform components. The key contribution of the harmonised FIWARE NGSI API and the central Context Broker is the provision of a basis for interoperability of smart solutions/services that run on top of "Powered by FIWARE" platforms which significantly eases their portability and replicability.

A rich suite of complementary FIWARE components can be combined with the FIWARE Context Broker in a modular architecture and integrated as part of a "Powered by FIWARE" platform. These components are referred to as FIWARE Generic Enablers (GEs). The complete set of FIWARE GEs are structured in the following four main chapters:

- *Core Context Management chapter*, comprising the core FIWARE Context Broker component as well as components enabling integration with multiple alternative data sinks for storage and further processing of historic context data
- Chapter comprising FIWARE GEs helping to implement the *interface with IoT devices, robots and third-party systems*, capturing context information updates and translating required actuations;
- Chapter comprising FIWARE GEs for *advanced monitoring, using dashboard and analytical support tools, as well as processing and analyzing current and historic context data* using event rules, advanced Big Data and AI algorithms, targeted to support smart decisions or the smart automation of processes;
- Chapter comprising FIWARE GEs dealing with *management, publication and monetization of context data and services*, preserving defined access and usage control policies.

OFERA results are being integrated into the chapter of "*Interfaces with IoT devices, robots and third-party systems"*. The component Micro XRCE-DDS was the first of the contributions this project made to the FIWARE Catalogue. The novel contributions to the FIWARE catalogue in 2021 are the SOSS-FIWARE system-handle and the micro-ROS framework as a whole. The aforementioned components along with Fast DDS, an eProsima product that is the default middleware for ROS 2, form the ecosystem of FIWARE Generic Enablers which gravitate around ROS and DDS based robotics systems.

As this stack of components is one of the main pillars of the FIWARE for robotics roadmap, the OFERA partner eProsima plays a major role within the FIWARE community. The role of eProsima goes beyond the maintenance of its enablers; they actively participate in the FIWARE Robotics WG by attending the regular meetings and collaborating in the development of the FIWARE strategic roadmap for robotics. Besides, the collaboration between microROS and FIWARE in regard to the creation of technical webinars for the FIWARE community continues and a new webinar is under preparation and will be presented in the first quarter of 2022 . OFERA members and micro-ROS are also playing major roles in the virtual FIWARE events (FIWARE Smart Fests) which are replacing the FIWARE Summit due to the pandemic.

3.1 Integration of micro-ROS results in FIWARE

The FIWARE chapter associated with robotics developments is the “Interfaces with IoT devices, robots and third-party systems” chapter. In it, the integration between FIWARE NGSI and robotics systems is being materialized in three main axes ROS-, DDS-, and OPC UA-based robotics integration. In particular, the evolution of the FIWARE NGSI integration with ROS 2 and DDS goes hand in hand. And this is mainly due to the extraordinary link that the pioneer FIWARE enabler for DDS, Fast DDS, has established between both worlds.

Fast DDS is the pioneer FIWARE enabler within the FIWARE DDS family and, in 2020, the Micro XRCE-DDS enabler was the first result from OFERA that was contributed to FIWARE catalogue. In 2021, the progress of both enablers has been periodically reported at the FIWARE TSC level and their repository and documentation has been continuously maintained. Besides the TSC, the technical roadmap, proposal for new features and achievements linked to these components have been continuously discussed under the umbrella of the FIWARE Robotics Working Group.

In 2021, The entire micro-ROS framework itself and the SOSS (System of Systems Synthesizer) are the new outputs from OFERA which extend the presence of DDS related components in the FIWARE catalogue. Both contributions are essential to bridge the gap between FIWARE Context Brokers (the core technology of the FIWARE technology framework) and the previous DDS components (Fast DDS and XRCE-DDS). The tracking of progress of these components at the TSC level as well as the analysis of required features for them under the umbrella of the FIWARE Robotics Working Group have been activated in 2021 and will be strengthened and evolved beyond the active OFERA time frame.

3.2 Collaboration Activities in the FIWARE Robotics Working Group

The FIWARE Robotics Working Group has the purpose of understanding the key application scenarios of each member and their ese cases as well as to monitor the status and roadmap established for current technical developments. The current list of members in the FIWARE Robotics Working Group includes the following organizations:

- Atos, Engineering, eProsima, FIWARE Foundation, Fraunhofer IML, NEC and TIS Inc

Among others, the collaboration lines and work streams which are of special relevance to the FIWARE Robotics Working Group are:

- Definition of Smart Data Models for Digital Twin Systems in Smart Robotics Applications
- Definition of a Multi-tier Reference Architecture for Robotics that clearly defines the components that must run in the robot, close to the robot (edge) or in the cloud and what communication requirements may be demanded (e.g., 5G) as well as the different deployments and required interfaces (e.g., robot ← → edge, robot ← → local datacenter, edge ← → cloud…)
- Integration of platform tiers with microcontrollers based on micro-ROS
- Design of a RTPS-DDS binding for NGSI (e.g., mapping of RTPS(DDS) concepts into NGSI-LD)
- Support of RTPS-DDS events as raw data streaming notifications in NGSI-LD Brokers
- 3D representation and visualization of robot digital twins in open source frameworks

3.3 FIWARE Smart Fest 2021

The main caretakers of the FIWARE's Robotics technical roadmap are OFERA members from FIWARE and eProsima. They actively collaborate with the rest of the members in the FIWARE Robotics WG and other members from the FIWARE community to prepare the robotics track in the FIWARE Summit. The most relevant yearly event which brings together the entire FIWARE community for 2-3 days.

Since the pandemic prevented the organization of physical events also in 2021, a movement was made to replace the traditional FIWARE Summit by the FIWARE Smart Fest. The FIWARE Smart Fest is a purely virtual, lighter event, which aims to mitigate the impact of the long period with no chance to organize a FIWARE Summit. The OFERA members prepared an interesting dedicated robotics track for the FIWARE Smart Fest and some of the project collaborators also participated in cross-cutting sessions like the Smart industry one.

Along with other collaborators from the FIWARE community, eProsima presented some of the OFERA results to the rest of the FIWARE community and partners, giving them the opportunity to network and offer an insight into the rich range of smart projects and innovative initiatives by the FIWARE foundation in the virtual hall enabled for the Smart Fest event.

The OFERA talk was entitled "micro-ROS: bringing ROS 2 to microcontrollers". The session included an overview of micro-ROS, the presentation of the Integration Service utility, and some guidelines on how to achieve an integration with the FIWARE platform. It concluded with a demonstration of a use case.

3.4 Preparation of FIWARE Technical Webinar for 2022

Another pillar of the FIWARE Technical Roadmap is the series of FIWARE Wednesday webinars in which specific aspects of the FIWARE technology is presented to the vast community that gravitates around the use of standardized context information in a number of domains. Some of the FIWARE Wednesday webinars belong to a specific series with a clear focus on FIWARE for robotics applications and micro-ROS, one of the most relevant results of the OFERA project, plays a major role in them. Most of the contacts and collaboration opportunities that emerged in the past from these webinar sessions resulted in the creation and/or contribution to some of the work streams identified for the FIWARE Robotics WG.

In 2021, new developments associated with the micro-ROS Joint Use Case contribute to extending the previous work on the integration between micro-ROS and FIWARE ecosystems with some interesting features. In particular, the use of the standard FIWARE IoT Agent node lib as a bridge between micro-ROS and FIWARE Context Brokers is a relevant step which aims to raise the interest of NodeJS and other web developers. The standard FIWARE node lib offers a rich implementation of FIWARE NGSI communication patterns and makes the micro-ROS framework accessible to technical teams which are outside the ROS ecosystem. The same applies in the opposite direction. The joint use case demonstrates how micro-ROS architectures can easily integrate with advanced ICTs for data persistence, time-series analysis and online supervision GUIs. In parallel to the Joint Use Case developments, convenient documentation and training materials for a new micro-ROS webinar emerge. The new webinar is scheduled for the first quarter of 2021 and will show a mature level of integration between micro-ROS and FIWARE that will boost the collaboration opportunities between both communities.

4 Collaboration with other EU-funded Projects in Robotics

4.1 Collaboration with the DIH^2 Project

The participation of OFERA members (FIWARE and eProsima) in the DIH^2 project is creating active synergies between both projects. The purpose of DIH^2 is to establish a large European network of Digital Innovation Hubs (DIHs) with a clear focus on robotics. From the technical point of view, DIH^2 is materializing the concept of an Open Digital Platform for Robotics Based Agile Production and FIWARE has been selected as the underlying technology for this platform. There is a Technology Transfer Program in DIH^2 to implement and validate real proof of concepts for the proposed platform.

The DIH^2 technology transfer program considers 26 experiments in real manufacturing companies. Therefore, 26 consortia including at least one manufacturing SME and one or two tech providers are in charge of developing and validating robotics based solutions for the agility problems they are facing. In this context, eProsima and FIWARE are leading and mentoring these technical developments and giving visibility to some OFERA results like micro XRCE-DDS and micro-ROS as complementary approaches to more traditional default technologies offered for the field level middlewares like OPC UA, DDS or ROS 2. Since the core layer of the DIH^2 platform is based on the FIWARE NGSI standard the selected consortia are exploring the use of micro-ROS technology , making the Technology Transfer Program in DIH^2 a great opportunity to showcase its performance in a real manufacturing environment. Those experiments which include complex robotics stations made up of custom sensor and actuator integrations are particularly interested in the benefits that a combined approach based on ROS 2 and micro-ROS may bring to their technical solution.

4.2 Collaboration with the ALMA Project

The EU-funded project ALMA stands for a new machine learning technique based on the algebraic representation of data, the Algebraic Machine Learning (AML), and aims at developing a new generation of interactive, human-centric machine learning systems.

The participation of OFERA members (FIWARE and eProsima) in the ALMA project is creating active synergies between both projects. eProsima coordinates the ALMA project and is responsible for the middleware architecture of the distributed learning concept and the integration with Robot Operating System (ROS 2) and Fast DDS.

AML systems reduce bias and prevent discrimination, recall prior learnings while learning new content, facilitate trust and reliability and integrate complex ethical constraints into human-artificial intelligence systems. This represents a new paradigm and a totally different approach to AI with interesting properties, including the following top contributions:

- AML algorithms are robust regarding the statistical properties of the data and are parameter-free.
- AML can be implemented in a distributed way, and thus facilitate a new distributed, incremental collaborative learning method by going beyond the dominant off-line and centralized data processing approach.

5 Other Collaboration Activities

5.1 Canonical

Snap is a package manager designed to bundle and handle applications and their dependencies on several Linux distros, like Ubuntu. In 2020, the XRCE-DDS Agent was wrapped and delivered as a snap package tool. In 2021, the same process was followed for the micro-ROS Agent and it is already available as a snap package too.

The preparation of the Agent snap release was carried out in collaboration with Canonical and it comes with two ways of running it: as a simple executable or by means of a Linux service. More details on this package and a full list of its configurable parameters can be found here.

5.2 Renesas

A collaboration between Renesas and the OFERA member eProsima is focused on lowering barriers for the adoption of robotics in the industrial and IoT sectors. The proposal of the Renesas RA6M5 based micro-ROS project is a disruptive solution which covers the full development cycle of embedded applications in ROS 2. The project aims to have a strong impact on the reduction of time-to-market for robotics solutions in many different sectors.

The Renesas RA6M5 based micro-ROS project offers HIL (hardware in the loop) testing CD/CI and integration with the e² studio, an Eclipse-based integrated development environment (IDE) that enables developers a professional embedded software environment. The objective of this HW & SW combo project is to provide a comprehensive tool that covers the full cycle of SW development in embedded systems that target a wide range of applications: Service robots for Logistic & Warehouse, Defense & Security, Agriculture and Healthcare.

More details on the achievements which come from the joint collaboration between Renesas Electronics Corporation (TSE:6723), a premier supplier of advanced semiconductor solutions and eProsima, the middleware expert SME, can be found here [Link] .

Training materials on how to integrate micro-ROS with RA Family in high-level systems as well as convenient links to the source code repositories can be found here.

5.3 PX4 Ecosystem

The collaboration between micro-ROS and the PX4 Ecosystem was already active in previous reporting periods. The PX4 Developer Summit is one of the key milestones where the achievements of the collaboration between OFERA and PX4 ecosystems are presented. This event, hosted by te Dronecode Foundation for the PX4 Autopilot drone development community, is a 2-day international event in which professionals from all over the world exchange technological insights of the drone sector. In 2020, the results were presented in a webinar entitled “Bringing micro-ROS to PX4-based flying systems”[7].

In 2021, the new results of collaborative projects between OFERA and PX4 ecosystems were presented by the eProsima Embedded Software Engineer Pablo Garrido, and Nuno Marques, Software Engineer, Systems Integrator and founder of dronesolutions.io, in the talk “ROS2 and PX4: Technical Details of a Seamless Transition to XRCE-DDS and Micro-ROS”. The talk elaborated on two main topics: i) the basic concepts and achievements around the micro-RTPS bridge which integrates PX4 into the DDS world and ii) the developed proposal for using Micro XRCE-DDS and micro-ROS and the core concepts and technical details behind this migration. Check the full video [here].

5.4 Software for Embedded Systems Research Group, RWTH Aachen University

Thanks to the layer to layer compatibility of micro-ROS with the ROS 2 architecture, testing new middlewares is just a matter of writing a new RMW implementation and, due to the embedded nature of micro-ROS, some light porting adjustments. This interesting synergy between micro-ROS and ROS 2 led in 2021 to a new collaboration activity, this time linked to the Software for Embedded Systems Research Group, RWTH Aachen University.

The contribution of this collaboration allows micro-ROS to be compiled either with Micro XRCE-DDS for low-mid MCUs or with embeddedRTPS for larger devices that are used in critical applications. This way, the developer can easily choose the preferred middleware for any application. Alexandru Kampmann (research profile), who works for the RWTH Aachen University is the main contributor of embeddedRTPS. On the OFERA side, members from eProsima are working to provide equivalent features to the official ROS 2 embedded solution. A basic rmw_embeddedrtps for micro-ROS has been created and although it is not complete, allows the basic functionality of publishing, subscribing and using ROS 2 services. All of this using the well-known micro-ROS C99 API: rclc.

Further details on how Middleware implementations such as embeddedRTPS, bring the possibility of using RTPS communication layers on mid to high range MCU with networking capabilities can be found in this video. Detailed discussions on embeddedRTPS related aspects are available in this thread from the ROS Discourse site.

[7] The talk was given by Jaime Martin (eProsima) and Nuno Marques (Drone Solutions) and is available here: https://youtu.be/8JCH_Yg8eX4 .

5.5 EuRobotics

The collaboration between OFERA and EuRobotics ecosystems is also quite active. In 2021, the members from OFERA organized within the context of the European Robotics Forum 2021 a dedicated workshop in which micro-ROS and the results of its relevant collaborations with other community members played a major role. Members from WYCA Robotics and Hydra System contributed and presented at this workshop and a very lively discussion with the EuRobotics Community took place after a panel session that accounted for Pablo Garrido Sanchez (eProsima), Alexandre Malki (PIAP), Jan Staschulat (Bosch), Anaëlle Sarazin (WYCA Robotics) and Tomasz Rokosz (Hydra System) as panelists.

Main topics of the workshop were:

- The micro-ROS architecture, supported platforms, demonstrators and new features like the versatile API for custom transports, continuous fragment mode, static memory pools in the RMW and time synchronization between client and agent
- Overview of the RCLC API with a code example and highlighted the deterministic behavior of the RCLC Executor
- Two micro-ROS industrial use-cases: “Elodie and micro-ROS” (Anaëlle Sarazin, WYCA Robotics) and “micro-ROS enabled GNSS receiver” (Tomasz Rokosz, Hydra System)

The outputs of the associated collaboration activities are captured in the presentations of the workshop, which are available at the micro-ROS Website (https://micro.ros.org/blog/2021/04/13/ERF2021/).

5.6 micro-ROS Website

The micro-ROS documentation and especially the sections in micro-ros.github.io dedicated to concepts and tutorials and demos are spaces of continuous collaboration for the OFERA ecosystem and the entire micro-ROS community. The consortium understands that these sections are essential to maintain micro-ROS attractive to new users and create further collaboration opportunities.

6 Conclusion

This document reports on collaboration activities performed during 2021 under the umbrella of the OFERA project in relation to the micro-ROS platform. Some of these activities are associated with the reinforcement of existing collaboration frameworks while others are totally new and have resulted from the good evolution of micro-ROS in this particular reporting period. The activities reported have been organized in 4 axes:

- Collaboration activities between micro-ROS and the ROS ecosystem
- Collaboration activities between micro-ROS and the FIWARE ecosystem
- Collaboration activities between micro-ROS and EU-funded Projects (DIH^2 and ALMA)
- Other Collaboration Activities (i.e.,PX4, Renesas, Aachen University, Canonical and EuRobotics)

As the OFERA project comes to an end, the OFERA members will do its best to establish new lines of collaboration and to further strengthen those that are active as part of the exploitation activities planned beyond the context of OFERA. The micro-ROS ecosystem will be the new umbrella for the continuation of these activities.