D7.19
Exploitation Plan - Year 4

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Abstract	SWOT and business analysis for right positioning of micro-ROS. Individual exploitation plans.

Disclaimer

As of today, 21 December 2021, the Covid-19 pandemic has been heavily affecting business and private life not only in Europe but in the rest of the continents and had implications on the Ofera project. We are working and taking decisions in a way that should minimise the effects on the project organization and its achievements. However, the current situation prevented the complete fulfilment of some of the activities scheduled and described in the D7.2 and may prevent the ones planned for year 2021: the regularly required mobility of project staff is currently limited as per decision of the public authorities and companies alike, so to prevent the physical participation of individuals in meetings and events organised by beneficiaries in the context of the Ofera project.

The Ofera project coordinator, in agreement with all project beneficiaries and Project Officer, is taking appropriate decisions for the general health and wellbeing of all partners' staff involved in the project. Whether or not the events which were scheduled and will be scheduled for the next months will go forward, will need to be confirmed based on how the situation around COVID-19 evolves at national and international level. So, we kindly ask the reader to check the project and travel updates regularly on project related websites before taking any decision based on the plan described in this deliverable.

Changes compared with the last annual report

Change	Section	Short description
ALR	3.3 Strategic Approach to Materialize the Vision	ALR sections have been revisited and updated accordingly with ALR not participating in the project anymore
Mico XRCE-DDS	3.3.1 DDS-XRCE & Micro XRCE-DDS	Updated DDS-XRCE & Micro XRCE-DDS information
Client library	3.3.2 ROS 2 Embedded Client Library and Building Blocks	Update client library components
Brand	3.3.4 micro-ROS brand	Update brand status
Competition and SWOT	3.4 Competition and SWOT analysis	Update competition and SWOT
Dissemination and communication	3.6 Revision of Actions and Priorities regarding Communication and dissemination Activities	Updated dissemination and communication actions
Individual exploitation plans	4 Individual Exploitation Plans	Revised individual exploitation plans

Abbreviations

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

1 Introduction

1.1 Executive summary

In this document, we discuss the exploitation plan for the micro-ROS project, especially linking it with the activities undertaken by all the members of the OFERA consortium during 2021 and with the decisions that have been made regarding the strategic approach to exploitation.

The exploitation of the outcomes from OFERA project has been updated and completed from the original version presented in D7.12 Exploitation Plan - Year 3.

The general exploitation plan has not suffered major changes or deviations, keeping the same vision of enabling European companies to rapidly deliver robotics products integrating highly resource-constrained devices (microcontrollers).

During this last year, micro-ROS has evolved towards a more complex environment which allows users to choose their preferred platforms, both on the hardware and on the software side. This implies an important change with respect to the original strategy, which envisioned a reference platform (Olimex board with NuttX RTOS), and materializes in the build system `micro_ros_setup`, which provides a set of out-of-the-box cross-compilation tools to allow users to select their preferred environment to deploy their embedded micro-ROS application.

Based on this, the suite of supported ROSes has expanded to include new RTOSes. During the Y4 extension, micro-ROS Galactic and Rolling was updated to offer new and standalone support for NuttX's latest versions, namely 10.0 and 10.1 and for Azure ThreadX RTOS.

At the same time, micro-ROS has been ported to new boards. Some of these ports have been carried out by members of the OFERA consortium and are officially supported by the project, at least until its natural deadline (December 2021, given the extension by one year that was granted), such as Arduino Portenta H7 or Raspberry Pi Pico RP2040, ROBOTIS OpenCR 1.0, Teensy 3.2, 4.0, 4.1 or Crazyflie 2.1 Drone. Professional support is being offered to Renesas EK6M5.

Others have been carried out instead by members of the community, which have started to actively contribute to the project in the second half of 2020, such as the Holybro Kakute F7 All-In-One 18 used in UAVs flight control management.

In addition, effort has been devoted to generating micro-ROS as a standalone library with header files, enabling it to be incorporated into external build systems. This approach has resulted successful by allowing the implementation of a micro-ROS component for the ESP-IDF, for the Zephyr build system and for the Arduino development framework. Support for the latter is the first experiment of bare-metal support for micro-ROS, since Arduino is a library for programming and not an RTOS. This micro-ROS library based on Arduino IDE or Arduino CLI is therefore the first step towards a true bare-metal support of micro-ROS, something which was not envisioned at the dawn of the project.

At this moment, the repositories hosting these modules to integrate micro-ROS into external build development environments are in the micro-ROS GitHub. However, the goal is to include them as official packages of the relevant build systems. This would be especially significant in terms of exploitation of the project, as the incorporation of micro-ROS libraries into platforms maintained by third-parties would ensure a long life to the project.

At the level of the users' API, significant additions have been made to the RCLC, to the RMW and to the Agent. At the RCLC level, several concepts available in the higher ROS 2 APIs such as executors and system modes, have been adapted to better fit the real-time and deterministic requirements of embedded applications. Also, publishers, subscriptions and services at the RCL level have been wrapped into RCLC functions. At the RMW and Agent level, the most significant functionality implemented has been that of the Graph manager.

Another significant strategy change during this year has been the effort devoted to dissemination and reachout activities. Indeed, the members of the consortium have devoted an overall significant amount of time to presenting micro-ROS to virtual workshops, conferences, working groups and so on. At the same time, we have increased our visibility in the relevant social media, especially the ROS Discourse, with the goal of making the community more and more aware of our activity. Together with this, several demos involving micro-ROS have been carried out and have been widely presented at several important appointments with the community.

Finally, the Embedded Working Groups, which has been dropped during the second year of life of the project due to the insufficient maturity of the project and lack of involvement of the community, have been retaken starting from July 2020. This second round of meetings has been extremely beneficial in terms of gathering the community around the project, and also to gain more attention, visibility and valuable contributions.

1.2 Purpose of Document

In this new version of the exploitation plan, we revisited the previous exploitation plan updating the main targets with the latest project and Consortium changes. This document's starting point is the previous document: D7.12 Exploitation Plan – Year 3.

In this document, we will detail the changes from this previous document and complete it with new content. The general exploitation plan for micro-ROS should provide details about how the project results will be positioned in the market. Such details will be discussed through: a) project's vision, b) strategic approach to materialize the vision, c) target customers, d) competition and SWOT analysis, e) unique selling propositions (USPs) and f) relationship to Communication, Dissemination, Collaboration and Standardization plans.

1.3 Partners Involved

Short Name	Full Name	Contribution
Bosch	Robert Bosch GmbH	Co-writing
eProsima	Proyectos y Sistemas de Mantenimiento S.L.	Leading author
Łukasiewicz-PIAP	Łukasiewicz Research Network - Industrial Institute for Automation and Measurements	Support
FIWARE	FIWARE Foundation	Support

2 General Exploitation Plan

2.1 Project's Mission and Vision

Robots today are networks of mixed devices which include general-purpose microprocessors and microcontrollers. Often, these networks are summarized as the interconnection of all networks into a (robot) global one, the robot network. Most often, microcontrollers within the robot network are used within sensors or actuators, coupled with additional electronics to interface appropriately.

micro-ROS vision is to enable European companies to rapidly deliver robotic products integrating highly resource-constrained devices (microcontrollers). micro -ROS aims to bridge the technological gap between the established robotic software platform for high-performance computational devices and the low-level libraries for microcontrollers. To do so, the project's mission is to bring microcontrollers as first-class participants of the Robot Operating System (ROS) 2 robot ecosystem, the de facto standard for robot application development.

2.2 Target Customers and Stakeholders

Target customers include:

- robot hardware/component vendors
- robot OEMs
- general hardware vendors
- microcontroller OEMs
- embedded engineers
- researchers

We have been receiving a steadily increasing interest by users in micro-ROS. Several external companies have contacted us, especially during the second half of 2021, in order to include micro-ROS in high TRL products to be commercialized in early 2022. First customers of micro-ROS appeared also in the second half of 2021 with marketing and commercializing purposes. And we foresee having micro-ROS involved in more close to market and already commercialized products in 2022 through commercial agreements with companies mainly from Europe and the United States..

Also, see the dissemination report for stakeholder-targeted dissemination activities.

2.3 Strategic Approach to Materialize the Vision

To materialize a reality where microprocessors and microcontrollers could be mixed together seamlessly in any robotic system, the project aims to expand the ROS 2 robot ecosystem to such devices, preferably through modifying ROS 2, where possible, but also through supplying complementary pieces where the current ROS 2 approach is unsuitable or non-existent. This strategy reduces the sustainability burden and eases adoption.

In addition, the growth of the resulting, larger ecosystem is supported through standardization and community building efforts. Through these efforts, in particular, the project also achieves enhanced visibility and influence of European actors in the world-wide ROS 2 community.

Specifically, the project's key results, as currently known (i.e. existing or planned), contribute to this as follows:

Key result	Type	Contribution
DDS-XRCE	OMG Standard	Ensures vendor-independent interoperability for deeply embedded devices.
Micro XRCE-DDS	Open Source	The reference implementation for DDS-XRCE, available for use and enhancement by the community. Also already provides message-level compatibility with ROS 2.
ROS 2 Embedded Client Library	Open Source	Optimal performance for embedded devices in the ROS 2 eco-system through a small runtime, and specialized scheduling support.
ROS 2 Embedded Building Blocks	Open Source	Useful building blocks for embedded applications, e.g., build-system, traceability.
micro-ROS	Brand	A unifying brand name for ROS 2 efforts targeted at deeply embedded devices
micro-ROS build system	Tool	Set of cross-compilation tools for porting micro-ROS applications across different platforms

All of the corresponding activities are based upon the following core principles:

- Commercial exploitation - with a particular focus on Europe
- Alignment with ongoing initiatives
- International community acceptance

In the following, we will discuss each one of the key results.

2.3.1 DDS-XRCE & Micro XRCE-DDS

This result of the project has been upgraded multiple times with new releases during the project and has meanwhile been adopted by several organizations, such as Robotis, Auterion, Renesas, Capra Robotics, SidewaysVehicles, Capgemini Engineering and many others, based on a clear unique selling point: Easy integration with the existing ROS 2 ecosystem through the agent.

This is an example of a mutually beneficial cycle: The project drives awareness of the DDS-XRCE standard, and the Micro XRCE-DDS implementation drives demand for, and adoption of additional layers of the stack. In this sense, Micro XRCE-DDS has benefitted from feedback from micro-ROS users and DDS-XRCE has incorporated the standard new mechanisms required in micro-ROS.

To further increase ease-of-use, integration with the standard ROS 2 middleware interface, rmw, has also been provided. This rmw implementation is an undergoing project being aligned with the latest ROS 2 versions, both on the Agent side and in the API level.

2.3.1.1 DDS-XRCE Barriers and Risks

Micro XRCE-DDS target applications are low range Microcontroller Units (MCUs) with highly constrained memory resources, so that it becomes critical to assess the XRCE-DDS Client memory consumption with extreme precision to help users selecting the adequate platforms to develop their applications.

Because of this, we investigated the memory footprint of the Micro XRCE-DDS Client and Agent libraries, by delivering a thorough and comprehensive report that we published on our webpage.

Apart from that, real-world experience with performance of the DDS-XRCE protocol is currently limited. Initial indications are promising but challenging use cases will need more evidence. Again, this is being collected as part of the project already.

2.3.1.2 Input from users

The project already includes users (Bosch, Łukasiewicz-PIAP), the big community of micro-ROS and existing customers are providing feedback directly to partner eProsima.

2.3.1.3 Roles of the partners

Partner eProsima is leading standardization, development and productization, partners Bosch is exploring use cases in their products, and partner Łukasiewicz-PIAP is exploring a research use case as well as performing benchmarking.

2.3.2 ROS 2 Embedded Client Library and Building Blocks

The client library represents the main entry-point for developers using ROS 2.

Modifying the existing client libraries, particularly for reduced resource usage, will greatly improve performance and enhance the user experience of newcomers to embedded devices.

Supplying embedded-specific building blocks, such as specialized executors with domain-specific scheduling APIs, improved system composition concepts and an embedded TF are all crucial to realize the potential of micro-controllers. Therefore, both uses within their own products, as well as the development of supporting products are natural exploitation pathways.

To control this development, the consortium has initiated a ROS 2 Embedded Special Interest Group, which has been nominated an official working group by the ROS 2 Technical Steering Committee (TSC) in early 2019. Furthermore, four members of the consortium are participating actively in the new Real-Time Working Group established in April 2019.

2.3.2.1 Barriers and Risks

With regard to the client libraries itself, the most important barrier is cultural: rcl, rmw and rclcpp are not written in the way of most embedded libraries. On the other hand, newcomers to embedded devices expect something Linux-like. Striking a balance between these two worlds could be characterized as the basic problem of the overall project, and a great deal of analysis and planning has been carried out in the first year to understand the situation fully.

The project has now committed to modifying the existing client libraries, rather than coding it from scratch. While this carries the risks of not being able to address the smallest use cases, it greatly increases the chances of keeping, and growing, the existing community and thus preventing the risk of a fork.

A second barrier is the use of the C++ standard library in the primary client library, rclcpp. The C++ standard library is not available on all platforms and only limited testing on its resource use could be carried out, yet, so there is also the risk of increased resource use. This will be addressed using more benchmarking and the exploration of greater modularization, to selectively use only what's necessary.

Last, but not least, there is also the risk of organizations "just" integrating Micro XRCE-DDS in their existing client code, and foregoing the full ROS2 implementation. We consider this risk minor – firstly, it would still represent a use of a key project result, and secondly, over time, we expect that as people come to realize that many of the features they require are already provided by ROS 2, they would migrate.

2.3.2.2 Input from users

As the consortium includes several users already, concrete feedback is always present.

Moreover, the project consortium has engaged the community in the ROS 2 Embedded Working Group (EWG), where it will carry out regular interactions, as outlined in the dissemination and collaboration reports.

2.3.2.3 Roles of the partners

Partner eProsima has performed the porting of the basic client libraries, on the information model, the drivers and the RTOS abstractions, partner Bosch is assisting with the basic libraries and working on the embedded building blocks. Partner PIAP provides benchmarking, crucial both for improvement and for promotion. Partner eProsima currently organizes the ROS 2 Embedded Working Group and the related dissemination activity, while partner Bosch offers support.

2.3.4 micro-ROS brand

At the time of writing, the European project OFERA is celebrating its third year of life. By now, the name "micro-ROS" is already firmly established as the brand standing for a deeply embedded version of ROS 2. A first step in this direction has been to distinguish "micro-ROS" from the name of the European project, to clearly mark it as something which is supposed to live on after the project. Such a vision of future sustainability is important to increase trust. As a result, "micro-ROS" has already become widely known thanks to the consortium's dissemination efforts, which concentrated specifically in this last year, with participation in several international workshop and conferences, the revitalization of the Embedded Working Group, and a steady activity on the media relevant to the ROS community such as the ROS discourse platform, and our endeavor for keeping with the spirit -- and the code -- of the ROS community. The success of this strategy is backed up by the achievement of a direct and widespread involvement of both the ROS 2 and the wider community, which has shown interest and active participation during this year.

This has given the opportunity to establish this name as a conduit for the interested embedded community as a whole, thus increasing Europe's influence on the overall ROS 2 eco-system.

2.3.4.1 Barriers and Risks

The most relevant risk as to these days is connected to the fragility of the community revolving around "micro-ROS", and its long-term survival after the project will end in December 2021. However, the efforts of the consortium during this year has provided a stronger sense of community and shared responsibility so as to ensure a fair distribution of the support that the project needs. Moreover, eProsima has an existing micro-ROS installed base already since June 2021.

2.3.4.2 Inputs from users

Input from parts of the target audience has already been sought and is continued to be sought within the ROS 2 Embedded WG. Bosch is also pursuing this internally, to gather inputs from its core embedded development business units. Similar input can likely be provided by all partners.

Each of the partners is using the "micro-ROS" name in its dissemination activities related to the project, and all of them have publicized its activities heavily, as outlined in the dissemination report. On behalf of the whole consortium, eProsima, with the support of Bosch, is currently in charge of organizing the EWG meetings.

Given the achievement of commercial agreements during 2021, “micro-ROS” name has presence in industrial communications and in external companies websites.

2.4 Competition and SWOT analysis

Opposed to micro-ROS, several contenders aim to become the reference approach for microcontrollers in robotics. The most relevant are:

- **rosserial**: rosserial is a protocol for wrapping standard ROS serialized messages and multiplexing multiple topics and services over a character device such as a serial port or network socket. It's available at http://wiki.ros.org/rosserial. rosserial is focused in ROS 1 and has been an interesting and useful source of inspiration for the OFERA project.
- **mROS**: Presented as a light-weighted runtime environment for ROS nodes onto embedded micro-controller. This work seems to be still in its early stages and the code is available at https://github.com/tlk-emb/mROS/.

Generally, we can differentiate between three major embedded device classes, with characteristics as described in the following table. Naturally, some devices are in-between these, but they are much more rare.

	SBC	**Regular MCU**	**Tiny MCU**
Example	Raspberry Pi	STM32F4	Arduino

Hardware	X86, ARM Cortex-A	>= ARM Cortex-M4		<= ARM Cortex-M0
Resources	>256MB RAM, >1G Storage	>100kB RAM, >1MB Storage		~16 kB RAM, ~256K Storage
Communications	Ethernet, 802.11 WiFi	Serial, WPAN, Ethernet		Serial, WPAN
Operating System	Linux, QNX, etc.	RTOS (e.g., NuttX, FreeRTOS)		-
Middleware	DDS variant	XRCE-DDS		Custom
Framework	ROS 2	**Micro-ROS**	**Custom**	Custom
MW Abstraction	RMW	RMW	-	-
Client Library	RCLCPP	RCL, RCLC	-	-
Execution Layer	RCLCPP/RCLPY/...	RCL + RCLC	-	-
Executors	Standard	Static, LET	-	-

Micro-ROS is intended for the “Regular MCU” case, whereas the classic “rosserial” approach from ROS 1 is intended primarily for the “Tiny MCU” case.

Regarding Micro-ROS, we are currently seeing two cases of adoption: In the first approach, the full Micro-ROS stack is adopted. In the second approach, only the XRCE-DDS middleware is adopted. This enables ROS 2 interoperability on the message exchange level, but lacks any further features, such as parameters, the life cycle, services, etc.

Until 2020, we have acknowledged in previous reports that (XRCE-DDS only, (second approach) is more common because it has been used by (at least) Robotis, Auterion, and Renesas at an official level.

However, during the last year 2021, high interest was shown on the entire micro-ROS stack. As a consequence of the increasing stability of the latter and the continuous addition of features, more and more companies and individuals have manifested that they are adopting the full stack, and will adopt it for product development. Several existing prototypes close to commercialization (Q1 2022) are using micro-ROS in a professional manner.

By the end of 2021, the partners have appreciated the changes listed below. In contrast with the previously described competing initiatives, currently and according to the partners and the insight and reactions received from the community, the SWOT analysis looks as follows (text in **bold** indicates additions while ~~crossed-over~~ text, removal):

- **Strengths:**
  - Cooperation with industry and SMEs
  - Experienced partners
  - ROS 2 compatibility (through a bridged device)

- Big community
- Based on standards (particularly including DDS-XRCE)
- Good channels for dissemination and exploitation
- Open source license
- Captivating ~~new~~ concept/product
- Increasing set of ROS 2 Concepts and API
- Growing interest in standardized robotic solution for embedded devices that is interoperable with the ROS ecosystem
- Very complete and up-to-date webpage
- Plenty of use-cases and demos to showcase micro-ROS capabilities
- Multi-platform support
- Bare-metal support
- Integration with external build systems
- Receiving valuable contributions from the community
- **Existing installed base**
- **Commercialized products using micro-ROS in Quarter 1 FY2022**

- **Weaknesses:**
  - Lack of adoption and use of DDS in the deeply embedded world
  - **Client/agent approach (No framework for those applications that doesn't want to depend on an agent)**
  - Scattered market regarding hardware (boards) and RTOs (FreeRTOS, Zephyr..)

- **Opportunities:**
  - Emerging market
  - No ~~big~~ competitors. **First- to-market**
  - Digitising European Industry as flagship initiative of EU Digital Single Market Strategy
  - FIWARE involvement
  - Good platform for researchers
  - Novel development environment for deeply embedded devices based on containers
  - OEM players adopting micro-ROS
  - A strong positive response from selected ROS community members
  - Integration with external platforms
  - Partnerships and collaborations with akin entities
  - Possibility for production-scale commercialization
  - ~~Introduction of peer-to-peer communication pattern~~
  - Further expansion of the pool of supported platforms
  - Official integration of micro-ROS packages as ROS 2 packages
  - Official integration into external build systems (Zephyr, ESP-IDF...)

- **Threats:**
  - ~~Reduced number of developers~~

- ~~Don't keep aligned with ROS 2 releases. "Fast" paced release schedule.~~
- DDS taking over ROS 2 API.
- ~~Slow adoption~~
- Overall implementation is too heavy for certain microcontrollers (alternatives have been considered)
- The tradeoff between capabilities/performance
- Appropriate governance is critical for the sustainability of the project

2.5 Unique Selling Propositions (USPs)

micro-ROS offers a unique proposition in the areas of embedding ROS 2 into resource-constrained devices and upgrading tiny computation devices to become first class participants of the ROS ecosystem. The project, pushed by experienced partners in the area of robotics, include all the necessary competences to release a worldwide technical trend. The partners are committed to drive results towards the interest of commercial entities and, most importantly, are committed to launching products based on micro-ROS. Moreover, the consortium members have relevant experience in Open Source and are committed to satisfy community needs for further growth of the project.

Thanks to the European leadership and strong presence in the area of microcontrollers, micro-ROS is becoming the de facto framework for deep embedded (microcontroller-based) robot application development. Most importantly, lately this has begun to being backed up both at an unofficial level, by means of users' contributions and the interest of several independent entities, industrial companies, and also on behalf of the Open Robotics, which is boosting micro-ROS adoption as a result of acknowledging its increasing role in the community and the observable trend of the community of integrating more and more projects involving ROS 2 with sensors and actuators operated by micro-ROS.

2.6 Revision of Actions and Priorities regarding Communication and Dissemination Activities

In addition to the above-listed collaboration and standardization activities, the exploitation strategies also materialize in communication and dissemination activities.

Target communities and working groups. The following table provides a revised list of the communities identified as targets for raising awareness of the project results. For each of them, partners already involved in the community which will be responsible for raising such awareness are listed.

Target community	Partner(s) responsible for raising awareness
ROS, ROS 2 Embedded WG, ROS 2 TSC and Open Robotics Foundation	EPROS, BOSCH, Łukasiewicz-PIAP
OPC Foundation	BOSCH
FIWARE	FF, EPROS
Internet Industrial Consortium	FF

International Data Spaces Association	FF
OMG	EPROS
DroneCode.org	EPROS

Project-wide activities. The following table provides a revised list of communication and dissemination activities defined for the whole project consortium along with the current achievements.

Activity	Target KPIs	Channels	Achieved KPIs 2020	Achieved KPIs 2021	Total KPIs
micro-ROS Web	> 10 post/Y + 1k visits	micro-ros.github.io	28 Posts / 700 views Web 6.1k views /2.1k users	13 Post /550 views / Web 11.2k views /3.6k users	55 Post /2.6k views / Web 18.8k views /6.4k users
OFERA Web		ofera.eu	Web 1.6k views/ 1.1k users	Web 1.5k views/ 1.2k users	Web 4k views / 3.1k users
Partner's Web + Forums	> 5 posts/year	fiware.org[1] Bosch	8 Posts / 1.3k views	1 Post (Bosch)	14 Post / +1.5k views
		eprosima.com	24 Posts	19 Posts	35 Post
		discourse.ros.org	25 topics	52 Topics/Activity	Topics 51 +23.7k views
Earned Media Third parties	> 5 / year	See all channels Reporting- link	20 Publications	14 Publications	34 Publications
Events technical conferences, workshops, events and fairs*.	2 Large trade fairs[2] > 20 tech present >500 attendees >50 downloads Slideshare	ROS World ROS-IC ERF FIWARE Summit ROS2 EWGs DIH² webinar PX4 summit	14 Events	6 Events	29 Events +25 presentations +13 slideshare +4.7k views slideshare 6 Workshops
ROS Working Group Meetings	N/A	ROS Real-Time WG ROS TSC	5 EWGs meetings	10 EWG Meetings	15 EWG Meetings
Presentations **Demos** **Podcast**	> 20 tech present >500 attendees	50 proposed 35 responded 35 performed	~ 22 presentations ~ 6 Demos 1 Podcast	12 Presentations 5 Demos	**45 Presentations** **17 Demos** **2 Podcast** **+40k visualizations**

[1] just micro-ROS post and news on fiware.org 2020

[2] KPI for all the project - Presence at major trade fairs canceled due to Covid (IoTSWC and Hannover Messe 2020)

Scientific publications	Journals and magazines	>10 publications	1	3	7 Scientific Publications[3]
Social Media	Regular posts through Partner's channels	>3 posts/month (Twitter, LinkedIn, Facebook) 1 video/year on YouTube >10 average likes /share per post	+115 Twitter Posts (+6.7k engagements - 234k Impressions) 66 Facebook Posts (216 Engagement - 3.5k Impressions) 71 LinkedIn Posts	225 Social Media Post (107 Linkedin) (15 Facebook) (109 Twitter)	+600 Social Media Posts
Marketing Materials	Flyers, brochures, videos	1 flyer 1 brochure 1 poster 1 infographic 1 promo video / year	1 Brochure, >1000 stickers +15 Featured youtube videos 2020 (~ 6k views) 2 Project videos (+6k views)	N/A	2 project videos +12k views) 1 Brochure 1 roll up +30 featured Youtube videos +40k views
Press releases - Awareness of decision and policymakers	Official communications	>=2/year	_EU Adopts FIWARE Platform and ROS 2/Fast DDS _FIWARE Foundation, micro-ROS is now a member of The Zephyr Project!	1 Renesas and eProsima Simplify Development Of Professional Robotics Applications	3 Press Releases
One-to-one communication - Awareness of target audiences	Newsletters Mailings	Featured article every two FIWARE monthly newsletters >1 featured mailings/year	5 Featured posts in FIWARE Newsletters 1 Marketing Roundup Presentation	N/A	7 featured post in FIWARE Newsletters

Partners dissemination plans. In the following revised lists of the individual communication and dissemination activities of each partner are provided.

EPROS:

Planned activities	**Implementation**
Presentation of the project on the Project and EPROS website, Press Release	• Hosted and maintained www.ofera.eu • Added micro-ROS and Micro XRCE-DDS related news and releases into EPROS website: https://eprosima.com/index.php/company-all/news

[3] See Appendix 1 - From D7.19

Concept Demos to eProsima Customers and interested companies	● Presented micro-ROS to international partners and Research institutions: Intel, Amazon WS, CEA, LUXonis, Samsung, Hyperterm, INtime, DIH², Thales, DireenTech, Wyca, ANTbotics, Robotis, Husarion, AERO41, Micro Trend Research, DoBots.
Promotion within ROS as ROS contributor and as ROS TSC member ● micro-ROS Website inside ROS.org, as a module of ROS. ● Presentations at the next ROS Conferences 2017-2020 [ROSCON] ● Articles, Blog posts.	● Along with the rest of the partners, promoted and maintained micro-ROS websites www.micro-ROS.github.io ● Published posts in ROS discourse regarding micro-ROS. ● Presented micro-ROS at ROS World 2021 and ROS Industrial USA 2021. ● Presented micro-ROS together with BOSCH at ROS-Industrial Conference 2021. ● Organized 4-weekly Embedded WG meetings. ● Presented micro-ROS in ROS 2 TSC. ● Updated ROS 2 TSC with micro-ROS and Embedded WG news. ● Active presence in ROS discourse, ROS answer and in micro-ROS slack. ● ROS Developers Day participation 2021 ● Published posts in third parties websites (Renesas, Husarion)
Promotion within FIWARE as FIWARE Foundation Chapter leader for Robotics and Middleware (Presentations, Articles, Examples, Web content, etc) ● Presentations and workshops at FIWARE summits. ● micro-ROS demos using FIWARE stands in important fairs (IoT Congress, Hannover Messe, etc) ● Web content for a new FIWARE website area devoted to robotics.	● micro-ROS status updates presented to FIWARE TSC ● micro-ROS presented in FIWARE Smart Fest 2021
Promotion within Dronecode.org (Presentations, Articles, Examples, Web content, etc)	● Made presentation to PX4 Developers Summit 2021
Presentations as a success case at OMG meetings.	● Proposed changes based on micro-ROS use cases.

Łukasiewicz-PIAP:

Planned activities	Implementation
Promotion within several robotic conferences and forums, including showcasing of demonstration platform.	● ROS2 Embedded WG benchmarking results presentation ● Prepared micro-ROS enabled 6-wheels vehicle for Barcelona IoT World Congress (canceled due to COVID) ● Automation 2022 two presentations submission (Smart warehouse as an example of micro-ROS application and Seamless multi-platform tracing: Shadow Builder)
Presentation of the micro-ROS benchmarking results	● Presentation of benchmarking results on micro-ROS website ● presentation on EWG 15 - benchmarks comparison between Dashing and Galactic versions to show significant progress
Publications	● Micro-ROS applications in wireless IoT devices - JAMRIS - under review ● Participation in ROSbook 2022 - accepted ● Smart warehouse as an example of micro-ROS application - Automation 2002 book - under review ● Seamless multi-platform tracing: Shadow Builder - Automation 2022 book - under review
Promotion at Łukasiewicz-PIAP Twitter, LinkedIn and Youtube	● several posts in social media ● forwarded micro-ROS other posts
Promotion in Łukasiewicz-PIAP	● presentation of micro-ROS progress on internal meetings ● information in Łukasiewicz-PIAP bulletin

BOSCH:

Planned activities	Implementation

Promotion at ROS-Industrial meetings/ conferences (Bosch is a full member of ROS-I EU)	● Presented micro-ROS at ROS-Industrial Conference 2018 ● Presented micro-ROS at ROS-I Spring Workshop ● Presented selected works from OFERA at ROS Meet-ups in Stuttgart, organized by ROS-I EU coordinator Fraunhofer IPA ● Presented runtime tracing tools developed in OFERA at ROS-Industrial Conference 2019 ● Presented Callback-group-level Executor concept and rclc Executor at ROS-Industrial Conference 2020
Promotion within the ROS 2 community, in ROS 2 Technical Steering Committee (TSC) and at ROSCon	● Presented works from OFERA at ROSCon 2018 ● Presented micro-ROS together with eProsima at ROSCon 2019 ● Presented micro-ROS together with eProsima at ROS World 2021 ● Co-organized workshop on execution management for ROS World 2021 and presented micro-ROS rclc Executor and further works on execution management from OFERA ● Participating actively in discussions on ROS for embedded systems, real-time execution management, runtime configuration and other relevant topics from OFERA in respective working groups, in ROS 2 TSC, in ROS Discourse, and in ROS Answers forum ● Participating actively in Real-Time Working Group and Middleware Working Group. Also presented the micro-ROS rclc Executor to the ROS Control Working Group in December 2021 ● Founded ROS Embedded Systems Working Group together with eProsima
Presentation at relevant non-robotic conferences from the Cyber-Physical-Systems and Real-Time Community (e.g., CPS-Week and DATE)	● Presented overview to micro-ROS and OFERA during full-day ROS Tutorial at CPS-Week 2018 in Porto ● Provided invited talk on micro-ROS at ASD Workshop at DATE conference 2019 in Florence ● Provided talk and presented a poster on execution management for ROS at ECRTS 2019 in Stuttgart ● Provided talk on rclc Executor at EMSOFT 2020.
Presentation within Bosch in annual reports and on the Wiki of the internal project that will back the micro-ROS activities of Bosch	● Presenting works from micro-ROS and status of OFERA project three times per year in Bosch-internal research project on systems and software engineering for robotics lead by Ralph Lange ● Presented micro-ROS and OFERA project in various talks at Bosch Corporate Research and selected

	business units ● Organized and delivered Bosch-internal tutorial on micro-ROS in July 2020 together with eProsima ● Maintaining internal Wiki on systems and software engineering for robotics with various pages works from micro-ROS

FF:

Planned activities	**Implementation**
FIWARE Summits, Sessions, workshops, hackathons, etc.	● The FIWARE summit now accounts for a dedicated session on robotics. ● micro-ROS was present in the robotics track within the FIWARE Summit in May (Genoa) ● micro-ROS was present in the robotics track within the FIWARE Summit in October (Berlin) ● micro-ROS was present in the robotics track within the FIWARE Fest (virtual Summit) in May 2021 ● 5 Dedicated online Webinars during 2020 reaching more than 2.7k audience ● Webinars offered to manufacturing companies as part of the DIH2 project ● A dedicated FIWARE's Working Group focused on robotics has started this year. The status of micro-ROS is reported in the meetings of this WG
Web content: Press Releases, Blog posts, new Robotic area, etc.	● New Robotics area within the FIWARE Catalogue [link] ● The Micro XRCE-DDS component has been added to this FIWARE Catalogue as an incubated enabler ● micro-ROS was presented as part of the FIWARE technology in the robotics webinar [link] ● micro-ROS and IoTSWC entries in the FIWARE's blog (total 13 - see D7.16) ● IoTSWC booth and micro-ROS 2 promotional project videos are available in the FIWARE's Youtube Channel ● Specific tech blog post Featuring all micro-ROS demos when interfacing with FIWARE Context Broker - To be released in January 2022.
Global Fairs (Hannover Messe, IoT Congress, Mobile World Congress, etc)	● micro-ROS and OFERA project had a dedicated space at the FIWARE's booth in the IoT Solutions World Congress 2019 (Barcelona, Spain) ● Check the booth at the IoTSWC video [link]

	● The micro-ROS promotional video was presented at the booth [link]

From the previous revision, all the promotion activities from ALR have been removed.

3 Individual Exploitation Plans

The individual exploitation plans of each partner of the OFERA project are presented in the following sections.

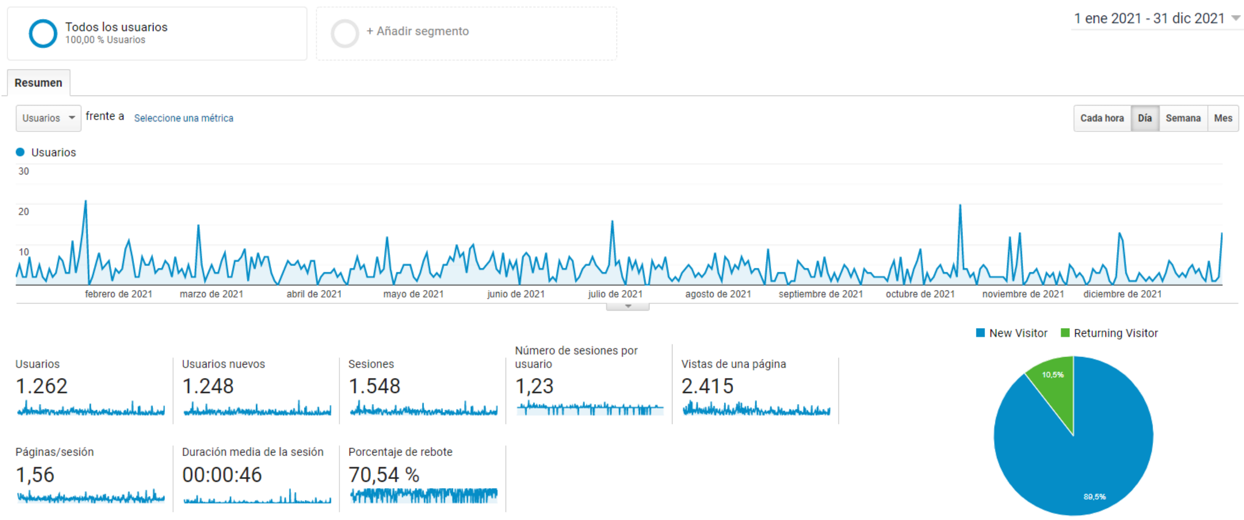
3.1 EPROS

eProsima will exploit the project innovations in several ways:

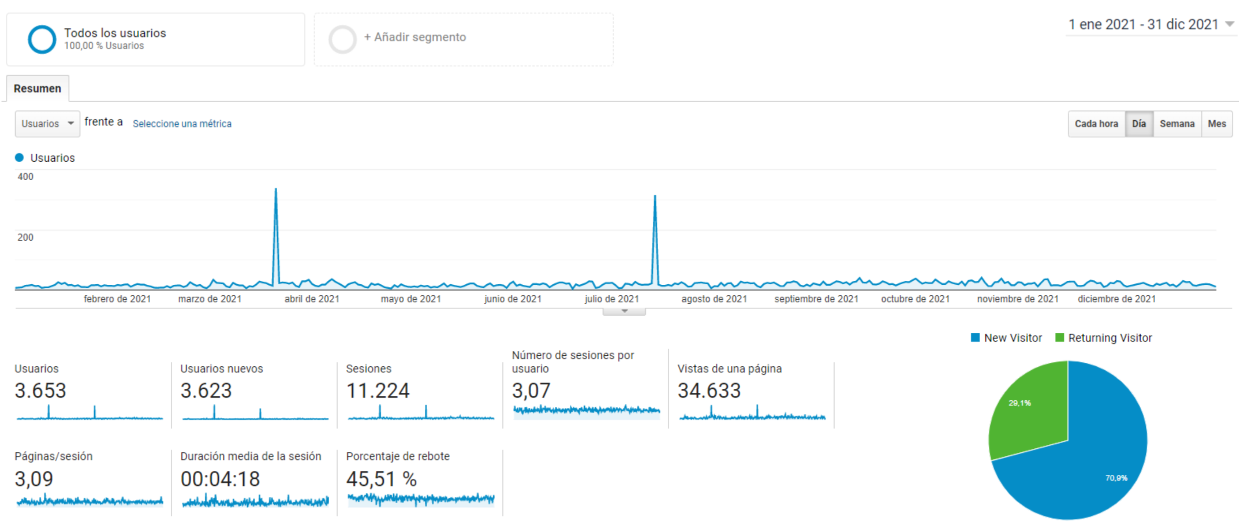
The platform will be used to increase eProsima presence in the Robotics market as a key ROS contributor, easing the ROS adoption, and new features will be added to eProsima main middleware products and released as OSS. eProsima will transfer the result of the projects to its current and future customer base with special emphasis in **the IoT** and the UAV areas, driving the adoption of micro-ROS in drones, continuing the ongoing work within Dronecode organization. As an OMG member, eProsima will bring the results of the project to this standardization bodies incorporating the lessons learned to ongoing standards such as XRCE-DDS, and proposing new specifications.

Measures/KPIs:

- 13 articles on eProsima websites
- ROS Discourse: 52 posts created and 231 likes received
- micro-ROS github in 2021: 5+ contributors, 49+ commits, clones 1232 - unique clones 196, views 1666 - uniqueviews 462, new repositories have been created
- OFERA 2021 statistics:



- micro-ROS 2021 statistics:



- 3 Improved Products (OSS): eProsima Micro XRCE-DDS (Additional features), Integration Service Core and FIWARE system handle (FIWARE Orion Context broker Interoperability with micro-ROS).
- Improved FIWARE GEs (OSS): Micro XRCE-DDS has been incorporated as an Incubated GE, SOSS has been promoted.
- XRCE-DDS OMG Standard contributions.

In bold it is marked the main change regarding the original strategy. This change is derived from a technology change which ends up with the creation of SOSS. SOSS is the replacement for FIROS2 and Routing Services for RTPS. In this new product, the functionalities from FIROS2 and Routing services for RTPS are incorporated in SOSS, with SOSS Core allowing the creation of new connection plugins such as SOSS-FIWARE. eProsima will benefit from the Improvement of SOSS Core and SOSS plugins required for micro-ROS interoperability with other systems as for example FIWARE.

Apart from that major change, a naming update was done changing micro RTPS for Micro XRCE-DDS.

Outcome 1:

2020 proposed changes and improvements to the XRCE-DDS standard have been accepted and included in the new revision. This has increased the quality of EPROS' XRCE-DDS open-source implementation Micro XRCE-DDS.

Outcome 2:

Micro XRCE-DDS technology has been contributed to FIWARE as Incubated FIWARE GE to the collection of enablers focused on interfacing with IoT devices, robotics and 3rd party systems. See D7.17_Annual_report_on_collaboration_Y4 for more details.

Outcome 3:

SOSS - FIWARE system handle. SOSS is a framework to communicate multiple systems using a common standard representation. One of these systems is the FIWARE system handle which allows a FIWARE context broker to communicate with any other system. Appealing to micro-ROS, are the connections to ROS 2 and with micro-ROS, allowing to communicate micro-ROS with FIWARE Context broker.

3.2 BOSCH

Bosch has a long history with ROS. As one of the eleven recipients of a PR2 robot in the PR2 Beta Program by Willow Garage,[4] researchers at the Bosch Research and Technology Center in California worked with ROS and contributed to ROS from the early beginnings.

Today, ROS is used in a number of research and advance development projects at Bosch, from component development to robotics and autonomous driving. The first internal product based on ROS has been the Autobod,[5] an autonomous transport platform for the shop floor, presented to the public in 2016. In 2019, the first external product based on ROS has been launched: A Development Starter Kit for Automation (DSKA) by the Bosch Engineering GmbH.[6]

General exploitation goals regarding ROS

This open-source activity is exploited to promote Bosch as a modern company active in robotics, acquire talented personnel, and, crucially, by providing building blocks for the community, we increase the quality of freely available components for future product development.

Examples of such contributions that are not related to micro-ROS include

- the zero-copy middleware Iceoryx with corresponding ROS 2 middleware adapter (https://projects.eclipse.org/proposals/eclipse-iceoryx, https://github.com/ros2/rmw_iceoryx),
- hooks in the ROS core layers for tracing with the Linux Trace Toolkit NG (https://github.com/boschresearch/ros1_tracetools),
- Gazebo plugins and tools for simulating unmanned underwater vehicles (https://github.com/uuvsimulator),

[4] https://spectrum.ieee.org/automaton/robotics/robotics-software/the-origin-story-of-ros-the-linux-of-robotics
[5] https://www.produktion.de/trends-innovationen/bosch-entwickelt-autobod-fuer-die-intralogistik-212.html
[6] https://developer.bosch.com/web/dska/

- a scripting library for procedural scene generation for Gazebo (https://github.com/boschresearch/pcg_gazebo_pkgs/), and
- an adapter for integrating Functional Mock-up Units according to the FMI Standard with ROS (https://github.com/boschresearch/fmi_adapter, -_ros2).

Furthermore, Bosch has sponsored the development of the ROS 2 core packages by a full-time developer from 2016 until 2021.[7]

All of these have been taken up by the community with great interest and lead to greatly increased prominence of Bosch in the robotics domain.

Exploitation goals regarding micro-ROS

The primary goal for micro-ROS has been to reduce the barrier in transfer of software and data between advance development/research and series development. Naturally, the specifics of this depend on the concrete product and business unit. The exploitation by Bosch Lawn and Garden has already been described in Deliverable D6.12.

Since early 2021, Bosch is working on a second, very concrete exploitation of the complete micro-ROS stack for Bosch Rexroth's off-road vehicle control unit BODAS. This effort is described in Section 7.2 of an upcoming book chapter on micro-ROS for Springer's ROS Book series, cf. Annex 1 of Deliverable D1.8.

Beyond this, we have more far-reaching exploitation activities ongoing. These will be detailed with respect to the concrete exploitable outcomes.

Outcome 1: The RTOS-based micro-ROS stack. Within Bosch Corporate Research, several other studies have already used micro-ROS for integrating microcontroller-based prototypes within the ROS ecosystem, particularly for exploration of new sensors, remote control of small robots, data acquisition and similar applications. These studies particularly include Master's theses.

Outcome 2: Micro-ROS client library technologies. The modular client library of micro-ROS comes with several technologies that can be exploited independently of the underlying middleware and operating system. On the part of Bosch Corporate Research, we aim at bringing these technologies into relevant business unit projects as reusable software assets and tools:

1. *System Modes:* This is a very generic concept and deemed to be relevant for most robotics systems. The present implementation is even largely independent of ROS but assumes some basic runtime component lifecycle only, which can be found in many component frameworks. The system modes concept reduces the complexity in robotics deliberation significantly and allows the developer of the deliberation layer of a robotic system to focus on the overall platform instead of the many individual software components. On the part of Bosch Corporate Research, the exploitation of this technology is fostered by internal training and consulting. TFirst transfers to two business unit projects/products are on-going. In addition, this technology has been exploited in the Integrated Technical Project (ITP) Metacontrol for ROS 2 (MROS) in the second open call of the EU project RobMoSys, cf. Deliverable D7.6.

[7] https://www.osrfoundation.org/bosch-research-and-technology-center-joins-forces-with-open-source-robotics-foundation-to-advance-the-development-of-ros/

2. *Real-Time Execution Management:* The execution management concept developed for ROS 2 largely differs from the concept in ROS 1. On the one hand, it comes with much more flexibility and particularly allows implementing own Executors. On the other hand, the default Executor does not provide any deterministic processing guarantees – not even the known FIFO processing known from ROS 1. We consider this as a hurdle in the adoption of ROS 2. By the works on predictable scheduling and execution in Task 4.2, this issue is resolved in close collaboration with the ROS community – in particular in the Real-Time Working Group and the Middleware Working Group (cf. Deliverable D7.6). By bringing the necessary changes and extensions into the ROS 2 mainline repositories - cf. the Callback-group-level Executor for ROS 2 Galactic[8] in May 2021 - they are also transferred to all Bosch-internal projects that use ROS 2 or micro-ROS.

3. *Tracing:* In a new task (as decided in the project review on 10 September 2019 in Luxembourg), mechanisms in the ROS 2 core layers for runtime performance tracing have been developed and contributed to the ROS 2 mainline repositories. These mechanisms enable detailed runtime analysis of ROS 2 and micro-ROS-based systems and the identification of performance, synchronization, and scheduling issues at very little development effort. In the past, developers typically implemented their own specific solutions for each algorithm or software asset to analyze. On the part of Bosch Corporate Research, the use of this technology in relevant applications and systems projects will be fostered by internal training and consulting.

3.3 Łukasiewicz-PIAP

Łukasiewicz-PIAP has a lot in common with ROS and ROS2, mainly due to its practical use. Łukasiewicz-PIAP uses it in many research projects as well as in commercial projects. In addition, we have ROS2 benchmarking experience related to participation in the R5COP project.

Micro-ROS will be used in subsequent projects or modifications to existing ones - generally wherever microcontrollers can be used. One of the products we intend to use micro-ROS results is our own line of mobile robot accessories. We aim to improve power consumption and faster development cycle of new products in that line.

In Łukasiewicz-PIAP we intend to use experience gained and software developed in micro-ROS to help support both our internal product development and external industrial customers. In 2021, Łukasiewicz-PIAP helped to implement a micro-ROS stack for the Hydrabox DGPS module offered by Hydrasystem. This effort is described in Section 7.1 of an upcoming book chapter on micro-ROS for Springer’s ROS Book series, cf. Annex 1 of Deliverable D1.8.

Specific areas will include:

- increase development speed and end quality of low power energy modules based

[8] See https://www.youtube.com/watch?v=5Sd5bvvZeb0 for a presentation of this concept and implementation.

- ease transfer of research results to production, thanks to better easier transfer of components developed in ROS environment
- improve quality of communication systems in low power environment,
- provide customers with quantitative benchmarks of solutions developed thanks to benchmarking solutions.

Specifically we want to continue to develop micro-ROS benchmarking solutions. It is offered as open source and we intend to support it as part of our offering for industry partners. This will be provided in form of source code containing instrumentation for conducting benchmarks on open source license as well as papers presenting the results. Additionally, benchmarking tools will be developed and supported in cooperation with the ROS community.

The benchmark tools developed in the OFERA project are available as open source and described in D5.8. These tools will also be used in Łukasiewicz-PIAP software development.

3.4 FIWARE

FIWARE aims at building an open sustainable ecosystem around public, royalty-free and implementation-driven software platform standards that will ease the development of new Smart Applications in multiple sectors. The FIWARE Foundation (FF) serves this purpose and it is evident that robotics will play a key role in smart applications of the future. Thus, in general terms, the main reason why FIWARE is participating in this project is to encourage focused activities and improve its positioning within this sector.

From this perspective, the FF understands that the micro-ROS project will be instrumental in helping the FIWARE and ROS communities meet each other. The use cases developed under the micro-ROS project will showcase how micro-ROS based robots can interact with context information to implement a smart behaviour, demonstrating the complementarities between ROS/micro-ROS and FIWARE de-facto standards. The ultimate goal is to convince developers that FIWARE is their open source platform of choice when incorporating management and processing of context information (coming from IoT sensor networks or a diverse number of sources) in robotics solutions.

The FIWARE Catalogue plays an essential role in enabling the synergies between the micro-ROS, ROS, and FIWARE communities. This catalogue is a rich suite of complementary FIWARE components, FIWARE Generic Enablers (GEs), that can be combined with the FIWARE Context Broker in a modular architecture and integrated as part of a “Powered by FIWARE” platform. Most of the collaborations and development ideas within FIWARE gravitate around the capabilities offered by these enablers and, thus, the inclusion of FIWARE enablers with clear focus on robotics is becoming more and more strategic for the FIWARE technical roadmap.

The complete set of FIWARE GEs is organized in different chapters and the one that integrates the results of micro-ROS is the chapter of “*Interfaces with IoT devices, robots and third-party systems*”. The component Micro XRCE-DDS was the first of the micro-ROS contributions to the FIWARE Catalogue. The second contribution from OFERA to the FIWARE Catalogue has been the entire micro-ROS framework itself as a FIWARE GE. These two components along with Fast DDS, an eProsima product that is the default middleware for ROS 2, form the ecosystem of FIWARE Enablers that gravitates around ROS and DDS based robotics systems. The DDS family stack is becoming one of the main pillars of the FIWARE technical roadmap within the robotics domain in which the OFERA partner eProsima plays a major role that 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.

Some results are already emerging: i) the number of participants in the FIWARE robotics working group has increased this year and now includes Atos, Engineering, eProsima, FIWARE, Fraunhofer IML, NEC, and the Japanese TIS Inc, ii) FIWARE is getting more and more traction within the sector of robotics based agile manufacturing with the new technology and refined vision of Powered by FIWARE architectures for robotics systems and iii) thanks in great part by the micro-ROS achievements new projects like the ones considered in the DIH^2 Technology Transfer Program and ALMA have been granted with fundings that will allow FIWARE to materialize its robotics roadmap, find and test the FIWARE technology in meaningful use cases and, therefore, to widen the FIWARE visibility in the robotics sector. In DIH^2, a series of fifteen industrial experiments in agile manufacturing companies will take place in 2022. FIWARE is the technical lead in these experiments and some candidates have already been identified as potential users of micro-ROS. Also in 2022, a new FIWARE webinar and a step-by-.step tutorial will be produced. That is, the results of the OFERA project will remain alive within the FIWARE ecosystem beyond the funded period.

Appendix 1: Scientific Publications

List of all scientific publications (in reverse chronological order) related to micro-ROS as input for the corresponding achieved KPI in Section 3.6

1. Under submission - Submission of technical content in peer-reviewed academic journal JAMRIS journal as well as a 52-pages book chapter on micro-ROS for Springer's ROS Book series
2. Under submission - Alexandre Malki, Tomasz Kołcon and Mateusz Maciaś, “Seamless multi-platform tracing: Shadow Builder”, Automation 2022 book, submitted December 2021
3. Under submission - Alexandre Malki, Tomasz Kołcon and Mateusz Maciaś, “Smart warehouse as an example of micro-ROS application ”, Automation 2022 book, submitted December 2021
4. Under submission - Tomasz Kołcon, Alexandre Malki, Mateusz Maciaś*, Maria Merlan* "Micro-ROS applications in wireless IoT devices", JAMRIS, submitted September 2021
5. Daniel Casini, Tobias Blass, Ingo Lütkebohle, and Björn B. Brandenburg: “Response-Time Analysis of ROS 2 Processing Chains under Reservation-Based Scheduling.” *Proceedings of 31st Euromicro Conference on Real-Time Systems (ECRTS 2019), Stuttgart, Germany, July 2019.*
6. Irati Zamalloa, Iñigo Muguruza, Alejandro Hernández, Risto Kojcev, Víctor Mayoral: “An information model for modular robots: the Hardware Robot Information Model (HRIM).” *CoRR arXiv:1802.01459, Feb 2018.*
7. Jan Staschulat, Ingo Lütkebohle, and Ralph Lange: “The rclc Executor: Domain-specific deterministic scheduling mechanisms for ROS applications on microcontrollers” (Work-in-Progress). In *Proc. of Int'l Conf. on Embedded Software (EMSOFT)*, pp. 18–19. Singapore, Singapore. Sep 2020. IEEE.

8. Jan Staschulat, Ralph Lange, Dakshina Narahari Dasari: "Budget-based real-time Executor for Micro-ROS". arXiv 2105.05590, May 2021.

Appendix 2: Technical Presentations

List of all technical presentations (in reverse chronological order) related to micro-ROS as input for the corresponding achieved KPI in Section 3.6

#	Date	Title	Location	Presenter(s)
		2021		
	submitted for 2022	Smart warehouse as an example of micro-ROS application	Automation 2022	Tomasz Kołcon
	submitted for 2022	Seamless multi-platform tracing: Shadow Builder	Automation 2022	Tomasz Kołcon
	December, 9th	Developing ROS 2 professional applications based on MCUs	ROS-Industrial Conference 2021	Maria Merlan
	December, 1st	The role of open-source platforms for robotics based agile manufacturing	COOCK Project Workshop: Open Source Platforms for Smart Manufacturing	Francisco Melendez
	November, 23rd	micro-ROS benchmarking	ROS 2 Embedded WG 15	Alexandre Malki
	October 23rd	micro-ROS goes easy: Developing professional applications using Eclipse based IDEs	ROS World 2021	Maria Merlan, Pablo Garrido
	October 23rd	micro-ROS: New client library and middleware features	ROS World 2021	Maria Merlan, Ralph Lange
	October 19th	The rclc executor; Callback groups executor	ROS 2 Executor Workshop, ROS World 2021	Jan Staschulat, Ralph Lange
	September , 14th	ROS 2 in PX4: Technical details of a seamless transition to XRCE-DDS and micro-ROS	PX4 Developers Summit 2021	Pablo Garrido

	June, 22nd	micro-ROS	ROS Con France 2021	Maria Merlan, Jan Staschulat
	June, 10th	micro-ROS: bringing ROS 2 to microcontrollers	Fiware Smart Fest 2021	Jose Antonio Moral
	June, 1st	micro-ROS Galactic	ROS 2 Embedded WG 10	Pablo Garrido
	March, 25th	Open Source Platforms for Robotics-based Agile Production	EU Data Week	Francisco Melendez
	April, 13th	Deeply embedded software	European Robotics Forum 2021	Francesca Finocchiaro
2020				
	December, 16th	micro-ROS: bringing ROS 2 to MCUs	ROS-Industrial Conference 2020	Francesca Finocchiaro, Pablo Garrido Sanchez
	December, 16th	Advanced Execution Management in ROS 2	ROS-Industrial Conference 2020	Ralph Lange
	November, 12th	micro-ROS: bringing ROS 2 to MCUs	ROS World 2020	Francesca Finocchiaro
	November, 12th	Powered by FIWARE Systems for Robotics-based Agile Manufacturing	ROS World 2020	Francisco Melendez
	November, 11th	Powered by FIWARE Systems for Agile Production	ROS Embedded Working Group	Francisco Melendez
	October, 26th	Powered by FIWARE Digital Twins for ROS, micro-ROS and OPC UA based robotics systems	Joint FIWARE and ETSI ISG CIM Workshop on Digital Twins	Francisco Melendez
	September, 23rd	FIWARE & micro-ROS "Enabling Robotics Systems on Micro-controllers"	FIWARE Wednesday Webinars	Francisco Melendez
	September, 20th	The rclc Executor: Domain-specific deterministic scheduling mechanisms for ROS applications on microcontrollers	EMSOFT 2020	Jan Staschulat
	September	micro-ROS: Bringing ROS 2 into	ROS 2 TSC	Francesca

	, 17th	microcontrollers		Finocchiaro
	September , 16th	micro-ROS benchmarking	ROS2 Embedded WG #2	Alexandre Malki
	September , 1st	micro-ROS: Bringing ROS 2 into microcontrollers	ROS Real-Time Working Group	Francesca Finocchiaro
	July, 22nd	FIWARE Interfaces with Machine and Robots	FIWARE Wednesday Webinar	Francisco Melendez
	July, 16th	The micro-ROS tutorial at BOSCH	BOSCH internal Workshop	Pablo Garrido Sanchez, José Antonio Moral Parras, Francesca Finocchiaro, Ralph Lange, Jan Staschulat
	July, 7th	Bringing micro-ROS to PX4-based flying systems	PX4 Developers Summit	Jaime Martín
	June, 27th	Introduction to micro-ROS: getting started with Zephyr	ROS Developers Day	Pablo Garrido Sanchez
	June, 25th	Micro XRCE-DDS & micro-ROS - Bringing DDS and ROS into microcontrollers	DIH² Webinar	Francesca Finocchiaro
	June, 22th	Micro XRCE-DDS & micro-ROS - Bringing DDS and ROS into microcontrollers	FIWARE TSC	Francesca Finocchiaro
	June, 17th	Micro XRCE-DDS & micro-ROS - Bringing DDS and ROS into microcontrollers	FIWARE Foundation webinar	Francesca Finocchiaro
	June, 12th	Micro XRCE-DDS & micro-ROS - Bringing DDS and ROS into microcontrollers	FIWARE Robotics Tech Roadmap WG	Francesca Finocchiaro
	March, 4th	OFERA	Workshop on Overcoming the boundaries of today's Robotics Software Engineering at ERF 2020	Ralph Lange

			in Malaga, Spain	
	February, multi-day session	Webinar series on Powered by FIWARE Architectures for robotics systems for Agile Production based on DDS, ROS, micro-ROS and OPC UA	Webinar Series for 11 manufacturing Companies and 20 Tech Providers within the Transfer Technology Program of the DIH^2 Project	Francisco Melendez
		2019		
1	December, 24th	ROS in micro controllers using u-ROS	ROS Developers Podcast	Borja Outerelo Gamarra
2	November 11th	ROS 2 Tracing: Performance Analysis and Execution Monitoring	ROS-Industrial Europe Conference, Stuttgart, Germany	Ingo Lütkebohle
3	November 2nd	micro-ROS: ROS 2 on microcontrollers	ROSCon 2019, Macau, China	Ingo Lütkebohle Borja Outerelo Gamarra
4	October 31st	Execution in ROS 2 - Determinism (or lack thereof), performance, and the way forward.	Real-Time Workshop at ROSCon 2019, Macau China	Ingo Lütkebohle
5	October 24th	Applying Context Data Principles to Robots	FIWARE Summit Berlin	Francisco Melendez
6	October 24th	Building Interfaces with ROS2-based Robotics Systems	FIWARE Summit Berlin	Francisco Melendez
7	September 23th	Micro-ROS - benchmarking	ROS2 Embedded WG #5	Tomasz Kołcon
8	July 10th	Practical and Easy to Use Real-Time Execution Mechanisms for ROS	31st Euromicro Conference on Real-Time Systems (ECRTS), Stuttgart, Germany	Ralph Lange

9	July 10th	Response-Time Analysis of ROS 2 Processing Chains under Reservation-Based Scheduling	ibd	Tobias Blass
10	May 22th	FIWARE Robotics: ROS2 & micro-ROS	FIWARE Summit Genoa	Jaime Martin-Losa
11	May 7th	Micro-ROS	ROS Industrial Spring Workshop, Stuttgart, Germany	Ingo Lütkebohle
12	May 7th	System Modes and Execution Management	ROS Industrial Spring Workshop, Stuttgart, Germany	Ralph Lange
13	March 29th	Bringing the Next Generation Robot Operating System on Deeply Embedded Autonomous Platforms	Workshop on Autonomous Systems Design (ASD) at the DATE conference, Florence Italy	Ralph Lange
14	March 22th	OFERA - Open Framework for Embedded Robot Applications	European Robotics Forum TG Software & System Engineering Meeting	Ingo Lütkebohle Borja Outerelo Gamarra
2018				
15	December 12	ROS on Embedded Devices - Recent Developments	ROS Industrial Europe Conference 2018, Stuttgart, Germany	Ingo Lütkebohle
16	December 12	System Integration and Modularity in Robotics using ROS	ROS Industrial Europe Conference 2018, Stuttgart, Germany	Victor Mayoral Vilches
17	November 28th	micro-ROS	FIWARE Summit Malaga	Jaime Martin-Losa
18	November 13th	micro-ROS	ROS Developers Podcast	Ralph Lange
19	September 29th	Callback-group-level Executor	ROSCon 2018, Madrid, Spain	Ralph Lange
20	May 9th	micro-ROS introduction	FIWARE Summit Porto	Jaime Martin-Losa

21	April 10th	Fundamentals of the Robot Operating System (ROS)	CPS Week, Porto Portugal	Ralph Lange