D3.4

Micro-ROS middleware interface Software Release Y1

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Abstract	This document provides links to the released software and documentation for deliverable D3.4 *Micro-ROS middleware interface* of the Task 3.2 *MicroROS middleware interface* (*urmw*).

Contents

1 Summary

micro-ROS provides an RMW implementation using the latest code from eProsima's middleware for devices with low computing and memory capacities, Micro XRCE-DDS. In this version, we have a C implementation for part of the middleware primitives declared by the ROS *rmw* upper layer.

In micro-ROS, *rmw_microxrcedds*, as it is the only rmw_implementation found, will be used as the default one by *rmw_implementation* (*rmw_implementation* defaults the rmw implementation to use as *rmw_fastrps_cpp* in case it is located, otherwise it will use the first available alphabetically sorted). This unique implementation avoids the dependency with the third-party library Poco, used for the dynamic load of rmw_implementations.

The *rmw_microxrcedds* library is a ROS2 Middleware Abstraction Interface used by micro-ROS. This library defines the interface used by upper layers in ROS2 stack and implemented using some middleware in the lower layers.

2 Acronyms and keywords

Term	Definition
RMW	ROS2 Middleware
XRCE	Extremely Resource Constrained Environments
DDS	Data Distribution Service
rmw_microxrcedds	Micro-ROS middleware interface package

3 Overview to Results

This document provides links to the released software and documentation for deliverable D3.4 *Micro-ROS middleware interface* of the Task 3.2 *MicroROS middleware interface* (*urmw*).

4 Links to Software Repositories

The rmw_microxrccedds is provided as a ROS2 package available at:

- Git repository: https://github.com/microROS/rmw-microxrcedds.git
  Package name: rmw_microxrcedds
  Package path: ./rmw-microxrcedds
  Commit: fd0732557b7eb675662f5014a4a6ce82dfc5e85c

The rmw_microxrccedds module is provided as a ROS2 package available at:

- Git repository: https://github.com/microROS/rmw-microxrcedds.git
  Package name: microxrcedds_cmake_module
  Package path: ./microxrcedds_cmake_module
  Commit: fd0732557b7eb675662f5014a4a6ce82dfc5e85c

Package rmw documentation available at:

- Git repository: https://github.com/microROS/micro-ROS-doc.git
  Path: ./rmw_microxrcedds
  Commit: d7864d8073a3645a950a63a9dc9b764f34ee4d77

The rosidl_typesupport_microxrcedds is provided as a ROS2 packages available at:

- Git repository: https://github.com/microROS/rosidl_typesupport_microxrcedds.git
  Package names:
  - rosidl_typesupport_microxrcedds_c
  - rosidl_typesupport_microxrcedds_cpp
  - rosidl_typesupport_microxrcedds_cpp_tests
  - rosidl_typesupport_microxrcedds_c_tests
  - rosidl_typesupport_microxrcedds_shared
  - rosidl_typesupport_microxrcedds_test_msg
    Commit: 0bc5713205c2c7ab94e8d28406eea4a1d66d16bb

Package rosidl_typesupport_microxrcedds documentation available at:

- Git repository: https://github.com/microROS/micro-ROS-doc.git
  Path: ./rosidl_typesupport_microxrcedds
  Commit: d7864d8073a3645a950a63a9dc9b764f34ee4d77

5 Annex 1: GitHub documentation (rmw)

5.1 Architecture

rmw_microxrcedds library can be divided into five main components:

- Node
- Publisher
- Subscription

- Service Client
- Service Server

Apart from that main components, it provides with diverse set utilities as could be

- Initialization and shut-down functions
- Wait functionality to listen to incoming topics in subscribers
- Functions to query on ROS graph
- Memory functions
- Name checkers

In micro-ROS we are using the upper *rmw* as it is in ROS2.

The *rmw-microxrcedds* library provides a definition to the API declared in *rmw*. At the moment we have a partial definition of that API including:

- Nodes.
- Publishers.
- Subscription.
- Wait on subscriptions.

The middleware used to implement these components is Micro XRCE-DDS.

5.1.1 Nodes

This component provides the upper layer, *rcl*, with the capability to create Nodes. In our case, a Node initializes a Micro XRCE-DDS session and creates a participant in the Micro XRCE-DDS Agent.

In micro-ROS there is a limited amount of nodes to be created. This limitation can be configured in the user configuration before building the application.

5.1.2 Publishers

With a node, the *rcl* can create a publisher to a topic upon user request. To create the publisher, the upper layers provide the type support for the type of the topic along with the topic name itself. The creation of a rmw_publisher creates a publisher a datawriter and registers the topic in the Micro XRCE-DDS Agent.

In *rmw_microxrcedds* the creation of the entities could be configured to use XML or refs. Some of their fundamental differences are:

- rmw generates XML at runtime and refs are statically configured, with all the memory requirements this implies. Memory wise; refs are less memory demanding than XML representations.
- XMLs are generated at runtime, and refs need to be pre-configured in the Micro XRCE-DDS Agent.
- Refs reduce the payload size, so it provides an improvement in bandwidth usage compared to the usage of XML.

In this first version, there is a Micro-ROS-agent package which generates that Micro XRCE-DDS Agent and its configuration for you automatically using the ROS message definitions built.

Once a publisher is created *rmw_microxrcedds* implements a publishing API. This will take a non-serialized message for a topic, serialize it using the type support provided to the publisher creation function and then push the message to the Micro XRCE-DDS Agent.

5.1.3 Subscriptions

Analogous to publishers, subscriptions can be created using an already created node. On subscription creation, a subscriber and datareader are created on Micro XRCE-DDS Agent, and the topic is registered.

A vital thing to notice is that topic messages are not received until a wait is performed. For more information on the reasons for this, please read the official Micro XRCE-DDS documentation along with the XRCE-DDS protocol it implements.

On each call to wait, only one subscription is processed, so to process all the subscriptions, some looping mechanism should be provided (spin functions, for example).

5.1.4 Waits

For message receptions, rmw_wait must be performed. On this call, *rmw_microxrcedds* will ask all the publications to get new data from their topics. That request uses the Micro XRCE-DDS request data function, which asks the Micro XRCE-DDS Agent for the latest messages on the topics.

After requesting data, *rmw_microxrcedds* waits on the Micro XRCE-DDS session till a timeout occurs or at least one new topic message arrived. The subscription is flagged as pending to read data from.

Once the wait gets triggered, a take data is called for the subscription with new messages. This call deserialises the data using the type support provided to the subscription on its creation and passes the deserialised data to the upper layers which will call the user callback.

5.2 Configuration

The middleware implementation uses static memory assignations. Because of this, assignations of the memory are upper bounded so must be configured by the user before the build process. By default, the package sets the values for all memory bounded. The upper bound is configurable by a file that sets the values during the build process. The configuration file is placed in the rmw implementation: 'rmw_microxrcedds_c/rmw_microxrcedds.config' and has the following configurable parameters.

- CONFIG_MICRO_XRCEDDS_TRANSPORT (UDP/Serial): This parameter sets the type of communication that the Micro XRCE-DDS client uses.
- CONFIG_IP: In case you are using the UDP communication mode, this value indicates the IP of the Micro XRCE-Agent.
- CONFIG_PORT: In case you are using the UDP communication mode, this value indicates the port used by the Micro XRCE-Agent.
- CONFIG_DEVICE: In case you are using the serial communication mode, this value indicates the file descriptor of the seal port (Linux).

- CONFIG_MICRO_XRCEDDS_CREATION_MODE: chooses the preferred XRCE-DDS entities creation method. It could be XML or references. Both create entities on the associated the Micro XRCE-DDS Agent; the difference is that the client dynamically creates XML, and references are pre-configured entities on the Micro XRCE-DDS Agent side.
- CONFIG_MAX_HISTORY: This value sets the number of MTUs buffers to. Micro XRCE-DDS client configuration provides their size.
- CONFIG_MAX_NODES: This value sets the maximum number of nodes.
- CONFIG_MAX_PUBLISHERS_X_NODE: This value sets the maximum number of publishers for a node.
- CONFIG_MAX_SUBSCRIPTIONS_X_NODE: This value sets the maximum number of subscriptions for a node.
- CONFIG_RMW_NODE_NAME_MAX_NAME_LENGTH: This value sets the maximum number of characters for a node name.
- CONFIG_RMW_TOPIC_NAME_MAX_NAME_LENGTH: This value sets the maximum number of characters for a topic name.
- CONFIG_RMW_TYPE_NAME_MAX_NAME_LENGTH: This value sets the maximum number of characters for a type name.

5.3 API guide

```
1 rmw_ret_t rmw_init(void)
```

Initialize all required parameters and functionalities for using the rmw_microxrcedds. It must be called before calling anything else.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
1 rmw_node_t * rmw_create_node(const char * name, const char * namespace, size_t domain_id, const
    rmw_node_security_options_t * security_options)
```

Create a new node. A new session with the Micro XRCE-DDS Agent will be opened.

name Node name.

namespace namespace.

domain_id Domain id.

security_options Ros2 security options. This parameter is not used.

Return Pointer to the owner node. If error, a NULL value is returned.

```
1 rmw_ret_t rmw_destroy_node(rmw_node_t * node)
```

Destroy node. The associated session with Micro XRCE-DDS Agent will be closed.

node Pointer to the owner node.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
const rmw_guard_condition_t * rmw_node_get_graph_guard_condition(const rmw_node_t * node)
```

No implemented yet.

```
rmw_publisher_t * rmw_create_publisher(const rmw_node_t * node, const rosidl_message_type_support_t *
    type_support, const char * topic_name, const rmw_qos_profile_t * qos_policies)
```

Create a new publisher. Required entities for the publisher in the Micro XRCE-DDS agent will be created.

node Pointer to the owner node.

type_support Used type support.

topic_name Pointer to topic name string.

qos_policies Pointer to quality of service pointer. The rmw_microxrccedds library does not use this parameter.

Return Pointer to the created publisher. If error, a NULL pointer is returned.

```
rmw_ret_t rmw_destroy_publisher(rmw_node_t * node, rmw_publisher_t * publisher)
```

Destroy an existing publisher. All created entities in the Micro XRCE-DDS Agent will be destroyed.

node Pointer to the owner node.

publisher Pointer to the publisher to destroy.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
rmw_ret_t rmw_publish(const rmw_publisher_t * publisher, const void * ros_message)
```

Publish a message using an existing publisher.

publisher Existing publisher pointer.

ros_message Pointer to message to publish.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
rmw_ret_t rmw_publish_serialized_message(const rmw_publisher_t * publisher, const
    rmw_serialized_message_t * serialized_message)
```

No implemented yet.

```
rmw_subscription_t * rmw_create_subscription(const rmw_node_t * node, const
    rosidl_message_type_support_t * type_support, const char * topic_name, const rmw_qos_profile_t *
    qos_policies, bool ignore_local_publications)
```

Create a new subscription. Required entities for the publisher in the Micro XRCE-DDS agent will be created.

qos_policies Pointer to quality of service polices. The rmw_microxrccedds library does not use this parameter.

ignore_local_publications Set True to ignore local publications. The rmw_microxrccedds library ignores this parameter.

Return Pointer to the created subscription. In error, a NULL pointer is returned.

```
rmw_ret_t rmw_destroy_subscription(rmw_node_t * node, rmw_subscription_t * subscription)
```

Destroy an existing subscription. All created entities in the Micro XRCE-DDS Agent will be destroyed.

node Pointer to the owner node.

subscription Pointer to the subscription to destroy.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
rmw_ret_t rmw_take(const rmw_subscription_t * subscription, void * ros_message, bool * taken)
```

Take a received subscription message.

subscription Pointer to the subscription object.

ros_message Pointer where the message will be stored.

taken Indicates if the message has been taken.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
1 rmw_ret_t rmw_take_with_info(const rmw_subscription_t * subscription, void * ros_message, bool *
    taken, rmw_message_info_t * message_info)
```

Take a received subscription message with info.

subscription Pointer to the subscription object.

ros_message Pointer where the message will be stored.

taken Indicates if the message has been taken.

message_info This parameter is not used.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
1 rmw_ret_t rmw_take_serialized_message(const rmw_subscription_t * subscription,
    rmw_serialized_message_t * serialized_message, bool * taken)
```

No implemented yet.

```
1 rmw_ret_t rmw_take_serialized_message_with_info(const rmw_subscription_t * subscription,
    rmw_serialized_message_t * serialized_message, bool * taken, rmw_message_info_t * message_info)
```

No implemented yet.

```
1 rmw_client_t * rmw_create_client(const rmw_node_t * node, const rosidl_service_type_support_t *
    type_support, const char * service_name, const rmw_qos_profile_t * qos_policies)
```

No implemented yet.

```
rmw_ret_t rmw_destroy_client(rmw_node_t * node, rmw_client_t * client)
```

No implemented yet.

```
rmw_ret_t rmw_send_request(const rmw_client_t * client, const void * ros_request, int64_t *
    sequence_id)
```

No implemented yet.

```
rmw_ret_t rmw_take_response(const rmw_client_t * client, rmw_request_id_t * request_header, void *
    ros_response, bool * taken)
```

No implemented yet.

```
rmw_ret_t rmw_service_server_is_available(const rmw_node_t * node, const rmw_client_t * client, bool
    * is_available)
```

No implemented yet.

```
rmw_service_t * rmw_create_service(const rmw_node_t * node, const rosidl_service_type_support_t *
    type_support, const char * service_name, const rmw_qos_profile_t * qos_policies)
```

No implemented yet.

```
rmw_ret_t rmw_destroy_service(rmw_node_t * node, rmw_service_t * service)
```

No implemented yet.

```
rmw_ret_t rmw_take_request(const rmw_service_t * service, rmw_request_id_t * request_header, void *
    ros_request, bool * taken)
```

No implemented yet.

```
rmw_ret_t rmw_send_response(const rmw_service_t * service, rmw_request_id_t * request_header, void *
    ros_response)
```

No implemented yet.

```
rmw_ret_t rmw_serialize(const void * ros_message, const rosidl_message_type_support_t * type_support,
    rmw_serialized_message_t * serialized_message)
```

No implemented yet.

```
rmw_ret_t rmw_deserialize(const rmw_serialized_message_t * serialized_message, const
    rosidl_message_type_support_t * type_support, void * ros_message)
```

No implemented yet.

```
rmw_guard_condition_t * rmw_create_guard_condition(void)
```

Create a new guard condition.

Return Created guard condition pointer. If error, a NULL pointer is returned.

```
rmw_ret_t rmw_destroy_guard_condition(rmw_guard_condition_t * guard_condition)
```

Destroy a guard condition.

guard_condition Pointer to guard condition to destroy.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
rmw_ret_t rmw_trigger_guard_condition(const rmw_guard_condition_t * guard_condition)
```

No implemented yet.

```
rmw_wait_set_t * rmw_create_wait_set(size_t max_conditions)
```

Create a new wait set.

Return Created wait set pointer. If error, a NULL pointer is returned.

```
rmw_ret_t rmw_destroy_wait_set(rmw_wait_set_t * wait_set)
```

Destroy a wait set.

wait_set Pointer to wait set to destroy.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
rmw_ret_t rmw_wait(rmw_subscriptions_t * subscriptions, rmw_guard_conditions_t * guard_conditions,
    rmw_services_t * services, rmw_clients_t * clients, rmw_wait_set_t * wait_set, const rmw_time_t *
    wait_timeout)
```

Waits until one of the given events occurs.

subscriptions Pointer to subscriptions list to wait. Set to NULL to ignore.

guard_conditions Pointer to guard conditions list to wait. Set to NULL to ignore. This parameter not supported yet.

services Pointer to services list to wait. Set to NULL to ignore. This parameter not supported yet.

clients Pointer to clients list to wait. Set to NULL to ignore. This parameter not supported yet.

wait_set Pointer to wait set list to wait. Set to NULL to ignore. This parameter not supported yet.

wait_timeout Max time to wait until a timeout occurs.

Return:

- RMW_RET_OK
- RMW_RET_ERROR
- RMW_RET_TIMEOUT

```
rmw_ret_t rmw_get_node_names(const rmw_node_t * node, rcutils_string_array_t * node_names)
```

No implemented yet.

```
rmw_ret_t rmw_count_publishers(const rmw_node_t * node, const char * topic_name, size_t * count)
```

No implemented yet.

```
rmw_ret_t rmw_count_subscribers(const rmw_node_t * node, const char * topic_name, size_t * count)
```

No implemented yet.

```
rmw_ret_t rmw_get_gid_for_publisher(const rmw_publisher_t * publisher, rmw_gid_t * gid)
```

No implemented yet.

```
rmw_ret_t rmw_compare_gids_equal(const rmw_gid_t * gid1, const rmw_gid_t * gid2, bool * result)
```

No implemented yet.

```
rmw_ret_t rmw_set_log_severity(rmw_log_severity_t severity)
```

No implemented yet.

```
rmw_ret_t rmw_get_topic_names_and_types(const rmw_node_t * node, rcutils_allocator_t * allocator,
    bool no_demangle, rmw_names_and_types_t * topic_names_and_types)
```

No implemented yet.

```
rmw_ret_t rmw_get_service_names_and_types(const rmw_node_t * node, rcutils_allocator_t * allocator,
    rmw_names_and_types_t * service_names_and_types)
```

No implemented yet.

5.4 Roadmap

Here we will enumerate all the planned features that will be released in the future.

- Services support.
- Graph support.
- Full static memory allocate support

6 Annex 2: GitHub documentation (type support)

In Micro-ROS, as in regular ROS2, message types are defined using .msg files. During Micro-ROS compilation the .msg files are used to generate a type support library with all the needed code to create, serialise and deserialise message types.

This process is automatic, and the only user interaction is for creating the message definition files and for the use of the generated code and utilities provided by rclc.

6.1 Architecture

For Micro-ROS, the type support used is *rosidl_typesupport_microxrcedds_c* for C language. This ROS2 package generates Micro XRCE-DDS and Micro-CDR specific code to handle all the message types.

In Micro-ROS case, Micro XRCE-DDS type support generates four functions:

- cdr_serialize
- cdr_deserialise
- get_serialized_size
- max_serialized_size

Those four functions are equivalent to the ones generated by Micro XRCE-DDS Gen tool from Micro XRCE-DDS implementation. In Micro-ROS, *rosidl_typesupport_microxrcedds_c* generates code straight from .msg files without using intermediate IDLs nor Micro XRCE-DDS Gen. This generation uses a group of EmPy templates you can find in the *rosidl_typesupport_microxrcedds_c* package.

6.2 API guide

6.2.1 Message type support

The generated message type support has a struct that contains the API used to handle the message serialisation and deserialisation.

```
const char * package_name_
```

Package name where the generated message code belongs.

```
const char * message_name_;
```

Message name

```
bool cdr_serialize(const void * untyped_ros_message, ucdrBuffer * cdr)
```

Serialize the message into a micro cdr buffer.

untyped_ros_message Message pointer to serialize.

cdr Micro buffer.

return True if successful.

```
bool cdr_deserialize(ucdrBuffer * cdr, void * untyped_ros_message, uint8_t * raw_mem_ptr, size_t
    raw_mem_size)
```

Deserialize the serialized message contained into the micro cdr buffer.

cdr Micro buffer.

untyped_ros_message Message struct pointer where the message will be deserialised.

raw_mem_ptr Byte memory pointer used to deserialise unbounded message data. If NULL, unbounded data will be not deserialised.

raw_mem_size Byte memory size.

return True if successful.

```
uint32_t get_serialized_size(const void *);
```

Get the se rialized message size.

return Size.

```
size_t max_serialized_size(bool full_bounded);
```

Get the maximum serialized message size.

6.2.2 Service type support

The generated service type support has a struct that contains the API used to handle the service. This API will provide a message type support for the client request message and message type support for the service request message.

```
const char * package_name_;
```

Package name where the generated message code belongs.

```
const char * service_name_;
```

Service name.

```
const rosidl_message_type_support_t * request_members_();
```

Message type support for the request.

return Type support pointer.

```
const rosidl_message_type_support_t * response_members_();
```

Message type support API for the message response.

return Type support pointer.

6.3 Code generation for C type-support

Type support generation starting point is a set of .msg files. These kind of files are the input for *rosidl_generator_c* ROS2 package which processes them and starts the type support generation during application build.

rosidl_generator_c take those message definitions and generates code from each one. It generates the *.h* that you should include to use your type. The code files generated by *rosidl_generator_c* provides you with the .msg definition in C along with the type support for it.

This type support, in this case, is tied with the code generated by *rosidl_typessuport_c*. *rosidl_typessuport_c* is another ROS2 package which generates functions to get the underlying middleware type support for each type. In our case, as we support *rosidl_typesupport_microxrcedds_c*, *rosidl_typessuport_c* generates a function which makes the association between the type and the type support used for Micro XRCE-DDS.

rosidl_typesupport_microxrcedds_c ROS2 package generates middleware-specific functions per each .msg found. This middleware-specific functions in our case include serialisation and deserialisation using Micro-CDR as in any other Micro XRCE-DDS application. Those functions get stored in a *rosidl_message_type_support_t* C structure which is used in the ROS2 messages serialisation and deserialisation later on.

As a result of this process, you will end up having a type representation and type support for it. The former should be used to represent data of that type, and the former are the structures which provide information to the publishers and subscribers on how to handle (serialise/deserialise) the type.

6.3.1 Usage

To use any type, you need to include the generated *.h* which provides you with enough utilities to create messages of that type. Also, it would help if you had a way to get the type support used by this type, for that purpose you have to get the type support functions. For simplicity, rclc provides a macro to help you get the right function names which give you the required *rosidl_message_type_support_t* tied to your type.

The *RCLC_GET_MSG_TYPE_SUPPORT* macro obtains the associated *rosidl_message_type_support_t* auto generated from the msg using *rosidl_generator_c*, *rosidl_typessuport_c* and *rosidl_typesupport_microxrcedds_c* ROS2 packages.

6.4 Usage examples

In this section, an example of how to generate a simple message will be described.

6.4.1 package.xml file

The ROS2 manifest must have the below dependencies:

- Must be *member_of_group* of *rosidl_interface_packages* group.
- Is *buildtool_depend* dependent of *rosidl_default_generators*

```
1 ...
2 <buildtool_depend>rosidl_default_generators</buildtool_depend>
3 <member_of_group>rosidl_interface_packages</member_of_group>
4 ...
```

6.4.2 Message.msg file

For this example, the ROS2 message will be as described below.

```
1 int32 data
```

6.4.3 CMakeList.txt file

Find the rosidl_default_generators package with REQUIRED rule.

```
find_package(rosidl_default_generators REQUIRED)
```

Call the *rosidl_generate_interfaces* macro giving the message relative path, the message dependencies and the name of the generation target.

```
rosidl_generate_interfaces(
    ${PROJECT_NAME}
    "Message.msg"
    DEPENDENCIES "builtin_interfaces"
    ADD_LINTER_TESTS
)
```

6.5 Roadmap

Here we will enumerate all the planned features that will be released in the future.

- Cpp type support for rclcpp.
- Services support in C language
- Services support in Cpp language.
- Upper bounded and unbounded arrays support in C language
- Upper bounded and unbounded arrays support in Cpp language