Neuron SDK

User's Manual

Powerful SDK for Intelligent Robotics Development

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LEADING EDGE COMPUTING

Preface

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Revision History

Revision	Description	Date
1.0	Initial release	2021-04-14

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1 Introduction

ADLINK’s Neuron SDK is a powerful software development package for intelligent robotics development based on the Open Robotics Robotic Operating System 2 (ROS 2) project. ROS 2 is the successor to the highly successful Robotic Operating System (ROS 1), and is now an industry standard robotic middleware.

Despite the success, ROS 1 had certain weakness due to its fundamental design. To address these issues, Open Robotics started development of ROS 2. By incorporating DDS as its data delivery mechanism, ROS 2 comes with several advanced features, including:

- Removed dependency on a single master (i.e. roscore) broker.
- Node life-cycle management.
- Better launch system, with time control and/or criteria.
- Support for different DDS vendors.
- Support for real-time operating systems

As a result of addressing many critical aspects of the robotic system, ROS 2 is becoming the new standard for the industry. Porting packages from ROS1 to ROS 2 is progressing rapidly and robotics platforms such as TurtleBot, Navigation, and Intel® Movidius™ are already ROS 2 ready. ROS 2 LTS Foxy Fitzroy was released on June 5th, 2020 for Ubuntu 20.04 LTS. Foxy will be supported for three years.

Neuron SDK is based on Eclipse Cyclone DDS and has the following features:

- Neuron Startup Menu to easily switch ROS development environment
- Neuron App as a reference design to reduce development time
- Neuron IDE for better development experience
- Neuron Library to operate peripheral of controllers, includes ROS 2 examples
- Shared memory that dramatically reduces resource costs and time delays
- Added QoS for ROS 2: Ownership (see 7.3.2 ADLINK Extra QoS - Ownership)

This user’s manual provides an explanation of the Neuron SDK features. Refer to the following sections for detailed descriptions.

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2 Installation Guide

The chapter describes how to install Neuron SDK on ADLINK ROS controllers. You can download the Neuron SDK package from the ADLINK website. The filename format of Neuron SDK is as follows:

Neuron-SDK_<ROS version>_<NSDK version>_<Architecture>.run

For example, **Neuron-SDK_foxy_1.0.0_x86-64.run** is Neuron SDK for ROS 2 Foxy, version 1.0.0, and able to run on an x86 platform.

2.1 Supported Platforms

The following platforms are supported by Neuron SDK:

- Supported OS platform:
  - Ubuntu 20.04
- Supported ROS version:
  - ROS 2 LTS Foxy Fitzroy

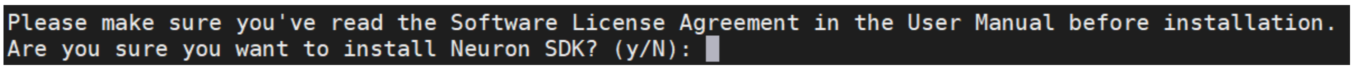
2.2 Installation Procedure

To install Neuron SDK, follow the steps below. Make sure the controller is connected to the Internet.

1. Install Ubuntu on the controller.
2. Connect the controller to the Internet and install Neuron SDK from the terminal.

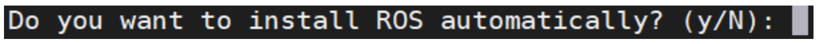
```
chmod a+x Neuron-SDK_foxy_1.0.0_x86-64.run
./Neuron-SDK_foxy_1.0.0_x86-64.run
```

3. A prompt will appear asking you to read the Software License Agreement in this user's manual (Ch. 8 Software License Agreement on page 47). Enter "Y" to continue installing Neuron SDK.



```
Please make sure you've read the Software License Agreement in the User Manual before installation.
Are you sure you want to install Neuron SDK? (y/N):
```

4. After installation, you will be asked to install ROS 1 and ROS 2. Enter "Y" if ROS is not installed on your controller.

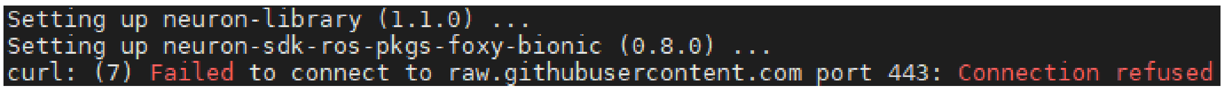


```
Do you want to install ROS automatically? (y/N):
```

5. The next time you open the terminal, you will see the Neuron Startup Menu. Select "ROS 2 foxy Neuron SDK" to run Neuron SDK (see Sec. 3.1 Usage on page 5).

2.3 Installation Troubleshooting

If you encounter a connection failure due to the **curl** command not recognizing the domain name while installing Neuron SDK, you must manually bind the URL to an IP address.



```
Setting up neuron-library (1.1.0) ...
Setting up neuron-sdk-ros-pkgs-foxy-bionic (0.8.0) ...
curl: (7) Failed to connect to raw.githubusercontent.com port 443: Connection refused
```

Follow steps below to fix the error.

1. Check if your system can connect to githubusercontent.com.

```
ping raw.githubusercontent.com
```

If the output is as follows, it means the system can connect to the target host, and the domain name server can translate the URL into the IP address (199.232.28.133). If you cannot make the connection, check your internet settings.

```
64 bytes from 199.232.28.133: icmp_seq=1 ttl=51 time=34.6 ms
```

2. Use a text editor to open /etc/hosts.

```
sudo gedit /etc/hosts
```

In the /etc/hosts file, add one line to map the IP address (199.232.28.133) from last step to raw.githubusercontent.com.

```
199.232.28.133 raw.githubusercontent.com
```

3. Save and close the modified /etc/hosts file.
4. Reinstall Neuron SDK. (See 2.2 Installation Procedure)

2.4 Manage Neuron SDK

To manage Neuron SDK, you can use the following nsdk-manager command line options.

- Show the current Neuron SDK version.

```
/opt/adlink/neuron-sdk/nsdk-manager version
```

- Uninstall Neuron SDK.

```
/opt/adlink/neuron-sdk/nsdk-manager uninstall
```

3 Neuron Startup Menu

Unix based systems often store its parameters in a format of "shell variables", commonly referred to as "environmental variables". Scripts and programs constantly load these variables as execution parameters or for internal usage. The process of configuring environmental variables is very tedious, especially when there are many conflicting settings between ROS / ROS 2, Python2 / Python3, OpenCV2 / OpenCV3, etc. Fortunately, Neuron SDK comes with a tool that prepares the environment for you: the **Neuron Startup Menu**.

After installing Neuron SDK, the user-friendly Neuron Startup Menu will display at each terminal startup. You can select from ROS, ROS 2 or ROS bridge in the menu. This saves time setting ROS environmental variables every time you open the terminal.

3.1 Usage

After installation, next time you open the shell, the terminal will show the following menu.

```
************ Neuron Startup Menu for ROS *************
* Usage: Please select the following options to load *
*              ROS environment automatically.             *
******************************************************
0) Do nothing
1) ROS 1 noetic
2) ROS 2 foxy
3) ROS 2 foxy Neuron SDK
4) ROS2/ROS1_bridge
h) Help
Please choose an option:
```

The menu options are as follows:

- Do nothing
  1. Don't setup an environment.
- ROS 1 noetic
  1. Setup a ROS1 environment.
  2. Set ROS_IP and ROS_MASTER_IP to be the same as your host IP.
- ROS 2 foxy
  1. Setup a ROS2 environment.
  2. Set ROS_DOMAIN_ID to 30 and RMW_IMPLEMENTATION to CycloneDDS.
- ROS 2 foxy Neuron SDK
  1. Do the same as “ROS 2 foxy”
  2. Setup a Neuron SDK environment.
- ROS2/ROS1_Bridge
  1. Do all the above for both ROS 1 and ROS 2 options.
  2. Run ROS bridge automatically.
- Help
  1. Show the ros_menu usage list.

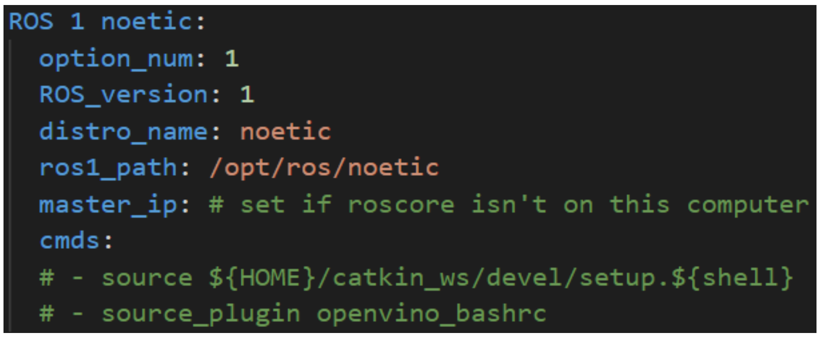
After selecting your option, you can view your settings via environmental variables or by running “**ros_menu_env**”.

```
# Check ROS version (1 or 2)
echo $ROS_VERSION
# Check ROS distribution (e.g. foxy)
echo $ROS_DISTRO
# Check DDS implementation (e.g. rmw_cyclonedds_cpp)
echo $RMW_IMPLEMENTATION
```

3.2 Configuration

You can configure the menu easily by modify ~/ros_menu/config.yaml. The following are the options you can control.

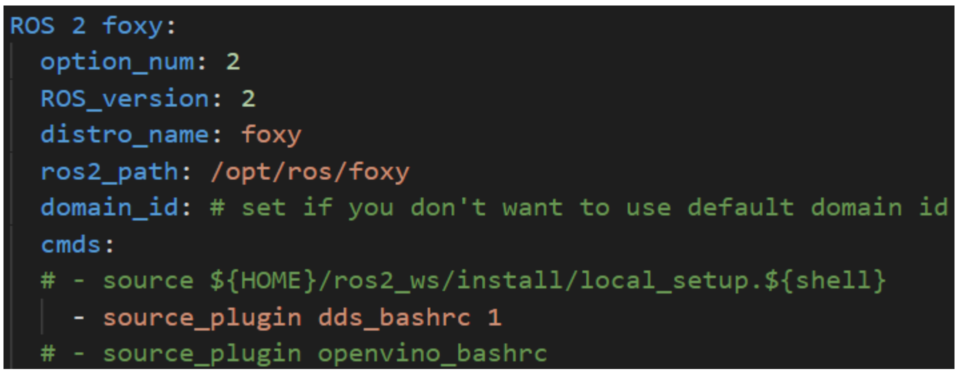
- Config:
  - menu_enable: "true" to enable the menu, “false” or otherwise do nothing.
  - ros_option: “menu” to show the whole menu, or any option_num you set to choose the option automatically.
  - default_ros_domain_id: set if you want to have the same domain ID for every ROS 2 version, otherwise the domain ID will be set to 30.
- Menu setting:
  - ROS 1:
    - option_num: give the option name to this option, avoid using specific characters(e.g:help,H,h,0) or duplicate option name
    - ROS_version: 1
    - distro_name: the name of the ROS 1 you are using.
    - ros1_path: the path where the ROS 1 is.
    - master_ip: set the IP address of the master if master isn't on current computer.
    - cmds: source your ROS 1 workspace here.



```
ROS 1 noetic:
  option_num: 1
  ROS_version: 1
  distro_name: noetic
  ros1_path: /opt/ros/noetic
  master_ip: # set if roscore isn't on this computer
  cmds:
  # - source ${HOME}/catkin_ws/devel/setup.${shell}
  # - source_plugin openvino_bashrc
```

  - ROS 2:
    - option_num: give the option name to this option, avoid using specific characters(e.g:help,H,h,0) or duplicate option name
    - ROS_version: 2
    - distro_name: the name of the ROS 2 you are using.
    - ros2_path: the path where the ROS 2 is.
    - domain_id: set the Domain ID for DDS communication. Keep empty to use $default_ros_domain_id(30)
    - cmds: source your ROS 2 workspace here.

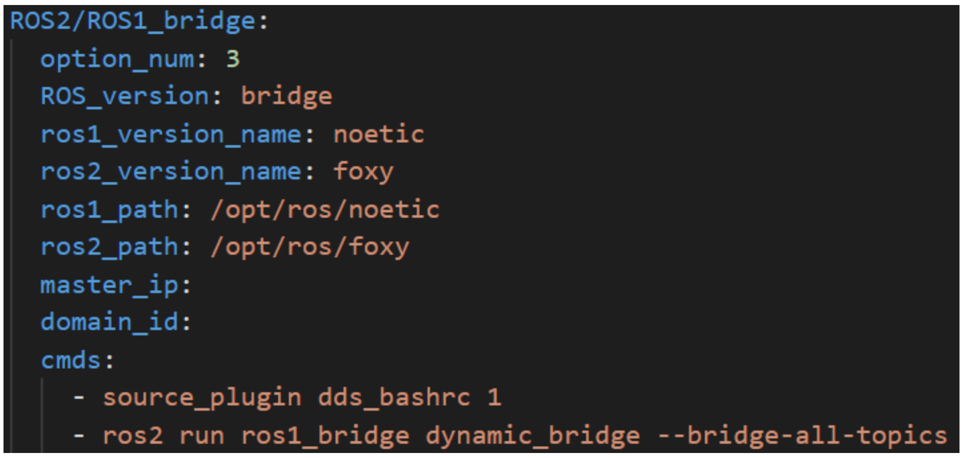
Note: source_plugin dds_bashrc is necessary when using ROS 2



```
ROS 2 foxy:
  option_num: 2
  ROS_version: 2
  distro_name: foxy
  ros2_path: /opt/ros/foxy
  domain_id: # set if you don't want to use default domain id
  cmds:
  # - source ${HOME}/ros2_ws/install/local_setup.${shell}
    - source_plugin dds_bashrc 1
  # - source_plugin openvino_bashrc
```

- ROS2/ROS1_bridge:
  - option_num: give the option name to this option, avoid using specific characters(e.g:help,H,h,0) or duplicate option name
  - ROS_version: bridge
  - ros1_version_name: the name of the ROS 1 you are using.
  - ros2_version_name: the name of the ROS 2 you are using.
  - ros1_path: the path where the ROS 1 is.
  - ros2_path: the path where the ROS 2 is.
  - master_ip: set the IP address of the master if master isn't on current computer.
  - domain_id: set the Domain ID for DDS communication. Keep empty to use $default_ros_domain_id(30)
  - cmds: any command you want to run every time using ROS bridge.

Note: source_plugin dds_bashrc and ros2 run ros1_bridge dynamic_bridge --bridge-all-topics is required when using ROS bridge



```
ROS2/ROS1_bridge:
  option_num: 3
  ROS_version: bridge
  ros1_version_name: noetic
  ros2_version_name: foxy
  ros1_path: /opt/ros/noetic
  ros2_path: /opt/ros/foxy
  master_ip:
  domain_id:
  cmds:
    - source_plugin dds_bashrc 1
    - ros2 run ros1_bridge dynamic_bridge --bridge-all-topics
```

3.3 Disable/Enable the Menu

To disable/enable the menu, type “ros_menu_disable“ / “ros_menu_enable”

```
#Disable ros_menu
ros_menu_disable
#Enable ros_menu
ros_menu_enable
```

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4 Neuron App

Neuron App is an integrated development package for AMR applications, ready for simulation and deployment on NeuronBot. When developing AMR applications, using Neuron App as a reference design can help reduce development time.

There are three essential AMR applications included in the Neuron IDE:

- **SLAM**: The Simultaneous Localization and Mapping (SLAM) application includes an algorithm that generates a map of the area surrounding a robot. With ranging data collected by LiDAR and pose data on the robot as input, SLAM performs mapping and localization at the same time. Remote operating a robot in the field will result in a complete 2D grid map as output.
- **Navigation**: A robot will locate itself by matching the input 2D grid map according to LiDAR, and autonomously navigate from one place to another. The path planner in this package can compute an optimized route and avoid obstacles to complete navigation.
- **Auto-inspection**: This application combines Behavior Tree, Navigation, and photos taken by an onboard camera. “Behavior Tree” is a task manager package which tasks the robot with autonomously navigating to each pre-defined location and then takes photos for each place. You can also implement deep learning object detection to reinforce robustness of inspection.

Neuron IDE is recommended for building and executing Neuron App on ADLINK hardware platforms for better performance. See the Neuron IDE section for more information on how to use Neuron App with Neuron IDE.

For more information on new apps, go to the Neuron App page on GitHub:

https://github.com/Adlink-ROS/neuron_app_overview

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5 Neuron IDE

5.1 Introduction

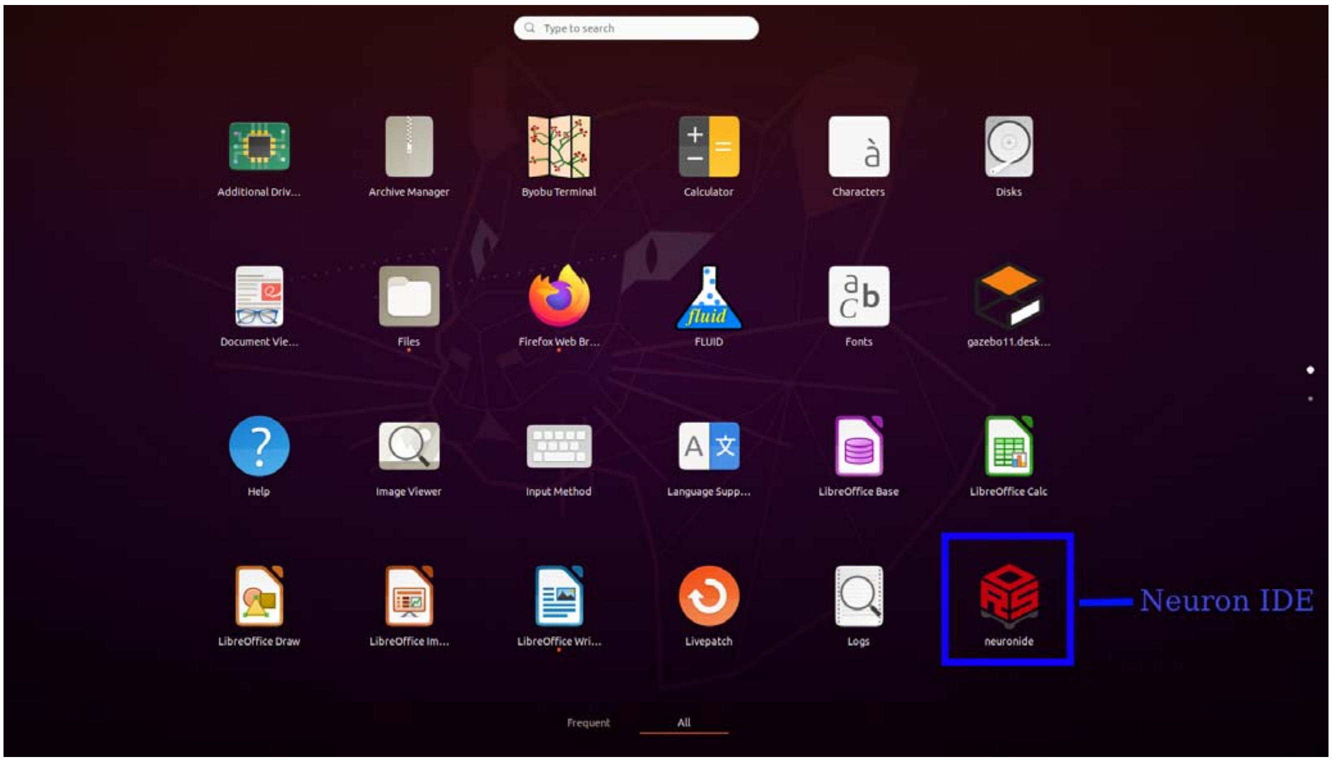
Neuron IDE is a code editor especially designed for ROS developers. It provides various functions for software development without the need to type commands in the terminal. By integrating with Git and ROS packages, developers now can find file management, version control, and code compilation in a single application.

With Neuron IDE, monitoring ROS processes is much more efficient. The ROS Resource Widget is used to launch ROS nodes, visualize sensor data via RVIZ, and dynamically adjust ROS parameters with RQT. Instead of launching these applications in different terminals, Neuron IDE can control all of them in a single terminal.

Note that Neuron IDE currently only support ROS 2.

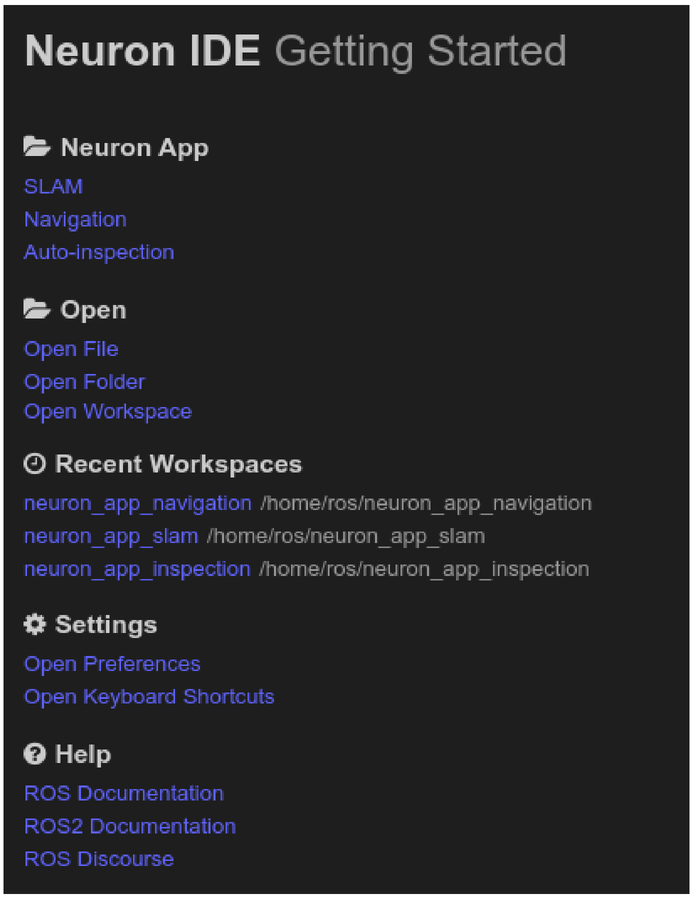
5.2 Installation

Neuron IDE comes preinstalled with **Neuron SDK**. Click the Show Applications icon to see the Neuron IDE shortcut.



5.3 Getting Started

When Neuron IDE is executed, the Getting Started page opens with a list of functions, as shown below.



Neuron IDE Getting Started

Neuron App
SLAM
Navigation
Auto-inspection

Open
Open File
Open Folder
Open Workspace

Recent Workspaces
neuron_app_navigation /home/ros/neuron_app_navigation
neuron_app_slam /home/ros/neuron_app_slam
neuron_app_inspection /home/ros/neuron_app_inspection

Settings
Open Preferences
Open Keyboard Shortcuts

Help
ROS Documentation
ROS2 Documentation
ROS Discourse

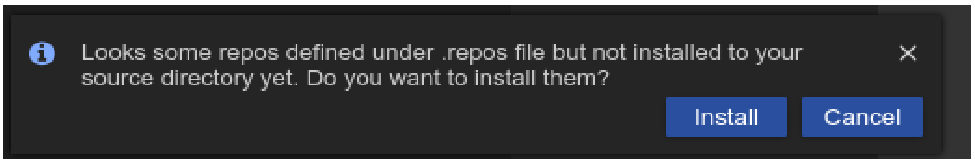
Some of the more important functions are further described in the following sections.

If you are already familiar with the functions of the Neuron IDE and would like to proceed directly to the user workflow, go to 5.3.4 User Workflow.

5.3.1 Neuron App

There are three Neuron Apps shown on the Getting Started page: SLAM, Navigation, and Auto-inspection.

Click any Neuron App to automatically download packages and enter its workspace. After entering the workspace, there is a notification at the bottom right corner indicating that you have to install the dependent packages defined in the Neuron App. Click ***install*** to install the dependencies and build the Neuron App.



Looks some repos defined under .repos file but not installed to your source directory yet. Do you want to install them?

For detailed information on the Neuron App Workspace, see Sec 5.3.3 Workspace.

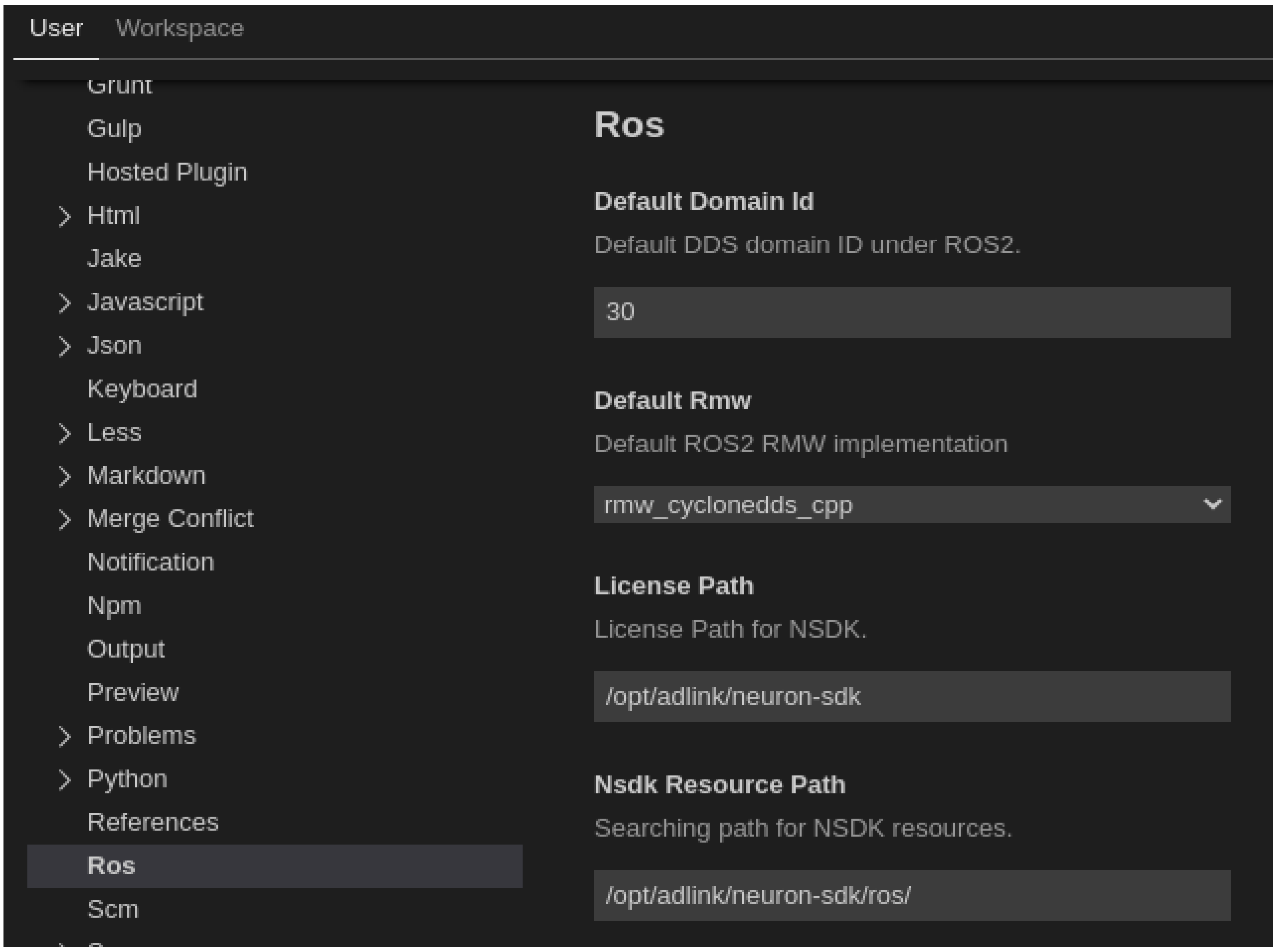
If there is an existing folder for package development, access the workspace by clicking ***Open Folder***. The folder should contain an **src** subfolder where the ROS packages should be placed.

5.3.2 Settings

Preferences are found and can be changed under ***Settings*** > ***Open Preference***. This section focuses only on the two parameters related to ROS usage, **Default Domain ID** and **Default Rmw**. To view the parameters, click ***Ros.***

- **Default Domain ID**: ROS 2 uses DDS as the underlying transport. DDS supports a physical segmentation of the network based on the "Domain ID". Make sure to separate machines for different uses under different domains.
- **Default Rmw**: Selects the ROS middleware vendor. The default value is **CycloneDDS**.

We do not recommend modifying other parameters (like License Path or Nsdk Resource Path) that could cause the Neuron IDE to stop working.



Ros

Default Domain Id

Default DDS domain ID under ROS2.

30

Default Rmw

Default ROS2 RMW implementation

rmw_cyclonedds_cpp

License Path

License Path for NSDK.

/opt/adlink/neuron-sdk

Nsdk Resource Path

Searching path for NSDK resources.

/opt/adlink/neuron-sdk/ros/

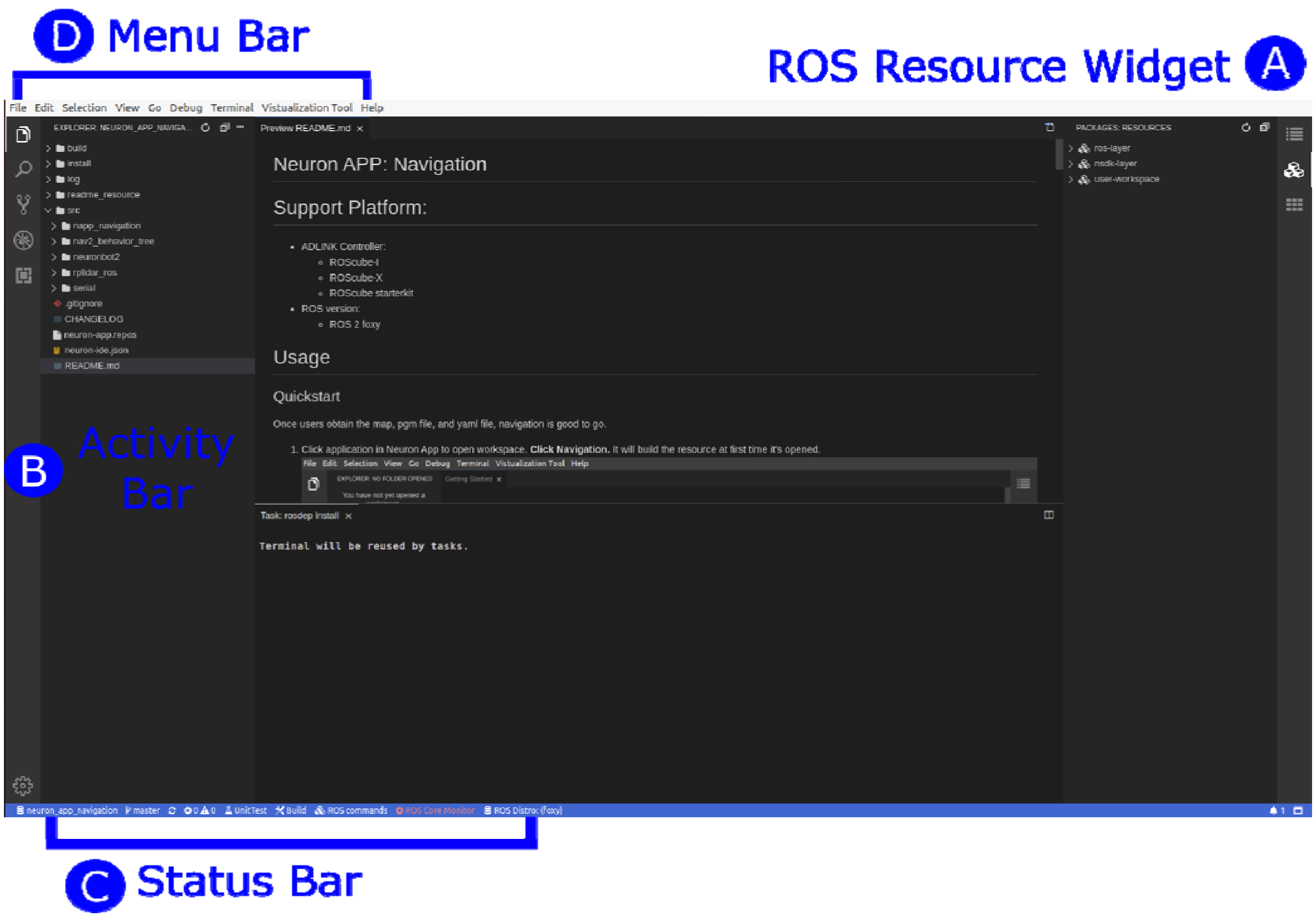
5.3.3 Workspace

As the main feature of Neuron IDE, workspace is where the ROS package development is done. A user interface with development tools is opened when accessing a Neuron App workspace. The development tools are easily accessed for ROS application development, include file editing, code compiling, and ROS resource management.

The workspace UI contains 4 elements:

- ROS Resource Widget
- Activity Bar
- Status Bar
- Menu Bar

Each of these elements is described in more detail in the sections below.



Neuron APP: Navigation

Support Platform:

- ADLINK Controller:
  - ROScube-I
  - ROScube-X
  - ROScube starterkit
- ROS version:
  - ROS 2 foxy

Usage

Quickstart

Once users obtain the map, pgm file, and yaml file, navigation is good to go.

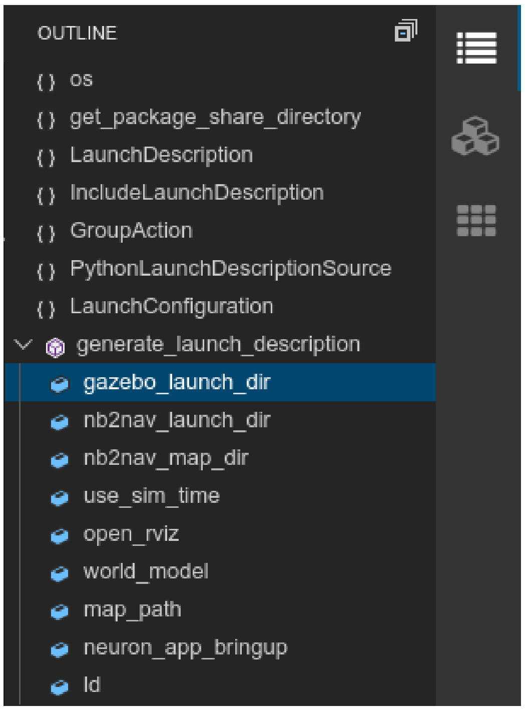
1. Click application in Neuron App to open workspace. **Click Navigation.** It will build the resource at first time it's opened.

```
Terminal will be reused by tasks.
```

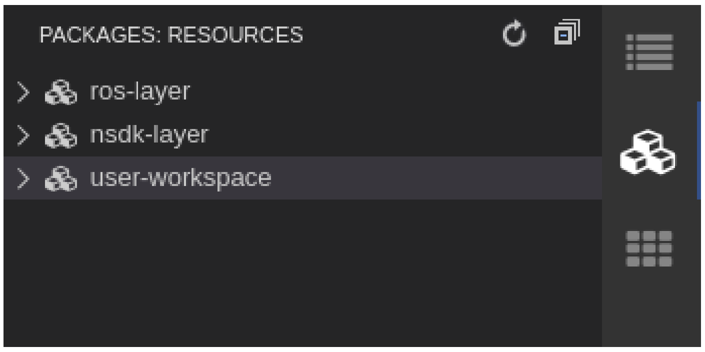
5.3.3.1 ROS Resource Widget

The ROS Resource Widget is the main toolbar for users to execute ROS functions. Developers can launch ROS applications in **Packages** and view active processes with **Monitor**.

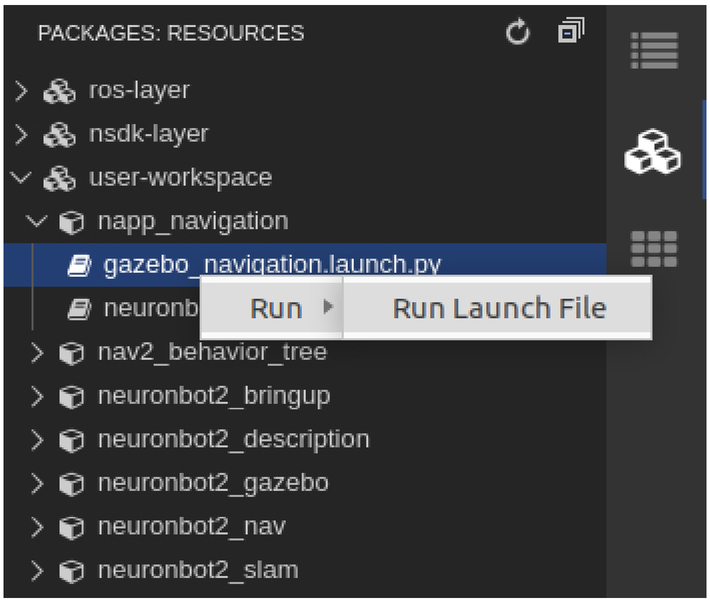
- **Outline**: The symbol tree of the current, active editor. It shows an overview of the code object in the current file. Click the name of an object to quickly jump to sections where it has been initially declared.



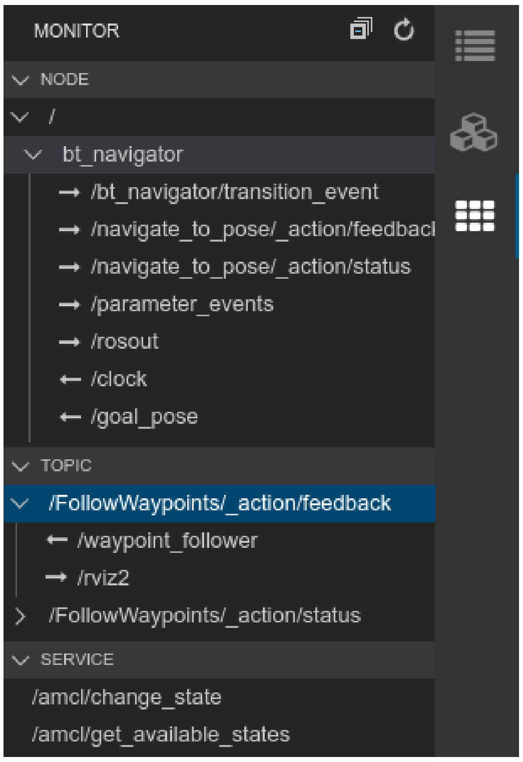
- **Packages**: List of user packages in the ROS environment. There are three categories:
    - ros-layer: Binary version of packages installed in the ROS repository
    - nsdk-layer: Overlay packages of Neuron SDK that executes functions of Neuron IDE as patches of the ros-layer package.
    - user-workspace: Built package in current workspace



The ***run*** and ***launch*** processes should be done in this section. Expand the resource list of the package, and then right-click on the selected launch file and click ***Run > Run launch file***.



- **Monitor**: Displays a list of executing processes.



MONITOR

NODE

/

bt_navigator

→ /bt_navigator/transition_event

→ /navigate_to_pose/_action/feedbacl

→ /navigate_to_pose/_action/status

→ /parameter_events

→ /rosout

← /clock

← /goal_pose

TOPIC

/FollowWaypoints/_action/feedback

← /waypoint_follower

→ /rviz2

/FollowWaypoints/_action/status

SERVICE

/amcl/change_state

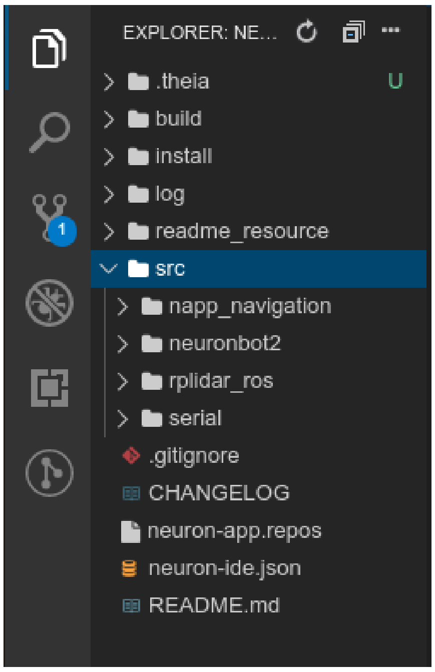
/amcl/get_available_states

- **Node**: List of current nodes. Expanding the list of each node shows topics and services related to the current node. A left-arrow indicates that a topic is published by the node. A right-arrow indicates that a topic is subscribed to by this node. An up-arrow indicates that the node is the service server.
- **Topic**: List of current topics. A left-arrow indicates that a node publishes this topic. A right-arrow shows the node subscribes to this topic.
- **Service**: List of current services.

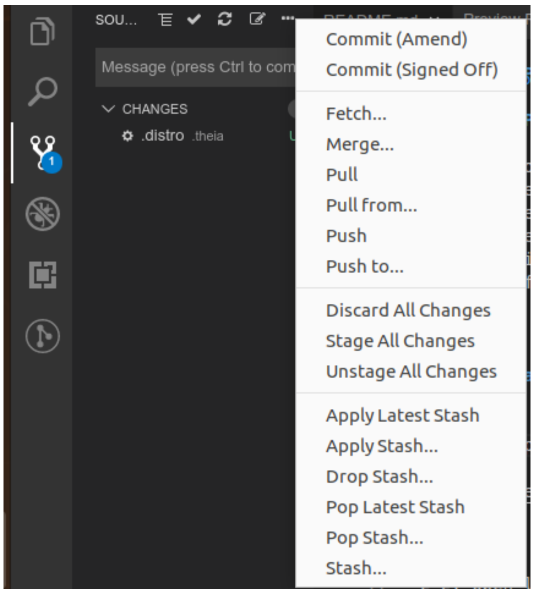
5.3.3.2 Activity Bar

The Activity Bar on the left can quickly switch between different components. Components can be inserted into the Activity Bar by clicking **View** in the **Menu Bar**.

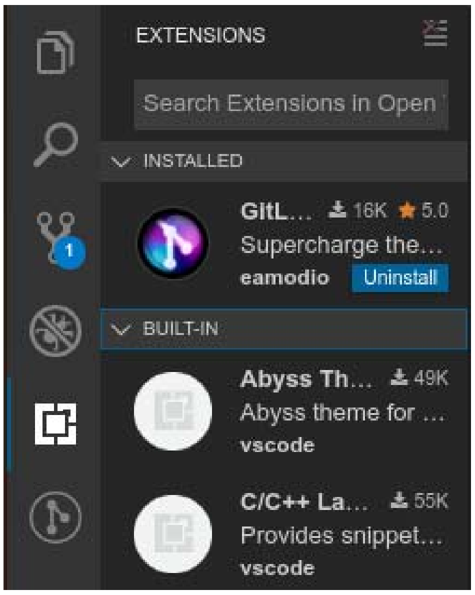
- **Explorer**: Used for file management in Neuron IDE to open, create, or edit files in the workspace.



- **Git**: Used for source control to compare file changes between commits. Git is an open-source distributed version control system that developers can use with various command to manage code changes and errors for projects. Found under “more actions”.

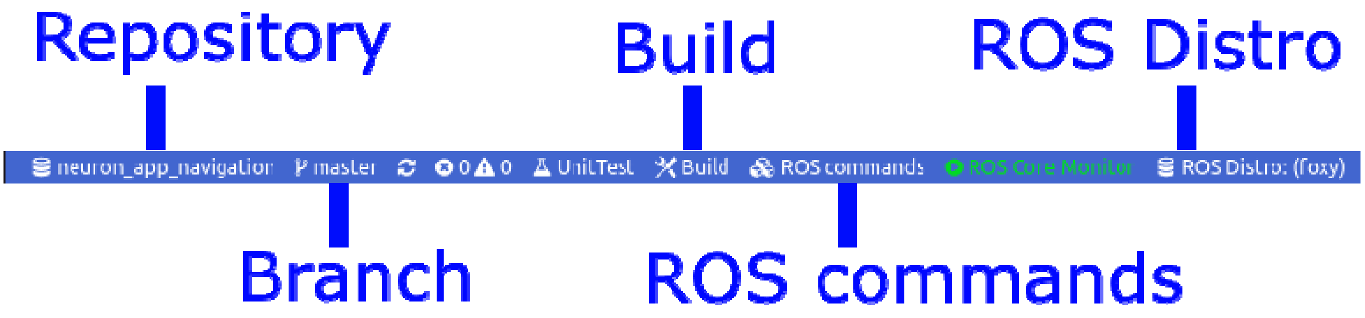


- **Extensions**: Used to install and manage additional extensions for programming.

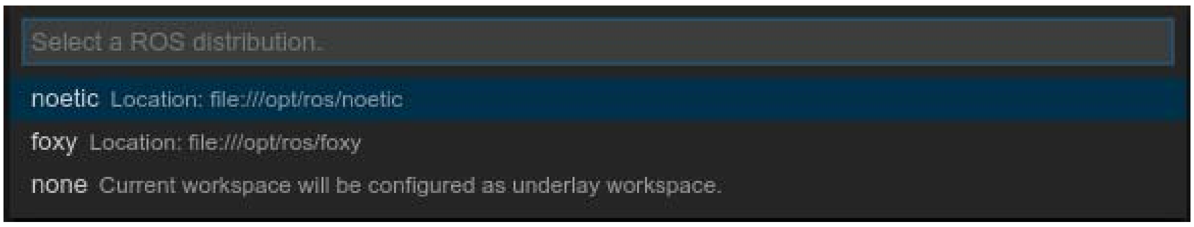


5.3.3.3 Status Bar

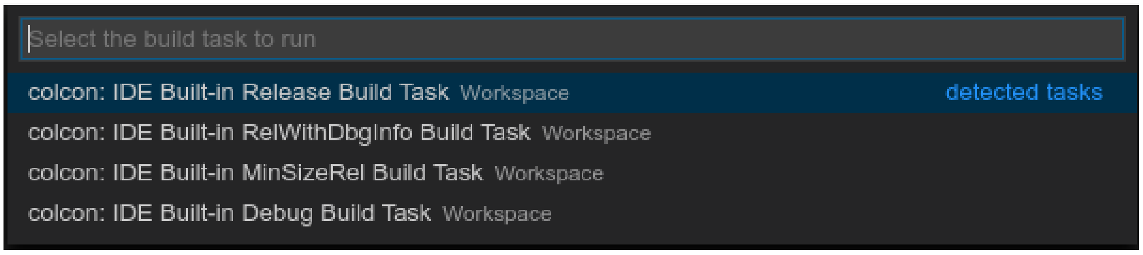
The Status Bar shows information about the open projects and the files you edit. It is provided to configure the Git repository and ROS environment for the current workspace.



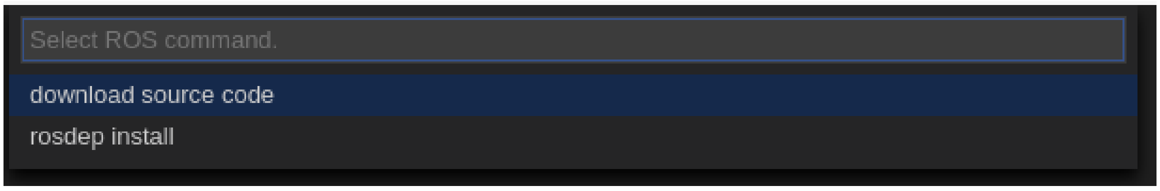
- **ROS Distro**: Selects the ROS distribution, versioned set of ROS packages, such as Foxy for ROS 2, or Noetic for ROS 1. ROS 2 foxy is the default version. Since ROS 1 is not supported now, you should only select ROS 2 version.


Select a ROS distribution.
noetic Location: file:///opt/ros/noetic
foxy Location: file:///opt/ros/foxy
none Current workspace will be configured as underlay workspace.

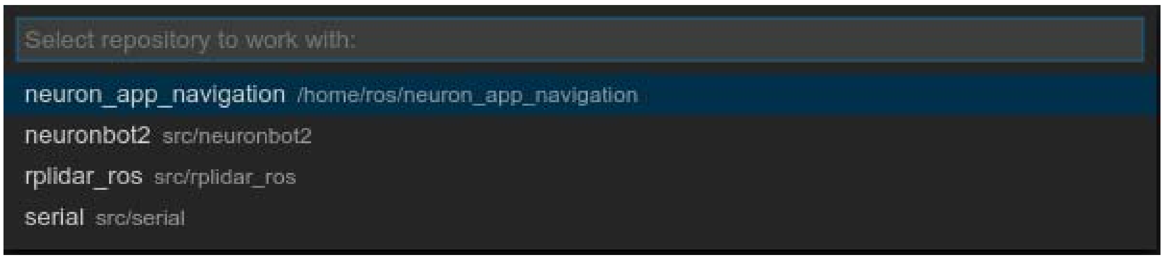
- **Build**: Compiles packages in your workspace. There are 4 build types can be specified:
  - Release: Build with no debugging information and full optimization.
  - Debug: Build including debugging information, no optimization, etc.
  - RelWithDebInfo: Same as ***Release***, but with debugging information.
  - MinSizeRel: Same as ***Release***, with optimization configuration set to minimize size.


Select the build task to run
colcon: IDE Built-in Release Build Task Workspace detected tasks
colcon: IDE Built-in RelWithDbgInfo Build Task Workspace
colcon: IDE Built-in MinSizeRel Build Task Workspace
colcon: IDE Built-in Debug Build Task Workspace

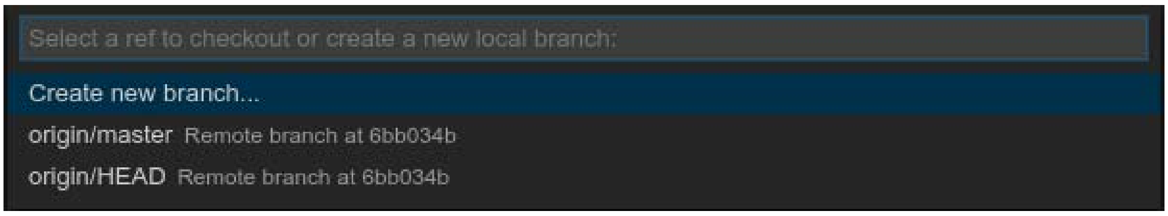
- **ROS commands**: Used to download source code or binary versions of ROS packages.
  - **download source code**: Download the Neuron App source code.
  - **rosdep install**: Install ROS dependencies required for ROS packages in workspaces.


Select ROS command.
download source code
rosdep install

- **Repository**: Switches the local Git repository to do source control. The Git section in the Activity Bar will be simultaneously changed.


Select repository to work with:
neuron_app_navigation /home/ros/neuron_app_navigation
neuronbot2 src/neuronbot2
rplidar_ros src/rplidar_ros
serial src/serial

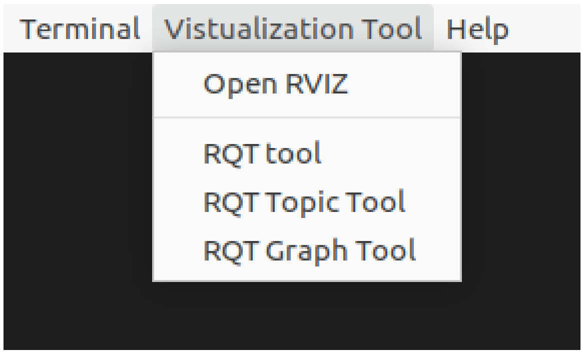
- **Branch**: Switches the Git branch of the current repository.


Select a ref to checkout or create a new local branch:
Create new branch...
origin/master Remote branch at 6bb034b
origin/HEAD Remote branch at 6bb034b

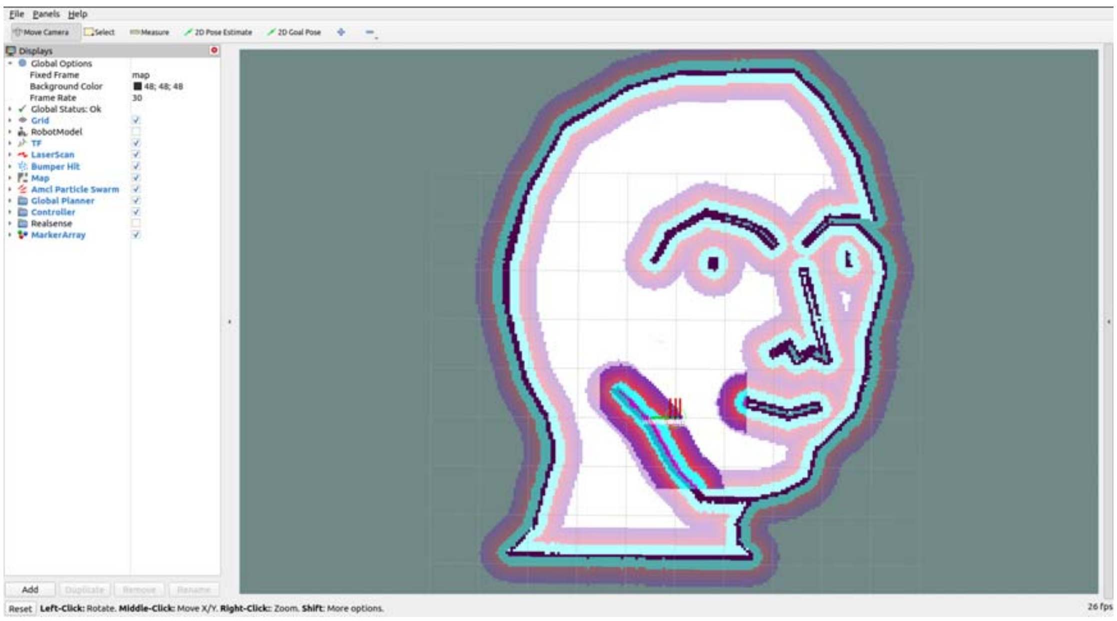
5.3.3.4 Menu Bar

The Menu Bar consists of the Neuron IDE basic operations. The following are development tools for ROS in the Menu Bar.

- **Visualization Tool**: Contains ROS GUI tools that visualize an active ROS node and data.



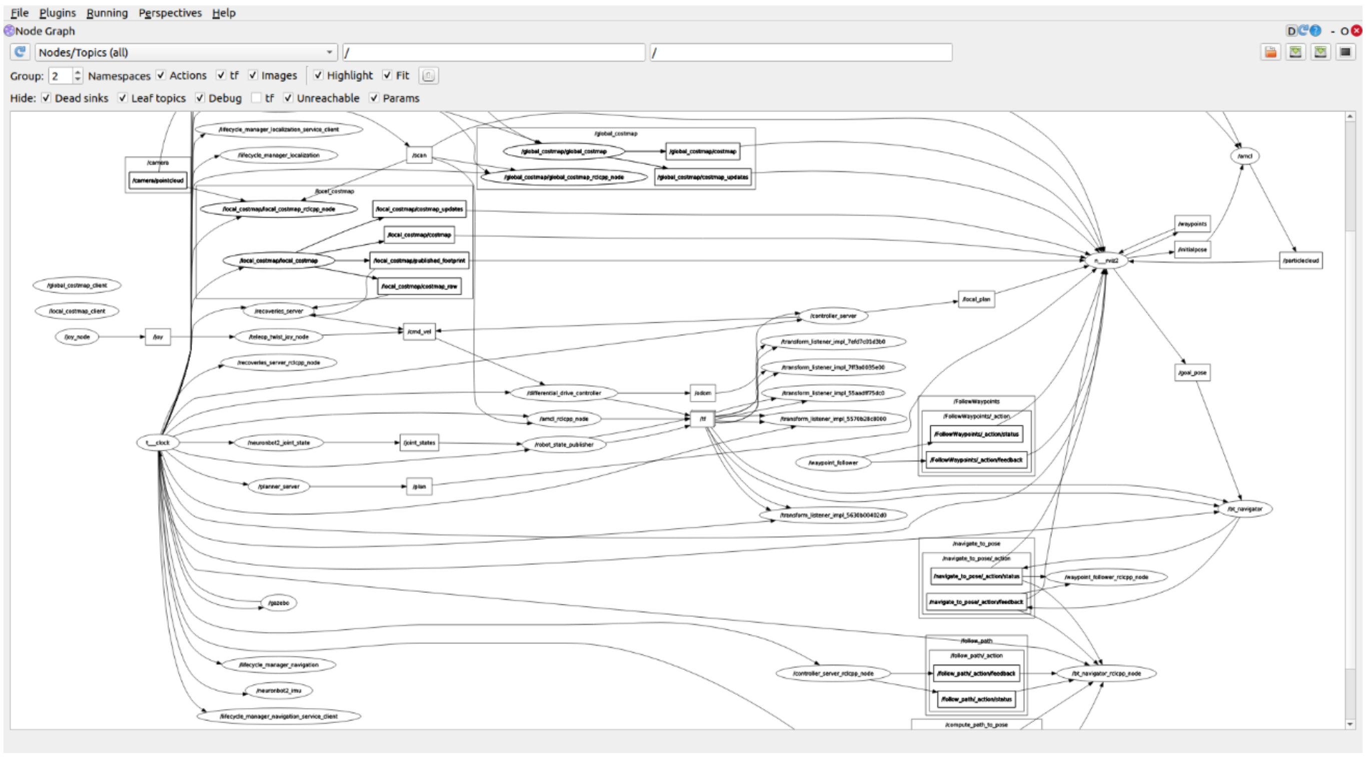
- RVIZ: A 3D visualizer for the ROS framework. It is used to display the position of each frame and published data, such as a laser scan, and point cloud.



Global Options	
Fixed Frame	map
Background Color	■ 48; 48; 48
Frame Rate	30
Global Status: Ok	
Grid	✓
RobotModel	
TF	✓
LaserScan	✓
Bumper Hit	✓
Map	✓
Amcl Particle Swarm	✓
Global Planner	✓
Controller	✓
Realsense	
MarkerArray	✓

Left-Click: Rotate. **Middle-Click:** Move X/Y. **Right-Click:** Zoom. **Shift:** More options.

- RQT: A graphical user interface framework that implements various tools and interfaces in the form of plugins. For example, in node graph you can monitor all the activating nodes and communicate between them.


File Plugins Running Perspectives Help

Node Graph

Nodes/Topics (all) / /

Group: 2 Namespaces ✓ Actions ✓ tf ✓ Images ✓ Highlight ✓ Fit

Hide: ✓ Dead sinks ✓ Leaf topics ✓ Debug tf ✓ Unreachable ✓ Params

/lifecycle_manager_localization_service_client
/lifecycle_manager_localization
/scan
/global_costmap
/global_costmap/global_costmap
/global_costmap/costmap
/global_costmap/global_costmap_rclcpp_node
/global_costmap/costmap_updates
/camera
/camera/pointcloud
/local_costmap
/local_costmap/local_costmap_rclcpp_node
/local_costmap/costmap_updates
/local_costmap/costmap
/local_costmap/local_costmap
/local_costmap/published_footprint
/local_costmap/costmap_raw
/amcl
/waypoints
/initialpose
/particlecloud
/global_costmap_client
/local_costmap_client
/joy_node
/joy
/recoveries_server
/teleop_twist_joy_node
/cmd_vel
/recoveries_server_rclcpp_node
/local_plan
/controller_server
/differential_drive_controller
/odom
/amcl_rclcpp_node
/tf
/goal_pose
/FollowWaypoints
/clock
/neuronbot2_joint_state
/joint_states
/robot_state_publisher
/waypoint_follower
/planner_server
/plan
/bt_navigator
/navigate_to_pose
/waypoint_follower_rclcpp_node
/gazebo
/follow_path
/lifecycle_manager_navigation
/neuronbot2_imu
/controller_server_rclcpp_node
/bt_navigator_rclcpp_node
/lifecycle_manager_navigation_service_client
/compute_path_to_pose

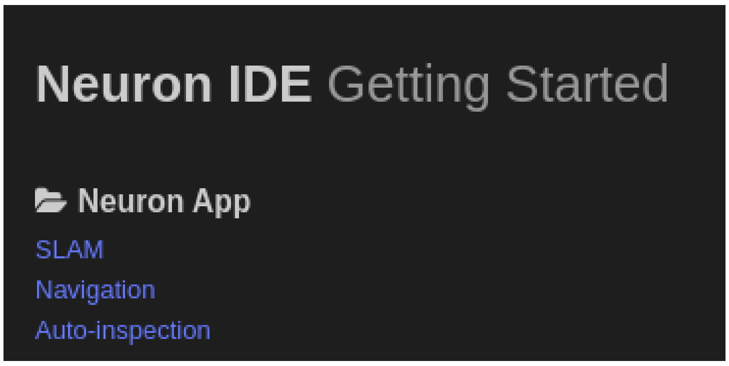
5.3.4 User Workflow

The followings are steps for developing Neuron Apps in the Neuron IDE workspace.

It is recommended that you deploy the Neuron App in the following order: SLAM → Navigation → Auto-inspection.

NOTE: shut down each terminal in the workspace when an application is done. Multiple Neuron Apps executed at the same time will cause Neuron IDE to become unstable.

1. Open a Neuron App workspace from the **Getting Started** page. (SLAM, Navigation, or Auto-inspection)


Neuron IDE Getting Started

Neuron App

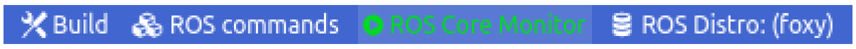
SLAM

Navigation

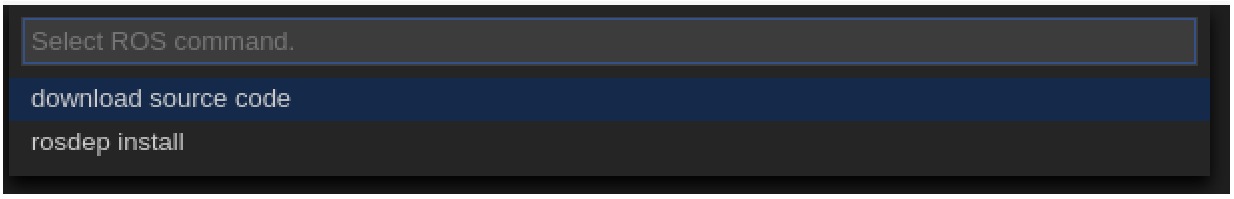
Auto-inspection

2. Download the required ROS package for the specific Neuron App.

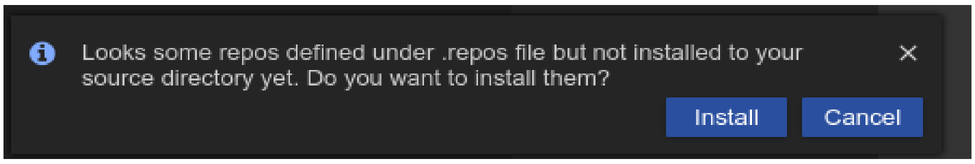
Click **ROS command** in the **Status Bar.**



Choose **download source code**.



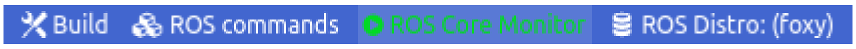
Click **Install** when prompted.



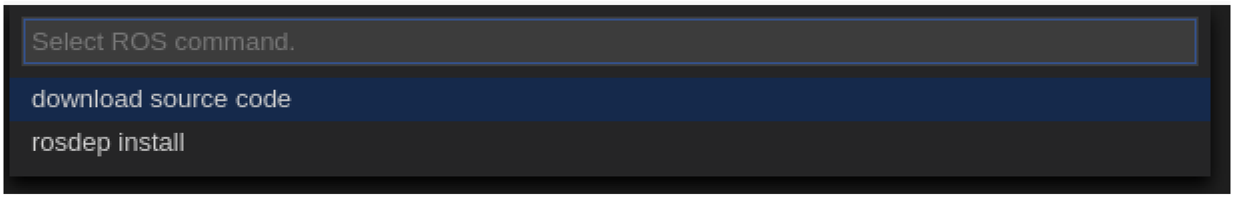
Looks some repos defined under .repos file but not installed to your source directory yet. Do you want to install them?

3. Install the binary version of the Neuron App dependency.

Click **ROS command** in the **Status Bar** at the bottom of the workspace.

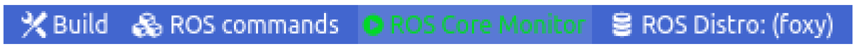


Choose **rosdep install**. Enter your password if required.

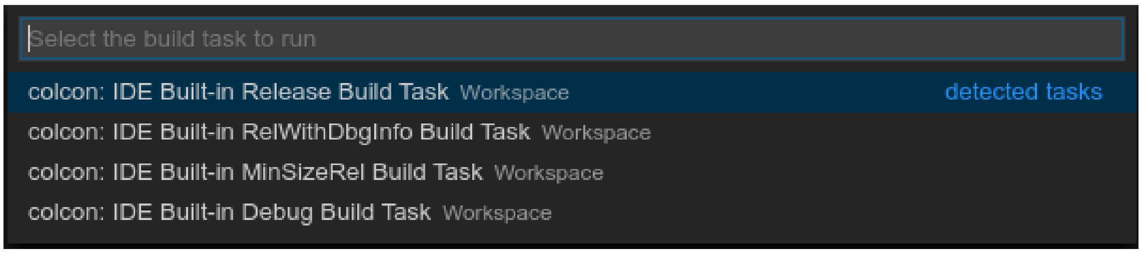


4. Build the ROS package in the current workspace.

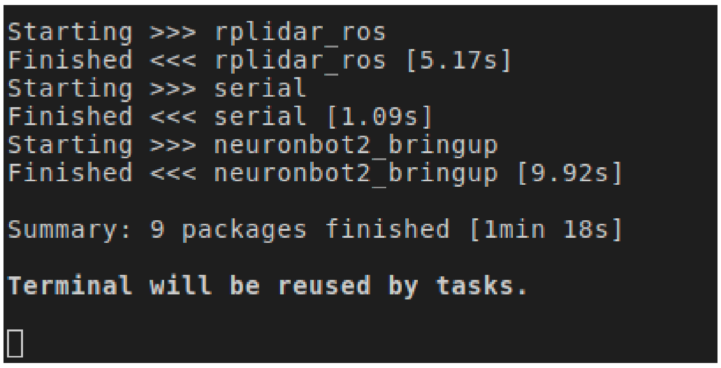
Click **Build** in the **Status Bar.**



Choose the desired build type.


Select the build task to run
colcon: IDE Built-in Release Build Task Workspace
detected tasks
colcon: IDE Built-in RelWithDbgInfo Build Task Workspace
colcon: IDE Built-in MinSizeRel Build Task Workspace
colcon: IDE Built-in Debug Build Task Workspace

The following message will be shown when the build task is done.



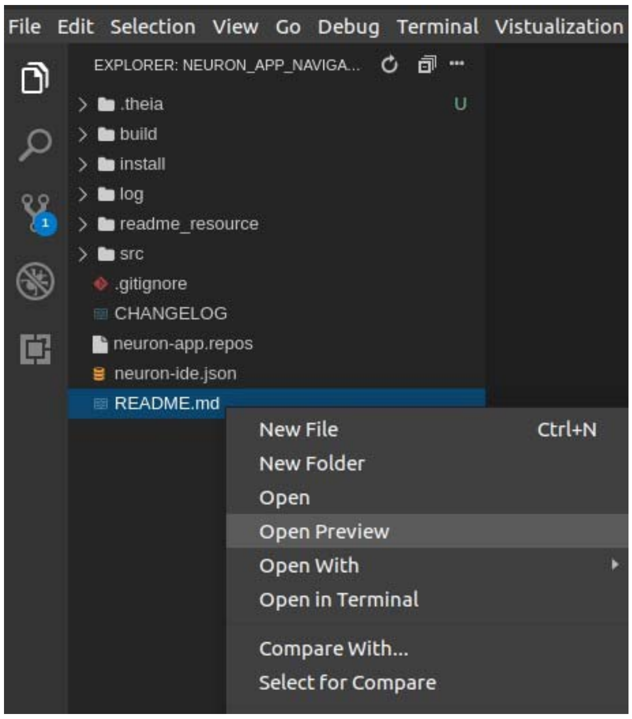
```
Starting >>> rplidar_ros
Finished <<< rplidar_ros [5.17s]
Starting >>> serial
Finished <<< serial [1.09s]
Starting >>> neuronbot2_bringup
Finished <<< neuronbot2_bringup [9.92s]

Summary: 9 packages finished [1min 18s]

Terminal will be reused by tasks.
```

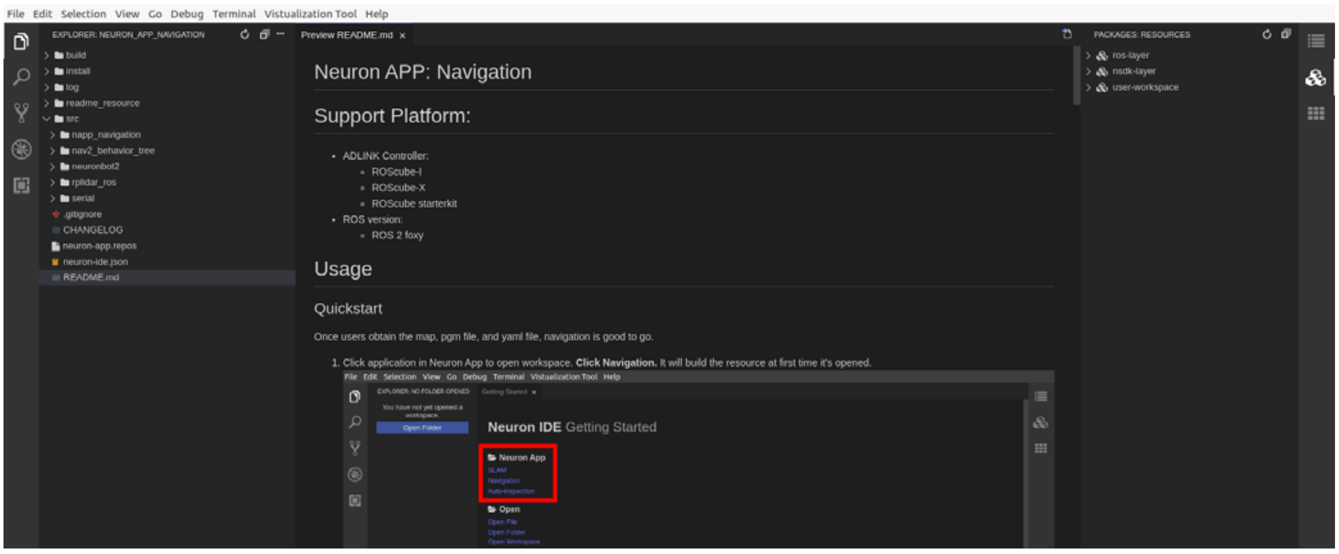
5. Open the Neuron App user instructions.

Right-click on **README.md** in the root directory, and then click **Open Preview.**



6. Follow the instructions and launch a ROS application.

NOTE: launching a ROS application for the first time can take longer than expected, as Gazebo needs to do some initialization first.



Neuron APP: Navigation

Support Platform:

- ADLINK Controller:
  - ROScube-I
  - ROScube-X
  - ROScube starterkit
- ROS version:
  - ROS 2 foxy

Usage

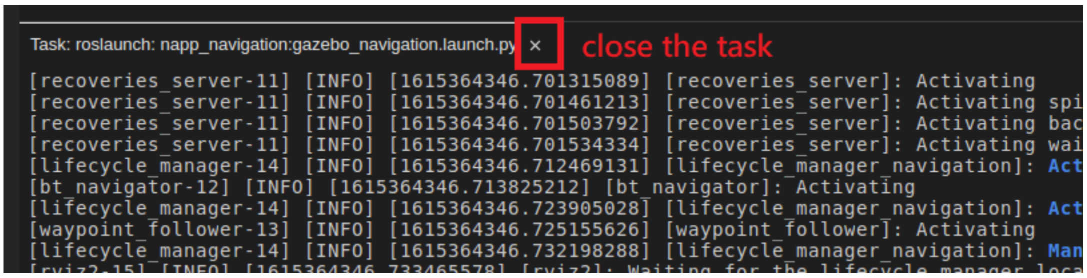
Quickstart

Once users obtain the map, pgm file, and yaml file, navigation is good to go.

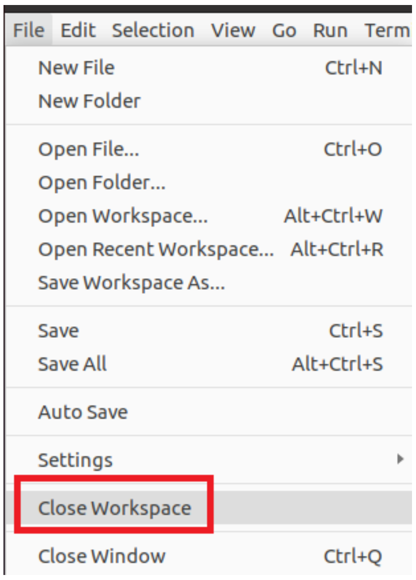
1. Click application in Neuron App to open workspace. **Click Navigation.** It will build the resource at first time it's opened.

File Edit Selection View Go Debug Terminal Vistualization Tool Help
EXPLORER: NO FOLDER OPENED
You have not yet opened a workspace.
Open Folder
Getting Started
Neuron IDE Getting Started
Neuron App
SLAM
Navigation
Auto-inspection
Open
Open File
Open Folder
Open Workspace

7. Remember to close the task and the workspace after running Neuron App. You cannot run several Neuron Apps at the same time.


Task: roslaunch: napp_navigation:gazebo_navigation.launch.py ×
close the task

```
[recoveries_server-11] [INFO] [1615364346.701315089] [recoveries_server]: Activating
[recoveries_server-11] [INFO] [1615364346.701461213] [recoveries_server]: Activating spi
[recoveries_server-11] [INFO] [1615364346.701503792] [recoveries_server]: Activating bac
[recoveries_server-11] [INFO] [1615364346.701534334] [recoveries_server]: Activating wai
[lifecycle_manager-14] [INFO] [1615364346.712469131] [lifecycle_manager_navigation]: Act
[bt_navigator-12] [INFO] [1615364346.713825212] [bt_navigator]: Activating
[lifecycle_manager-14] [INFO] [1615364346.723905028] [lifecycle_manager_navigation]: Act
[waypoint_follower-13] [INFO] [1615364346.725155626] [waypoint_follower]: Activating
[lifecycle_manager-14] [INFO] [1615364346.732198288] [lifecycle_manager_navigation]: Man
```



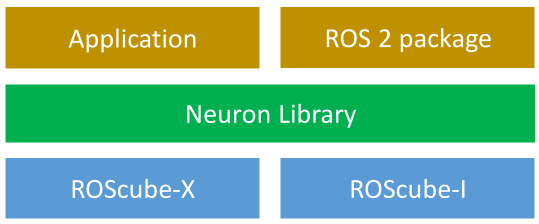
6 Neuron Library

6.1 Introduction

Neuron Library is the API library for ADLINK products, such as ROScube-I and ROScube-X providing a common API to control the peripheral I/O of the controller, and includes examples for various programming languages.

As show in the diagram below, Neuron Library provides the interfaces between your program and the hardware. Instead of controlling I/O using Linux commands and modifying your code for each platform, you just need to call the API from the Neuron Library. You can port your code between ROScube-I and ROScube-X without any modifications, only rebuilding is needed.

Since ROScube-I and ROScube-X are products that are mainly used for ROS based projects, some ROS 2 (Foxy) examples are provided to demonstrate how to use these APIs on ROS 2. You can rewrite these examples to build your own programs.



- If you want to develop applications to control the I/O directly, use the Neuron Library API.
- If you want to develop ROS packages, ADLINK also provides ROS 2 package examples using Neuron API. You can adapt the examples for your own project.
- Neuron Library is a hardware independent library. You can port your code between different hardware platforms without any modifications.
- Neuron Library updates can be found at https://github.com/Adlink-ROS/mraa, and include usage examples and detailed information of the latest version.

6.2 Supported Programming Languages

- C
- Python3

6.3 Hardware Pin Mapping

This library is developed for ADLINK products. Supported hardware and information about the ROSCube I/O pin mapping can be found at: https://github.com/Adlink-ROS/mraa#supported-hardware.

6.4 Usage

After installation, the Neuron Library will be located in "/opt/adlink/neuron-sdk/neuron-library/". Detailed API information can be found at:

- C: http://iotdk.intel.com/docs/master/mraa/
- Python3: http://iotdk.intel.com/docs/master/mraa/python/

6.4.1 For Neuron Library Users

For users not using ROS 2 for development (native users), refer to the examples in the following libraries:

- For C:
    1. Create a working space under the /home directory and navigate to it.
       ```
       mkdir neuronlibex_ws
       cd neuronlibex_ws
       ```
    2. Copy the example file to your working space.
       ```
       cp -r /opt/adlink/neuron-sdk/neuron-library/share/mraa/* .
       ```
    3. Create a 'build' directory under your working space and navigate to it.
       ```
       mkdir build
       cd build
       ```
    4. Build the examples.
       ```
       cmake ../examples/
       make
       ```
    5. Run the examples under the directory '~/neuronlibex_ws/build/c/'.
       ```
       cd c/
       #Examples should be run as root
       sudo ./<the example you want to execute>
       ```
- For Python:
    1. Create a working space under the /home directory and navigate to it.
       ```
       mkdir neuronlibex_ws
       cd neuronlibex_ws
       ```
    2. Copy the example file to your working space.
       ```
       cp -r /opt/adlink/neuron-sdk/neuron-library/share/mraa/* .
       ```
    3. Move into the directory with the python examples.
       ```
       cd examples/python/
       ```
    4. Run the python3 examples:
       Note: If the pin number is wrong, change the pin in the example.
       ```
       sudo python3 <the example you want to execute>.py
       ```

6.4.2 For ROS 2 Users

For ROS 2 users, examples provided from ADLINK are available at the following link:

https://github.com/Adlink-ROS/neuron_library_example.git

https://github.com/Adlink-ROS/neuron_library_example.git

Follow the steps below.

1. Install ROS.
2. Create a workspace and git clone the following package from github.

```
# You can name your workspace.
mkdir -p neuronlib_example_ws/src
cd neuronlib_example_ws/src
git clone https://github.com/Adlink-ROS/neuron_library_example.git
cd ..
```

3. Build the ROS 2 package.

```
colcon build --cmake-args -DCMAKE_BUILD_TYPE=Release
```

4. Source the package.

```
Source the package everytime you open a new terminal
source install/local_setup.bash
```

5. Tutorials of the examples are provided at the links below.

- GPIO example: https://github.com/Adlink-ROS/neuron_library_example/tree/master/gpio_example
- I^{2}C example: https://github.com/Adlink-ROS/neuron_library_example/tree/master/i2c_example
- LED example: https://github.com/Adlink-ROS/neuron_library_example/tree/master/led_example
- Serial example: https://github.com/Adlink-ROS/neuron_library_example/tree/master/serial_example
- PWM example: https://github.com/Adlink-ROS/neuron_library_example/tree/master/pwm_example
- SPI example: https://github.com/Adlink-ROS/neuron_library_example/tree/master/spi_example

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7 Neuron Comm

Neuron Comm is a ROS 2 communication tool providing users the best performance including, Data Distribution Service (DDS), shared memory, and Quality of Service (QoS).

- Data Distribution Service (DDS):

  DDS was released by the Object Management Group (OMG) in 2004. It is a data distribution/subscription standard specifically designed for real-time systems.

  DDS was first used in the US Navy to solve the compatibility problem of the large-scale software upgrades in the complex network environment of ships. It has become a mandatory standard of the US Department of Defense (DoD), and is widely used in defense, civil aviation, and industrial control, making it a standard solution for data publishing/subscription (pub/sub) in distributed real-time systems.

  ROS 2 with DDS can fulfill stability, security, real-time capabilities and decentralized communication.

- Shared memory:

  Any node-to-node communication in the same machine can use shared memory to perform efficient data transmission and reduce latency, compared with the traditional inter-process communication which goes through the network layer and causes latency.

- Quality of Service (QoS):

  QoS is used in DDS to perform multiple options for data transmission under different scenarios. For example, users can choose best-effort data transmission in real-time systems, and reliable transmission in data logging systems.

7.1 DDS Configuration

Neuron SDK uses Cyclone DDS as its DDS implementation. Although the out-of-the-box configuration works well in most cases, Cyclone DDS still provides many configurable options. Users can fine-tune Cyclone DDS for their own scenarios using these settings. The sections below will guide you in configuring Cyclone DDS on Neuron SDK.

7.1.1 Environmental Variables

Cyclone DDS will try to find the configuration file based on the environmental variable **CYCLONEDDS_URI**. Therefore, you can set the path of the configuration file with the following command:

```
export CYCLONEDDS_URI=file://$PWD/cyclonedds.xml
```

Note: You should run this command under the same path as cyclonedds.xml. You can also replace **$PWD** with the absolute path of cyclonedds.xml.

7.1.2 Configuration Options

The Cyclone DDS configuration file in XML format, as in the following example.

```
<?xml version="1.0" encoding="UTF-8" ?>
<CycloneDDS xmlns="https://cdds.io/config" xmlns:xsi="http://www.w3.org/2001/XMLSchema
-instance" xsi:schemaLocation="https://cdds.io/config https://raw.githubusercontent.co
m/eclipse-cyclonedds/cyclonedds/master/etc/cyclonedds.xsd">
    <Domain id="any">
        <General>
            <NetworkInterfaceAddress>auto</NetworkInterfaceAddress>
            <AllowMulticast>default</AllowMulticast>
            <MaxMessageSize>65500B</MaxMessageSize>
            <FragmentSize>4000B</FragmentSize>
        </General>
        <Internal>
            <Watermarks>
                <WhcHigh>500kB</WhcHigh>
            </Watermarks>
        </Internal>
        <Tracing>
            <Verbosity>config</Verbosity>
            <OutputFile>stdout</OutputFile>
        </Tracing>
    </Domain>
</CycloneDDS>
```

The following are some useful configuration settings.

- **NetworkInterfaceAddress**: Selects which network interface is used. You can override the default interface.
- **AllowMulticast**: Configures whether or not multicast will be used. Some network interfaces do not support multicasting.
- **MaxMessageSize**: Determines the maximum size of an RTPS message. RTPS is the communication protocol of DDS.
- **FragmentSize**: Determines the fragment size into which very large samples get split.
- **WhcHigh**: The threshold above which the sender will wait for acknowledgement from the receiver because it has buffered too much unacknowledged data.
- **Verbosity**: The amount of detail in the log to output. This is useful when you want to see what happens inside DDS.
- **Output**: Where to output the log.

For more configuration details, refer to option.md in the Cyclone DDS GitHub, or config.rst for more background knowledge about these options.

7.1.3 Neuron SDK Configuration Example

After installing Neuron SDK, you can find some DDS configuration examples under /opt/adlink/neuron-sdk/ros/$ROS_DISTRO/share/dds-configs/cyclonedds_configs/.

- basic.xml: General settings for Cyclone DDS, as in the example configuration shown above.
- shmem.xml: Configuration with shared memory enabled.
- dds_latency.xml: Configuration for better latency performance.
- dds_throughput.xml: Configuration for better throughput performance.
- latency_shmem.xml: Configuration with shared memory and better latency performance.
- throughput_shmem.xml: Configuration with shared memory and better throughput performance.

If you use a configuration with better throughput, you may need to adjust the socket buffer size if you assign a larger buffer size in the DDS configuration.

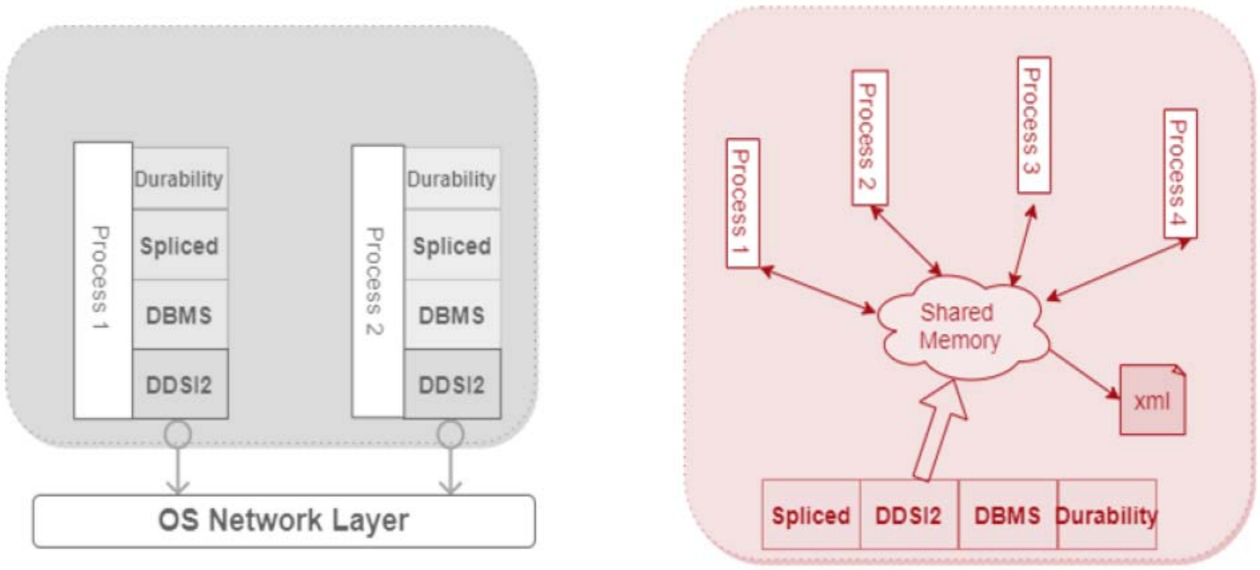
```
sudo sysctl -w net.core.rmem_max=26214400
```

7.2 Shared Memory

An important feature of the Neuron SDK is providing inter-process communication with shared memory. Although DDS is very effective at network communication, it still lacks efficiency when it comes to inter-process communication on single machine. Moreover, large data transmissions (e.g. point cloud, high resolution images) make the situation worse. To handle this shortcoming, ADLINK provides another inter-process communication mechanism for Cyclone DDS: shared memory.

Shared memory utilizes an inter-process communication (IPC) middleware for POSIX-based operating systems. It allows zero-copy data transfer and can be used in many domains like automotive, robotics, gaming, and provides a much more efficient communication mechanism. The Neuron SDK uses shared memory to optimize high volume inter-process data communication in Cyclone DDS.

The illustration below compares the communication mechanism between multiple ROS processes. Without shared memory, the data has to be copied into the network driver, while shared memory reduces the time needed for copying data.



7.2.1 Configuration

There are two parts to configure in order to run Cyclone DDS with shared memory in Neuron SDK.

- Cyclone DDS Configuration
- Shared Memory Configuration

7.2.1.1 Cyclone DDS Configuration

Set the path configuration file for Cyclone DDS with the environmental variable CYCLONEDDS_URI. The shmem_log.xml sample configuration file with shared memory enabled can be found under **/opt/adlink/neuron-sdk/ros/$ROS_DISTRO/share/dds-configs/cyclonedds_configs/**.

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<CycloneDDS xmlns="https://cdds.io/config" xmlns:xsi="http://www.w3.org/2001/XMLSche
ma-instance" xsi:schemaLocation="https://cdds.io/config https://raw.githubuserconten
t.com/eclipse-cyclonedds/cyclonedds/master/etc/cyclonedds.xsd">
    <Domain id="any">
        <General>
            <NetworkInterfaceAddress>auto</NetworkInterfaceAddress>
            <AllowMulticast>default</AllowMulticast>
            <MaxMessageSize>65500B</MaxMessageSize>
            <FragmentSize>4000B</FragmentSize>
        </General>
        <Internal>
            <Watermarks>
                <WhcHigh>500kB</WhcHigh>
            </Watermarks>
        </Internal>
        <Tracing>
            <Verbosity>config</Verbosity>
            <OutputFile>stdout</OutputFile>
        </Tracing>
        <SharedMemory>
            <Enable>true</Enable>
            <LogLevel>info</LogLevel>
            <CacheSize>256</CacheSize>
        </SharedMemory>
    </Domain>
</CycloneDDS>
```

The <SharedMemory> tag has three options:

- EnableShm: true/false. Determines whether or not to enable shared memory.
- LogLevel: Determines the shared memory log level (off, fatal, error, warn, info, debug, verbose).
- CacheSize: Determines the cache size of the shared memory subscriber. The default max. size is 256.

7.2.1.2 Shared Memory Configuration

In most cases, no special shared memory configuration is required and the out-of-the-box configuration is sufficient. However, if the data is too large for shared memory, you may need to increase the memory configuration.

Neuron SDK provides a sample configuration file under **/opt/adlink/neuron-sdk/ros/$ROS_DISTRO/share/dds-configs/iceoryx_configs/roudi_config.toml**.

```
[general]
version = 1

[[segment]]

[[segment.mempool]]
size = 32
count = 10000
...
[[segment.mempool]]
size = 4194304
count = 200
```

There are several mempools in the configuration that determine the size of pre-allocated memory chunks. For example, there are 10,000 pre-allocate memory chunks below 32 bytes.

7.2.2 Run

To run Cyclone DDS with shared memory, first run RouDi ("Rou"ting and "Di"scovery) before running the ROS application. RouDi is the core of the shared memory system, which is responsible for discovery, shared memory management, and system introspection. RouDi will pre-allocate shared memory based on the configuration file. When Cyclone DDS wants to transmit data, it will ask RouDi to provide the appropriate shared memory to transmit the data.

After entering the Neuron SDK environment, run RouDi.

```
iox-roudi
```

You can also run RouDi with your own configuration.

```
iox-roudi -c <your configuration path>
```

There will be many logs generated while RouDi is running. You can hide log messages with the --log-level or -l options.

```
iox-roudi -l off
```

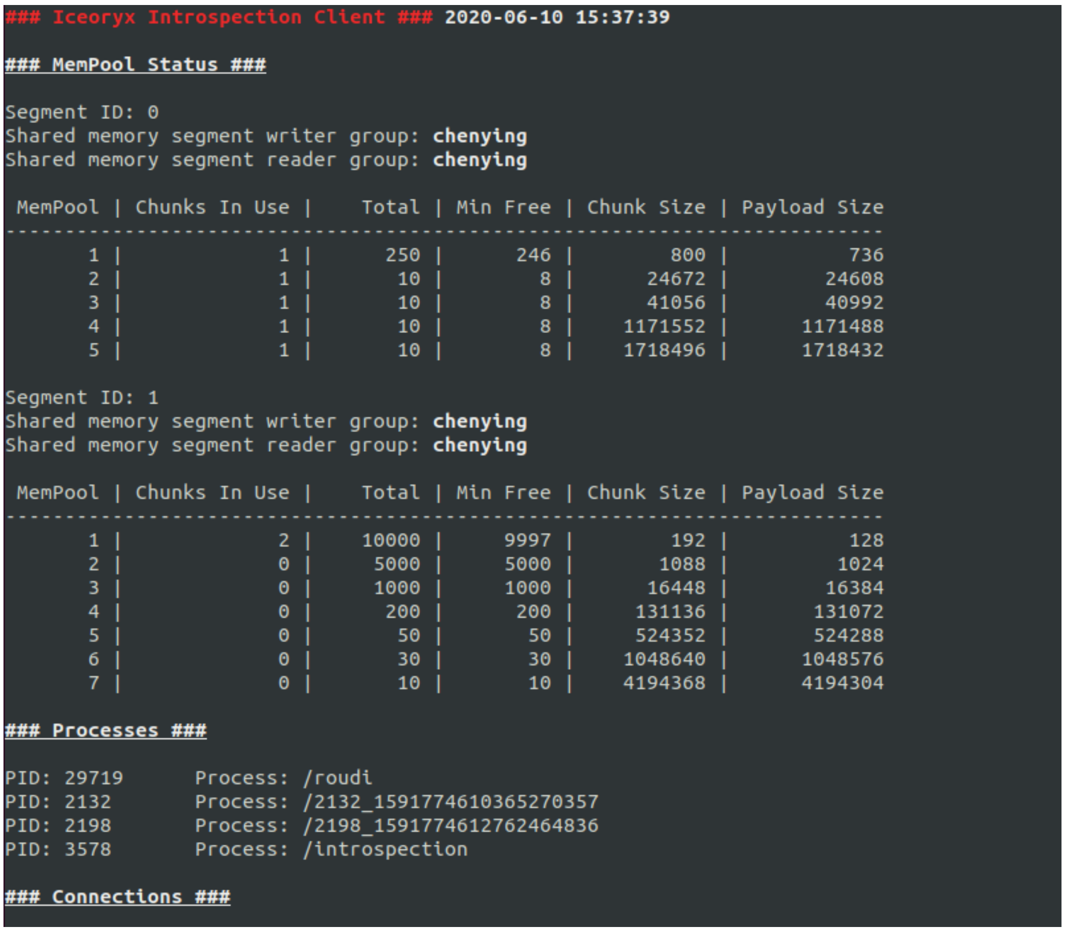
Now you can run any ROS application with shared memory.

7.2.3 Debug

When using shared memory communications, there is a introspection tool for monitoring communication status. To check the memory pool usage, processes and topics that are running, use the iceoryx_introspection_client command.

```
iox-introspection-client --all
```

Below is an example of the output.



```
### Iceoryx Introspection Client ### 2020-06-10 15:37:39

### MemPool Status ###

Segment ID: 0
Shared memory segment writer group: chenying
Shared memory segment reader group: chenying

 MemPool | Chunks In Use |    Total | Min Free | Chunk Size | Payload Size
--------------------------------------------------------------------------
       1 |             1 |      250 |      246 |        800 |          736
       2 |             1 |       10 |        8 |      24672 |        24608
       3 |             1 |       10 |        8 |      41056 |        40992
       4 |             1 |       10 |        8 |    1171552 |      1171488
       5 |             1 |       10 |        8 |    1718496 |      1718432

Segment ID: 1
Shared memory segment writer group: chenying
Shared memory segment reader group: chenying

 MemPool | Chunks In Use |    Total | Min Free | Chunk Size | Payload Size
--------------------------------------------------------------------------
       1 |             2 |    10000 |     9997 |        192 |          128
       2 |             0 |     5000 |     5000 |       1088 |         1024
       3 |             0 |     1000 |     1000 |      16448 |        16384
       4 |             0 |      200 |      200 |     131136 |       131072
       5 |             0 |       50 |       50 |     524352 |       524288
       6 |             0 |       30 |       30 |    1048640 |      1048576
       7 |             0 |       10 |       10 |    4194368 |      4194304

### Processes ###

PID: 29719      Process: /roudi
PID: 2132       Process: /2132_1591774610365270357
PID: 2198       Process: /2198_1591774612762464836
PID: 3578       Process: /introspection

### Connections ###
```

7.2.4 Performance Test

ADLINK provides a benchmarking tool to test the performance of ROS 2 communication. The tool is based on the benchmark tool from Apex AI. Neuron SDK has several launch files which can load the settings and run all the processes of the benchmarking tools.

```
ros2 launch nsdk_benchmark_tools benchmark_cyclonedds.launch.py topic:=Array1k rate:=0

ros2 launch nsdk_benchmark_tools benchmark_cyclonedds_shmem.launch.py topic:=Array1k rate:
=0
```

The commands below show how to test the performance of Cyclone DDS and Cyclone DDS with shared memory. benchmark_cyclonedds.lauch.py is only for Cyclone DDS, while benchmark_cyclonedds_shmem.launch.py is for Cyclone DDS with shared memory. After performance testing is done, a log file is generated in csv format.

Change the topic and publish rate by adjusting the arguments. Some arguments supported include:

- topic: Topic name. Used this to change the data size. For example, Array1k, Array4k, Array16k, Array32k, Array60k, Array1m, Array2m, Array4m PointCloud512k, PointCloud1m, PointCloud2m, PointCloud4m, and PointCloud8m.
- rate: Publish rate. Default is 1000. 0 is unlimited.
- max_runs: How many times the test runs.

7.2.5 Limitations

Although Cyclone DDS with shared memory is very powerful, there are some limitations.

- No multi-publisher support

Cyclone DDS with shared memory currently does not support multi-publisher mode, meaning you cannot have multiple publishers that publish to the same topic.

- No support for QoS in Cyclone DDS

Some QoSes need to utilize writer history cache (WHC) in DDS. When using shared memory, the data will go through shared memory directly and not enter into WHC. However, when using shared memory, the focus is often on large quantities and high rates of data. Under these conditions, QoS may not play an important role.

7.3 QoS

The latest version ROS 2 (Foxy Fitzroy) supports the following built-in QoS (Quality-of-Service):

- Reliability
- Durability
- History
- Lifespan
- Deadline
- Liveliness

Although these built-in QoSes are able to fulfill most use cases in robotics applications, there are still around 20 QoSes in a typical DDS implementation. Therefore, as a contributor of Cyclone DDS, ADLINK allows Neuron SDK to support an additional QoS, Ownership (see section 7.3.2).

7.3.1 ROS 2 Built-in QoS

The ROS 2 built-in QoS allows developers to tune communication between nodes by adjusting QoS policies. ROS 2 benefits from the flexibility of the underlying DDS transport in environments with lossy wireless networks where a “best effort” policy would be more suitable, or in real-time applications which Quality of Service is needed to set deadlines.

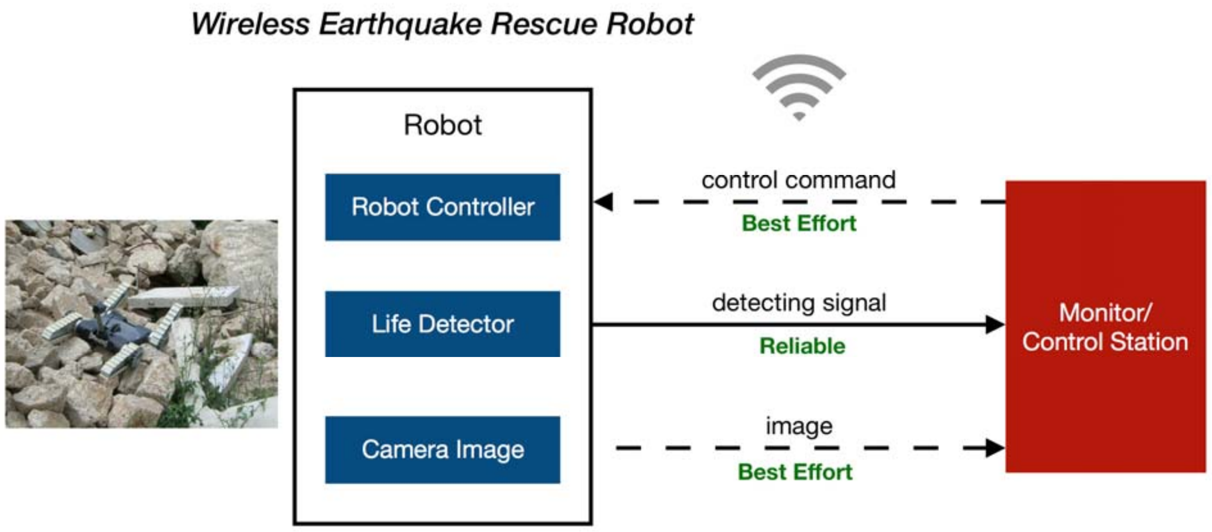
Introduction

ROS 2 provides a set of predefined QoS profiles for common use cases. The base QoS profile includes settings for the following policies.

Reliability

The Reliability QoS indicates the level of guarantee offered by the DDS in delivering data to DataReaders. The reliability of a connection between a DataWriter and DataReader is entirely user configurable.

The figure below describes a system diagram of a wireless earthquake rescue robot. There are three tasks in the automaton: a robot controller, a life detector, and a camera. There is also a remote station used to control and monitor the robot. In this case, low latency communication between the camera and control command is needed to ensure the robot still working by receiving the new data. However, it is also important that the life detecting signal be extremely reliable so that no survivors are overlooked even when the wireless network is unstable.



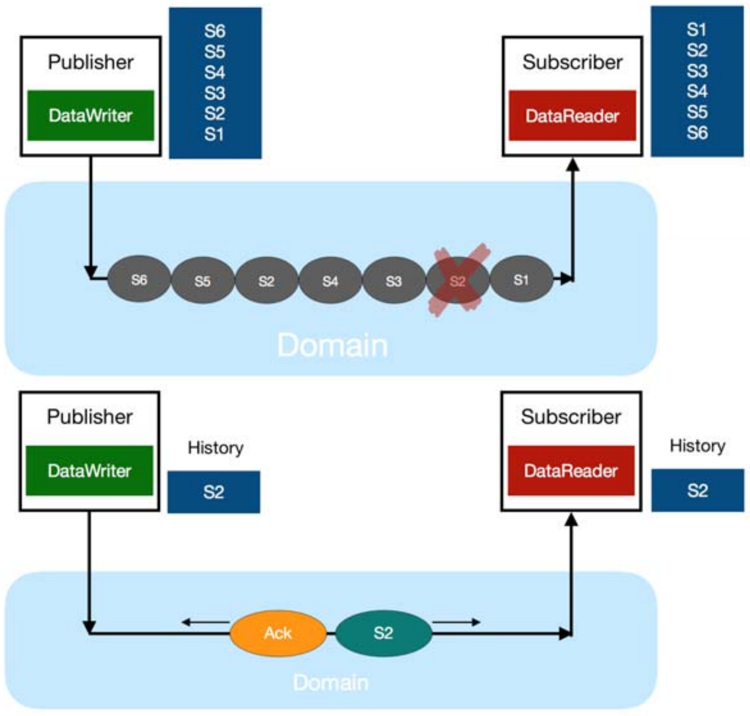
Possible variants include:

- Best Effort:

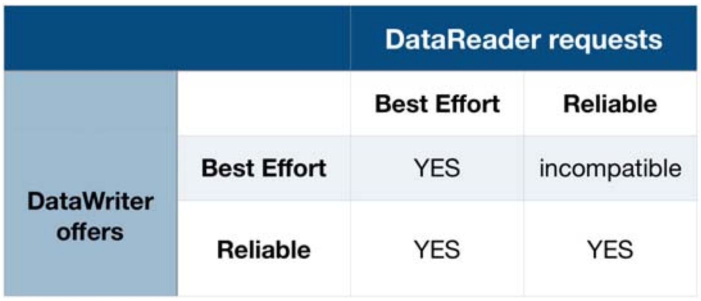
  This variant indicates that it is acceptable to not retry propagation of any samples. This is the fastest and most efficient method of getting the last-published value, but there is no guarantee that the data sent will be received. For instance, camera image and control command should be set as Best Effort as it is especially suited for use cases where a robot is working in a dangerous situation, such as sending control commands for a drone or robot arm.

- Reliable:

  This variant attempts to deliver all samples in its history. Missed samples may be retried. In steady-state the middleware guarantees that all samples in the DataWriter history will eventually be delivered to all DataReaders. Therefore, a life detecting signal should be set as Reliable. The Reliable delivery is particularly suited for rigorous use cases. For example, the video stream should be reliable during visual odometry calculation, because it may cause feature points to lose track if there are too many frames lost.



The figure above illustrates how Reliability works. Every time a packet is successfully sent to DataReader, it will feedback an acknowledgment to DataWriter. In contrast, when a packet fails to be sent to DataReader, it will feedback a negative acknowledgment to DataWriter to re-send the packet.



		DataReader requests	
		Best Effort	**Reliable**
DataWriter offers	**Best Effort**	YES	incompatible
	Reliable	YES	YES

The table above shows a ‘Request vs. Offered’ (RxO) model of reliability. Connections can only be made if the requested policy of the subscriber is not more stringent than that of the publisher. Reliability values are considered ordered such that BEST_EFFORT < RELIABLE. Hence when DataReader request "Best Effort", QoS can match it no matter if DataWriter offers "Best Effort" or "Reliable". However, QoS fails to match when DataReader requests "Reliable" and DataWriter only offers "Best Effort".

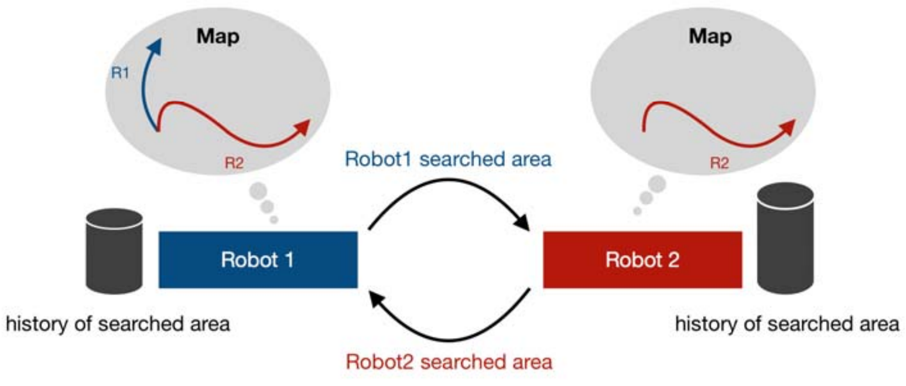
Durability

Durability determines how many instances of a topic should be saved after being published.

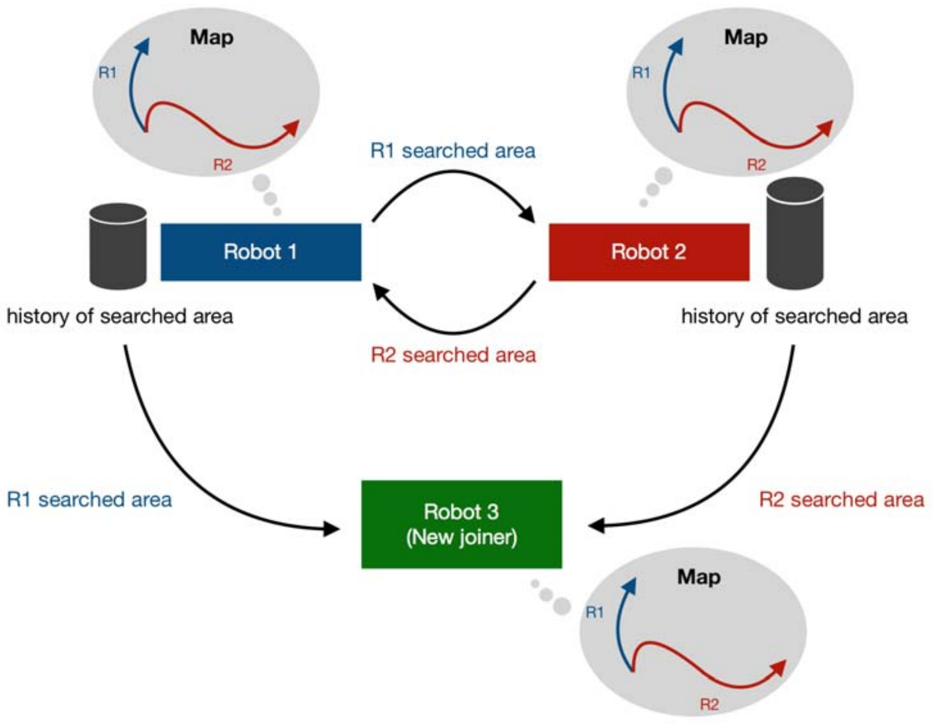
In general, as soon as DataWriter and DataReader match, data published by the DataWriter will be delivered to the DataReader. However, in real use cases, users can create DataWriter and DataReader at any time. Therefore, a DataWriter may publish data before a DataReader has been created. For example, before you subscribe to a thermometer, there might be previously published temperature data. Subscribers that are created after the data has been published (called late-joiners) may also be interested in the data that was published before they were created (called historical data). To facilitate this use case, DDS provides ‘durability’ which controls the data availability with respect to late-joiners.

The figure below shows an automatic multi-robot search and rescue example. In the beginning, there are two search and rescue robots searching for survivors. To work more efficiently, they send their odometry to each other in order to let each other know which area has already been searched. Later, the third robot joins the search. With PERSISTENT durability policy in each robot’s DataWriter, the third robot (late-joiner) can get the other robots’ previous odometry and join the search without covering any areas already searched.

Automatic Multi-robot Search and Rescue System



Initially, there are only two robot searching survival in disaster environment



Robot 3 start to join the rescuing work. With using PERSISTENT durability Robot3 can know the past searched area which done by Robot 1 and 2.

Cyclone DDS provides the following Durability variants:

- Volatile:

  Specifies that once data is published it is not maintained by DDS for delivery to late-joining applications.

- Transient_Local:

  Specifies that DataWriter stores data locally so that late-joining DataReaders get the last-published item if a DataWriter is still alive.

Although Transient and Persistent QoSes are included in the DDS specification, ROS does not currently support them.

History

This QoS policy configures the number of DDS samples that DDS will store locally for DataWriters and DataReaders. In other words, the QoS history policy controls whether the DDS should deliver only the most recent value, attempt to deliver all intermediate values, or do something in between.

The policy can be configured to provide the following parameters:

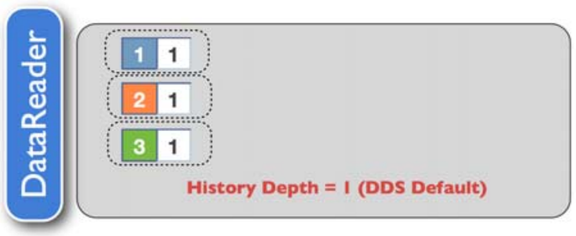
- kind:

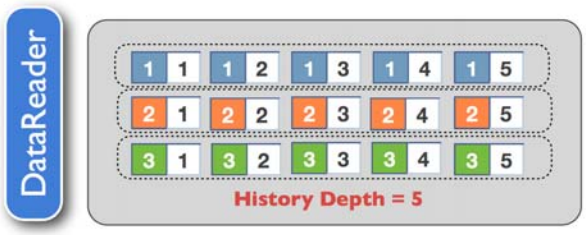
  Keep All: The DDS will attempt to keep all the samples of each instance of data identified by its key.

  Keep Last: The DDS will only attempt to keep the most recent "depth" samples of each instance of data identified by its key.

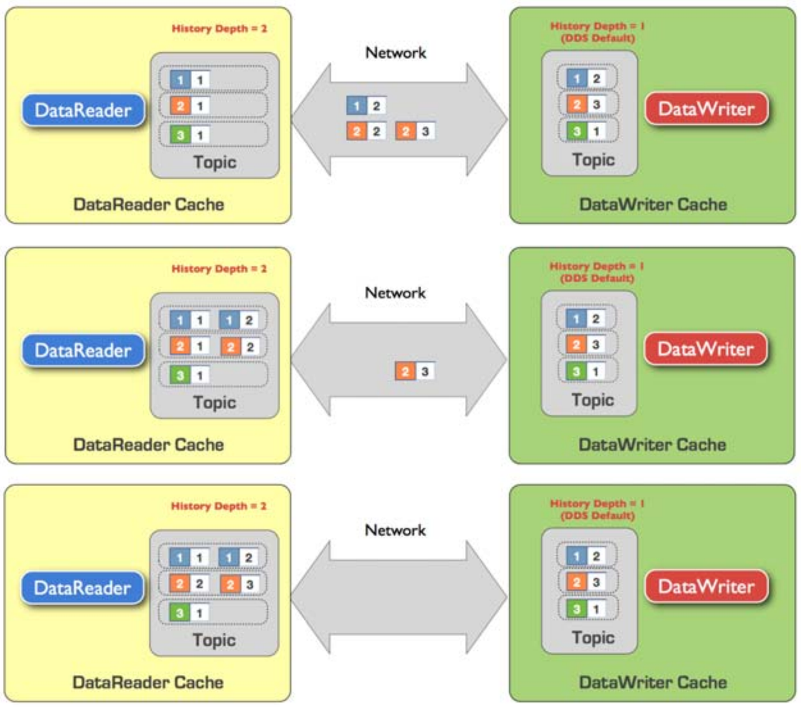
- depth:

  An integer. The figure below show the DataReader will only keep the most recent "depth" samples.





The figure below show an example when TRANSIENT_LOCAL durability is used on both DataWriter and DataReader, and the KEEP_LAST history policy with depth number settings as 1 and 2 is applied to DataWriter and DataReader, respectively. It is noticeable that the second instance delivers 1, 2 and 3, but the DataWriter only stores 3, which is the most recent value. On the other hand, DataReader keeps the last two values of 2 and 3.

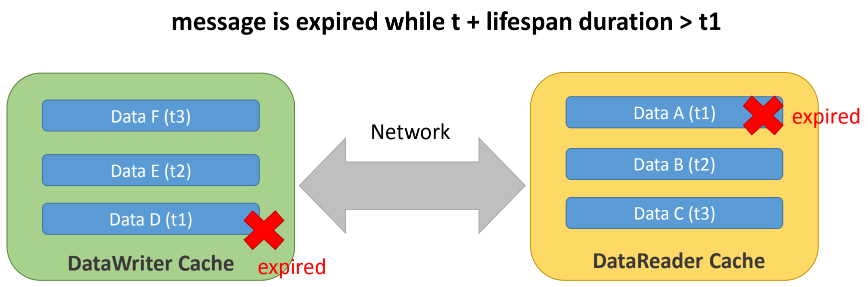


Lifespan

Lifespan defines how long a message is valid. A subscriber will not receive a message if it is expired, while the publisher will not send out the message in the same situation. QoS is useful for bypassing information that has expired and allowing only the latest messages to be processed.

The lifespan QoS attribute is “duration”, which is the maximum time for data validity. The expiration time can be computed by adding duration to the source timestamp. Note that lifespan QoS only takes effect on DataWriter, so there is no RxO limitation.

The following figure shows an example if current time t + lifespan duration is larger than t1, then the data in the cache will expire.



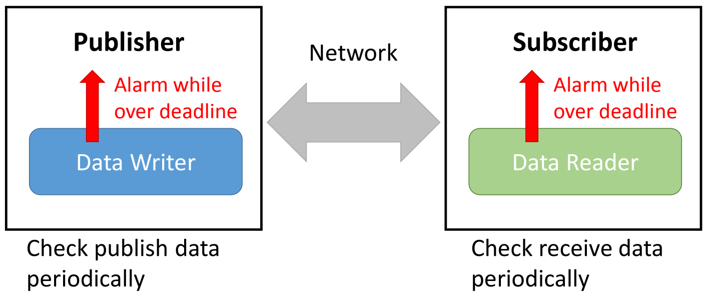
Deadline

Deadline makes sure the time interval between messages should not be over the maximum expected value. The QoS is often used while data is published at regular intervals. The deadline QoS attribute is “duration”. On the publishing side, an application must publish data periodically at intervals under the duration. On the subscribing side, a subscriber also expects to receive data at intervals not above the duration.

When the deadline duration cannot be fulfilled, it will trigger a user-defined callback. For example, the callback can alarm the manager to check the device or network status when the data fails to update.

For deadline QoS, RxO is supported. That is, the duration in DataWriter should be equal to or smaller than the duration in DataReader. Deadline QoS will be incompatible if it cannot match the condition.

In the following figure, Publisher should publish data periodically and not be over the deadline, while Subscriber should receive the periodic data. If the deadline is passed, they will alarm the application with a callback.


Publisher
Alarm while over deadline
Data Writer
Check publish data periodically
Network
Subscriber
Alarm while over deadline
Data Reader
Check receive data periodically

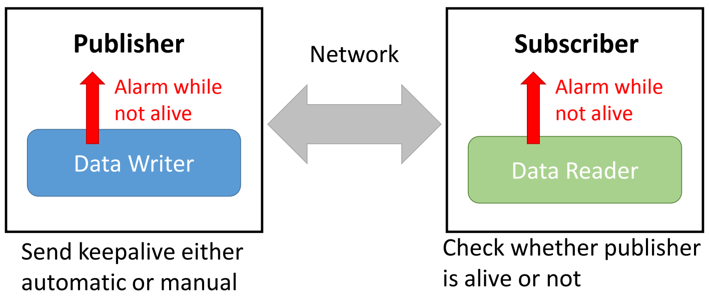
Liveliness

Liveliness is a QoS which defines how entities report whether they are alive or not. This can be used to prevent an entity terminating unexpectedly without notifying others. There are two attributes for liveliness QoS. The first one is duration, which means how often the liveliness must be reported. The second one is the liveliness policy. There are two policies in ROS: automatic and manual by topic. Automatic means if the participant is alive, all the entities in the participant are considered alive. An application only needs to detect failures. However, manual by topic means an application takes responsibility to signal liveliness by either publishing data or calling assert liveliness.

There are also callbacks in liveliness QoS. When DataWriter or DataReader detect liveliness failure, the user-defined callback will be triggered. The mechanism ensures that the user application can be notified in time once the remote entity dies suddenly.

For liveliness RxO, there are two limitations for QoS compatibility. The first is that the liveliness duration of the subscriber should be larger than the one on the publisher. The second is that the policy for the publisher cannot be automatic if the subscriber is set to manual by topic. If any one of these is not fulfilled, the communication will fail.

The following figure shows the liveliness mechanism. DataWriter should send a 'keepalive' message whether automatically or manually, while DataReader should check the liveliness of Publisher. When the entity is not alive, the alarm callback should be triggered.



ROS 2 Example

Refer to the ROS 2 demo code to learn how to develop robot applications with different QoS settings at:

https://github.com/ros2/demos/tree/foxy/quality_of_service_demo

There is a tutorial about how to use QoS settings to handle lossy networks at:

https://index.ros.org/doc/ros2/Tutorials/Quality-of-Service/

7.3.2 ADLINK Extra QoS - Ownership

Ownership is very useful in redundancy scenarios. In addition, Neuron SDK is built on standard ROS 2, so it also inherits the six built-in QoSes. Hence, by using ADLINK Neuron SDK, robotics developers can utilize the extra properties of the Ownership QoS for their applications.

Currently, Ownership only supports in C++ with the ROS 2 client library.

Rclcpp	rclpy
Supported	Not Supported

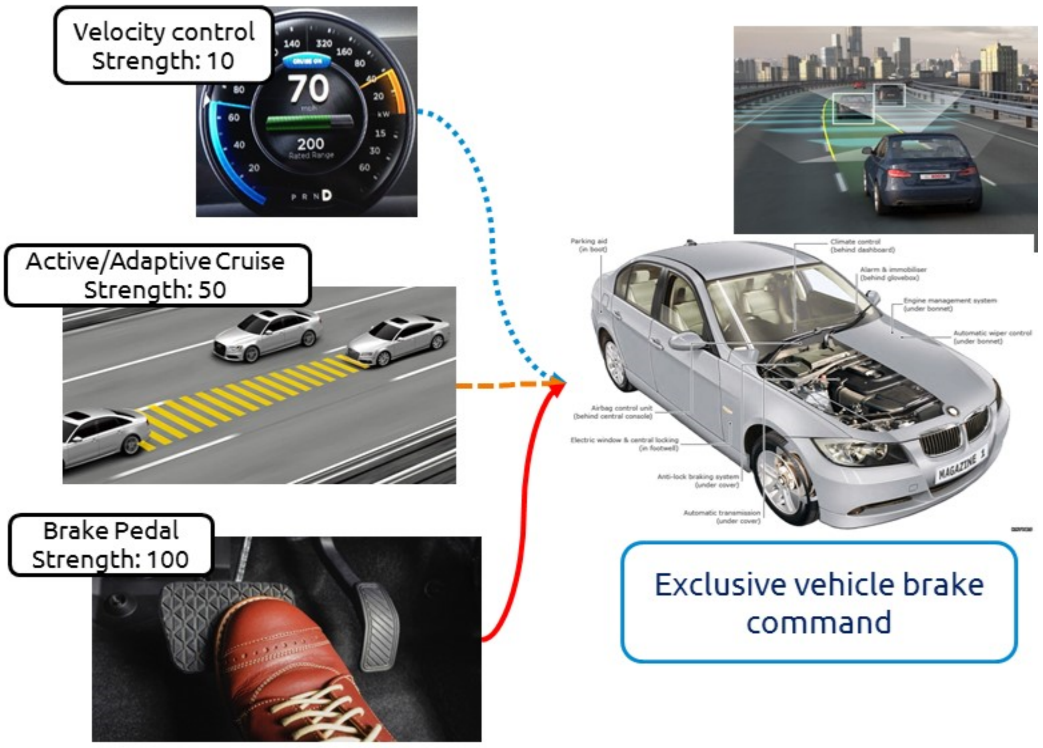
7.3.2.1 Introduction

Topic ownership specifies whether it is allowed for multiple publishers to publish to the same topic. It is also a simple and easy mechanism that ensures topic data only comes from a single source.

The figure below shows an example in which the vehicle control computer on an autonomous vehicle has several publishers that publish to the ROS 2 /cmd_vel topic. These nodes include:

1. Velocity Control
2. Adaptive Cruise Control that maintains following distance
3. Driver Input

Logically, the cruise speed control will have the lowest strength since any other condition will require the command to be overwritten. In this case, the driver's input will have the highest strength since the driver should be able to brake at any moment.


Velocity control
Strength: 10
Active/Adaptive Cruise
Strength: 50
Brake Pedal
Strength: 100
Parking aid (in boot)
Climate control (behind dashboard)
Alarm & immobiliser (behind glovebox)
Engine management system (under bonnet)
Automatic wiper control (under bonnet)
Airbag control unit (behind central console)
Electric window & central locking (in footwell)
Anti-lock braking system (under cover)
Automatic transmission (under cover)
MAGAZINE 1
Exclusive vehicle brake command

Type

There are two types of ownership: shared and exclusive.

- Shared:

  Shared ownership for each topic. Multiple publishers are allowed to update the same topic and all the updates are made available to the publisher.

- Exclusive:

  For a nominal subscriber, subscription of a topic does not guarantee the uniqueness of publishing source. As a result, two publishers can publish to a topic, causing the data of a certain topic to jump between two publishers. This behavior is often not desired. By setting the DataReader to exclusive reception, data from only one publisher can reach the publisher callback. Therefore, the above example is set as exclusive.

Strength

This policy only applies if the Ownership QoS policy is Exclusive. The publisher that has the right to present a topic to a DataReader is called the "owner" of the topic. If multiple publishers are publishing to the same topic, the "owner" is determined by "strength" assigned to the topic publisher. "Strength" is a simple integer assigned by the user, ranging from 0 to 65535 (0x0000 to 0xFFFF). In the example above, the strength of Driver Input, Adaptive Cruise Control, and Velocity Control are set as below:

- Driver Input strength: 100
- Adaptive Cruise Control strength: 50
- Velocity Control strength: 10

Neuron SDK comes with a ROS 2 wrapper for the DDS ownership QoS functionality that allows the user to easily assign a topic to be exclusive, and the topic subscriber will automatically choose the publisher with the highest strength. In the case that the node with the highest publishing strength goes offline, the same functionality will automatically switch to the next-highest-strength publisher. This backup mechanism is possible because topics from every node are actually already received by the underlying DDS structure and filtered by Cyclone DDS accordingly.

7.3.2.2 ROS 2 rclcpp Example

The following is an example of how to utilize the Ownership QoS. Although ROS 2 does not natively support Ownership, ROS 2 still provides an extra option which can be passed to the rmw layer while creating a ROS node. However, neither ROS 2 Dashing nor rclpy supports this extra option. This is why you the Ownership QoS in ROS 2 Dashing or rclpy cannot be used.

Follow these steps to use the Ownership QoS.

1. *#include "cyclonedds_options/cyclonedds_options.hpp"* is necessary regardless of the publisher or subscriber.
2. Create the *cyclonedds_options::PubOptions* object and set its kind and strength of Ownership.
3. Store the object into *rclcpp::PublisherOptions*, which is the extra option provided by ROS 2.
4. Assign *rclcpp::PublisherOptions* while calling *create_publisher*. Cyclone DDS will process the option and set the correct QoS.

```
#include "cyclonedds_options/cyclonedds_options.hpp"

class OwnershipPublisherNode : public rclcpp::Node {
  public:
    OwnershipPublisherNode(enum cyclonedds_options::qos_ownership_kind kind, uint32_t stre
ngth, uint32_t id_in)
      : Node("Ownership_pub")
    {
      rclcpp::SystemDefaultsQoS qos;
      std::unique_ptr<cyclonedds_options::PubOptions> cyclonedds_options(new cyclonedds_op
tions::PubOptions());
      cyclonedds_options->setOwnership(kind, strength);
      rclcpp::PublisherOptions po;
      po.rmw_implementation_payload = std::move(cyclonedds_options);
      pub_ = this->create_publisher<nsdk_ownership::msg::Ownership>("ownership", qos, po);
 ...
    }
 ...
};
```

A similar process needs to be performed on the subscriber side, but the option object is different from that of the publisher. Replace *cyclonedds_options::PubOptions* with *cyclonedds_options::SubOptions* and *rclcpp::PublisherOptions* with *rclcpp::SubscriptionOptions,* as show below.

```
#include "cyclonedds_options/cyclonedds_options.hpp"

class OwnershipSubscriberNode : public rclcpp::Node {
  public:
    OwnershipSubscriberNode(enum cyclonedds_options::qos_ownership_kind kind)
      : Node("Ownership_sub")
    {
      rclcpp::SystemDefaultsQoS qos;
...
      std::unique_ptr<cyclonedds_options::SubOptions> cyclonedds_options(new cyclonedds_
options::SubOptions());
      cyclonedds_options->setOwnership(kind);
      rclcpp::SubscriptionOptions so;
      so.rmw_implementation_payload = std::move(cyclonedds_options);
      sub_ = this->create_subscription<nsdk_ownership::msg::Ownership>("ownership",
          qos, callback, so);
    }
...
};
```

For *cyclonedds_options.hpp*, refer to **/opt/adlink/neuron-sdk/ros/foxy/include/cyclonedds_options/cyclonedds_options.hpp**. For the full example code, refer to https://github.com/Adlink-ROS/example_ownership/tree/foxy.

Note that, for example, if we have two nodes with A) exclusive subscriber and B) nominal default subscriber, then node A will receive a topic exclusively from the publisher with the highest strength while node B will receive data from all publishers like the original ROS 2 node behavior. In other words, Neuron SDK is compatible with any ROS 2 node.

7.3.2.3 ROS 2 Example Test

Step 1: First run the publisher with lower strength.

```
ros2 run nsdk_ownership ownership_pub -k exclusive -i 100 -s 100
```

Step 2: Run the subcriber.

```
ros2 run nsdk_ownership ownership_sub -k exclusive
```

Step 3: Then run the publisher with higher strength.

```
ros2 run nsdk_ownership ownership_pub -k exclusive -i 200 -s 200
```

Step 4: You will see that only the publisher with the higher strength in the *ownership_sub* terminal.

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7. **TERMINATION**

7.1 Either party may at any time by notice in writing to the other party terminate this Agreement with effect from the date of service of such notice if:

(a) the other party commits a material breach of this Agreement which is not remedied, or does not otherwise cease to be material, within 30 days after the non-breaching party has given written notice to the breaching party identifying the breach and requiring it to be remedied; or

(b) the other party has ceased business, been adjudged bankrupt or insolvent under the laws of any jurisdiction, made an assignment for the benefit of creditors, or filed a petition of bankruptcy, reorganization or other insolvency proceeding.

7.2 Upon termination or expiry of this Agreement, for whatever cause, all rights granted to the Customer under this license shall cease, the Customer must cease all activities authorized by this license and cease all use of the Software, remove or destroy the Software and Documentation and any copies made.

7.3 Termination under this clause shall not affect any other rights or remedies ADLINK may have.

8. **COMPLIANCE WITH LAWS AND REGULATIONS**

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US Department of Commerce Bureau of Industry and Security	http://www.bis.doc.gov/
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European Union	http://europa.eu/legislation_summaries/external_trade/index_en.htm
Local Country Regulations	http://www.wassenaar.org/

9. **GOVERNING LAW**

This Agreement will be construed by and governed in accordance with the laws of [Taiwan, the Republic of China]. The Parties submit to exclusive jurisdiction of the courts of [Taipei, Taiwan].

10. **GENERAL**

10.1 The parties expressly agree that the terms and conditions of this Agreement shall prevail over any standard terms and conditions printed or referred to in any such purchase contract, order or other written documentation issued by the Customer concerning the subject matter hereof.

10.2 This Agreement supersedes all prior discussions, negotiations and correspondence between the parties hereto and sets forth the entire agreement between the parties with respect to the subject matter hereof. This Agreement cannot be modified except by an instrument in writing.

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Version 3, 29 June 2007

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- Read the specifications section of this manual for detailed information on the operating environment of this equipment.
- When installing/mounting or uninstalling/removing equipment, turn off the power and unplug any power cords/cables.
- To avoid electrical shock and/or damage to equipment:
    - Keep equipment away from water or liquid sources.
    - Keep equipment away from high heat or high humidity.
    - Keep equipment properly ventilated (do not block or cover ventilation openings).
    - Make sure to use recommended voltage and power source settings.
    - Always install and operate equipment near an easily accessible electrical socket-outlet.
    - Secure the power cord (do not place any object on/over the power cord).
    - Only install/attach and operate equipment on stable surfaces and/or recommended mountings.
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- Never attempt to fix the equipment. Equipment should only be serviced by qualified personnel.

Getting Service

Ask an Expert: http://askanexpert.adlinktech.com

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