

Lab 5 - Preparing for Multi-Vehicle Operations

2.680 Unmanned Marine Vehicle Autonomy, Sensing and Communications



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1 Overview and Objectives

In Lab 5 we begin shifting our focus to autonomy configurations involving multiple vehicles. This precursor lab covers a few initial steps of Lab 6 for those who wish to get a jump on Lab 6. Our first focus will be on communications between two independently running **MOOSDB** processes, where typically a single **MOOSDB**, or "MOOS Community" is associated with a single vehicle. Ultimately the inter-**MOOSDB** or inter-vehicle communication may come over an acoustic modem link or a satellite link, our primary initial focus is on communications over an Internet connection, even if the multiple "nodes" are all running on your one laptop.

Gaining familiarity with this mode of operation will be essential for later labs and operation of vehicles on the water.

- The Shoreside and Vehicle(s) Topology
- Introduction to pShare via the xrelay mission
- Converting the Alpha Mission to use a Shoreside / Vehicle Topology

2 Preliminaries

Make Sure You Have the Latest Updates

It is possible we will be making changes to the MOOS-IvP tree during the semester. Always make sure you have the latest code:

```
$ cd moos-ivp
$ git pull
```

If you see a response similar to the below, indicating that no updates were pulled in from the server, then you shouldn't need to re-build the software.

```
Already up to date.
```

Otherwise you will need to rebuild:

```
$ ./build-moos.sh
$ ./build-ivp.sh
```

Make Sure Key Executables are Built and In Your Path

This lab does assume that you have a working MOOS-IvP tree checked out and installed on your computer. To verify this make sure that the following executables are built and findable in your shell path:

```
$ which MOOSDB
/Users/you/moos-ivp/bin/MOOSDB
$ which pHelmIvP
/Users/you/moos-ivp/bin/pHelmIvP
```

If unsuccessful with the above, return to the steps in Lab 1:

http://oceanai.mit.edu/ivpman/labs/machine_setup

Where to Build and Store Lab Missions

As with previous labs, we will use your version of the `moos-ivp-extend` tree. In this tree, there is a `missions` folder:

```
$ cd moos-ivp-extend
$ ls
CMakeLists.txt  bin/          build.sh*     docs/         missions/     src/
README          build/        data/         lib/          scripts/
```

For each distinct assignment in this lab, there should be a corresponding subdirectory in a `lab.06` sub-directory of the `missions` folder. Folders for missions in this lab (5) and the next lab should all be put into the folder `lab.06`. As before, check in just the mission files (`.moos` and `.bhv` files) and any launch scripts. No log file folders. See Section 5.1 for the full requested file structure.

Documentation Conventions

To help distinguish between MOOS variables, MOOS configuration parameters, and behavior configuration parameters, we will use the following conventions:

- MOOS variables are rendered in **green**, such as `IVPHELM.STATE`, as well as postings to the `MOOSDB`, such as `DEPLOY=true`.
- MOOS configuration parameters are rendered in **blue**, such as `AppTick=10` and `verbose=true`.
- Behavior parameters are rendered in **brown**, such as `priority=100` and `endflag=RETURN=true`.
- MOOS-IvP applications are rendered in **magenta**, such as `MOOSDB`, or `pHelmIvP`.
- General GNU/Linux commands are represented in **dark purple**, such as `wget`, `ls`, or `cd`.

More MOOS / MOOS-IvP Resources

A few further resources are worth mentioning for following up this lab with your own exploration.

- The **pShare** documentation
<http://oceanai.mit.edu/2.680/oxmoos/pshare.html>
- The slides from class which give a bit more background into marine autonomy and the IvP Helm.
http://oceanai.mit.edu/2.680/docs/2.680-06-multiple_vehicles_2026.pdf
- The IvP Helm and Utilities documentation: <http://oceanai.mit.edu/ivpman>
- The moos-ivp.org website: <http://www.moos-ivp.org>

3 The Shoreside (Topside) / Vehicle Topology

The layout of interconnected MOOS communities used in this lab is depicted in the figure below. This layout will be used for the remainder of the course, including during operations on the river. You will experience different versions of this arrangement. In the simplest arrangement, in the lab, the Shoreside and vehicle communities will all be running on your computer. As we mentioned previously, A MOOS community is a collection of MOOS apps, each connected to a single MOOSDB for that community. The Shoreside topology is sometimes also referred to as the *uField* topology since the uField Toolbox is a set of utility applications for facilitating the Shoreside arrangement.

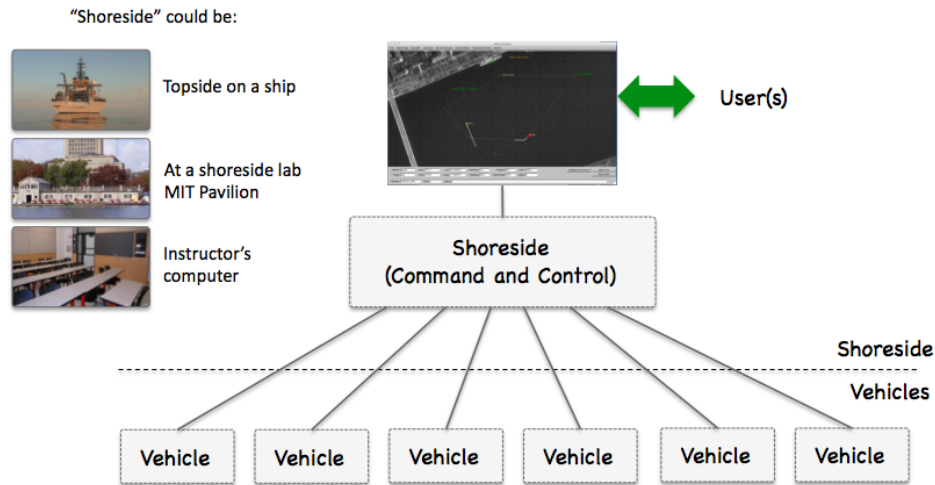


Figure 1: **Shoreside to Multi-Vehicle Topology:** A number of vehicles are deployed with each vehicle maintaining some level of connectivity to a shoreside command and control computer. Each node (vehicles and the shoreside) are comprised of a dedicated MOOS community. Modes and limits of communication may vary.

Communications between apps *within* a single MOOS community are typically high bandwidth with little or negligible latency. This is all handled over TCP communications between the app and the MOOSDB through the publish-subscribe protocol described thus far in class. Communications *between MOOS communities* will typically be much lower in bandwidth with higher latency. Communication modalities may also vary, but include WiFi, underwater acoustic modems, satellite networks like Iridium, and others. In these cases there can also be messages that are simply lost.

Because of these limitations, communications are also typically more deliberately arranged ahead of time. Communications *within* a MOOS community can be quite dynamic in the sense that any app can publish anything at any time, and any app can Register for information at any time. In autonomy systems where there are communications *between MOOS communities*, the allowed inter-node messages are usually declared beforehand, and there may also be message priorities and upper limits on message frequency for certain variables.

In our class, both in simulation and on the water, the app **pShare** is used for inter-node communications (comms between MOOS communities). Each MOOS community runs an instance of **pShare** as shown in Figure 2 below.

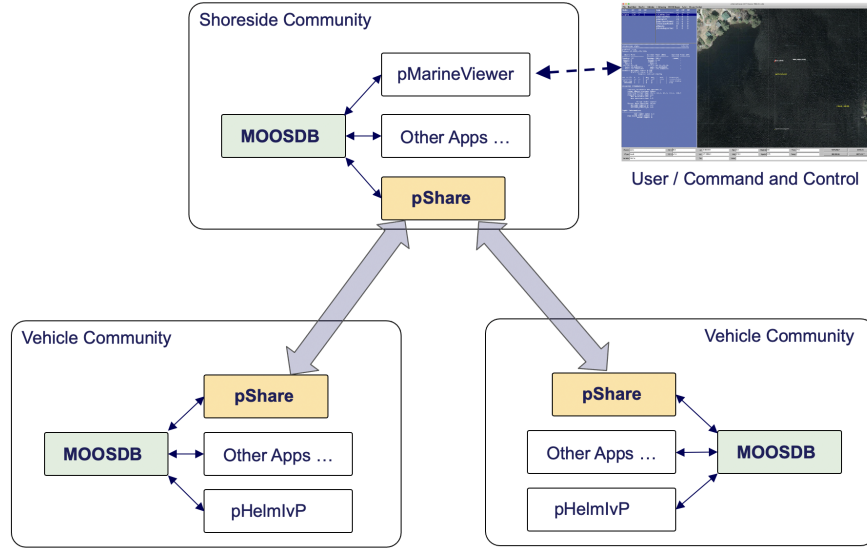


Figure 2: **Inter MOOS Community Communications:** Apps within a single MOOS community communicate over TCP, while communication between communities is assumed to be lossy. The **pShare** app is used in simulations in some field test environments to share a small configurable set of information between platforms.

Each instance of **pShare** is configured to listen on a unique channel. The channel is defined by its IP address and port number. Therefore, when multiple MOOS communities are simulated on a single machine (same IP address), the port numbers need to be different. When the multiple MOOS communities are on different platforms, each with its own unique IP address, then each **pShare** app may have the same port number.

In addition to specifying the channel for *incoming* messages, **pShare** needs to be configured to specify *outgoing* messages. An outgoing message configuration consists of specifying a MOOS variable in the local (source) community, and the destination of the message in terms of the IP address and port number of the receiving **pShare** app in the *destination* community. It is also possible to change the name of MOOS variable as it arrives in the destination community. So each **pShare** configuration will consist of two parts:

- The incoming listen port
- One or more MOOS variables mapped to a destination community.

When finally configured, a publication to a local MOOS variable involved in a **pShare**, will result in a near instantaneous similar publication in the destination community. Note that **pShare** works over UDP, and messages do not have the same guarantee of arrival as they do with TCP. Messages can and will drop. You are unlikely to experience a dropped message when simulating inter-node comms on a single computer, or even over reasonably strong WiFi connection. But there will be dropped messages when working on the Charles River when the robots have lossy comms to the shore. There are no mechanisms built into **pShare** to detect a dropped message. If a message is critical, the user will have to implement their own acknowledgment and re-send protocol.

Note: In an separate development branch, a new 2023 app called **pMediator** has been developed

to such an ack and re-send protocol. Ask if you're interested, but we won't need it in our labs in simulation.

Normally in our setups, the **pShare** communications are solely between the shoreside MOOS community and the one or more vehicle MOOS communities. We typically don't share information directly between vehicles, although there is nothing about **pShare** that would disallow this. While inter-vehicle communication is certainly desired, and part of our future labs, we implement all inter-vehicle communications to be routed through the Shoreside community. For reasons further explained in later labs, we use this "comms routed through the shoreside" arrangement so that we can simulate comms limitations often experienced in the field. We can drop comms based on inter-vehicle range, or we can limit the bandwidth between vehicles to simulate communications with similar limits, like satellite or underwater acoustic comms.

4 Experimenting with pShare

In the first exercise in the pre-lab, the goal is to become familiar with **pShare**. In these first couple of missions, we will be configuring **pShare** explicitly in our **.moos** files. In later missions, we will be using components of the uField Toolbox to automatically configure the share configurations.

4.1 Assignment 1 (self check-off) - Configure pXRelay with pShare

In this part we will:

- Prepare a copy of the xrelay mission for experimenting.
- Create two **.moos** files to launch two **MOOSDB** processes.
- Launch the two communities and confirm that sharing between two MOOS communities works with **pShare**.

4.1.1 Make a Copy of the pXRelay Mission

The first step is to copy the xrelay example mission from your **moos-ivp** tree in your own **moos-ivp-extend** tree.

```
$ cp -rp moos-ivp/ivp/missions/xrelay moos-ivp-extend/missions/lab_06/xrelay_pshare
```

The original xrelay mission had a single **.moos** mission configuration file, with a single **MOOSDB** and two **pXRelay** apps.

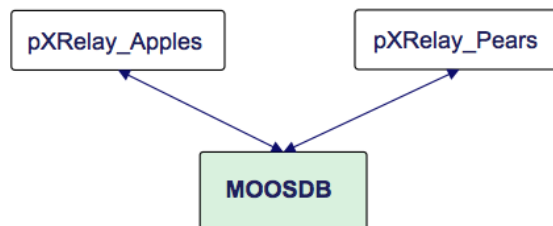


Figure 3: The original xrelay mission contained a single **MOOSDB** with two **pXRelay** applications uniquely named.

This will be transformed by you into two mission files, each launching a single **MOOSDB**, each with a unique community name:

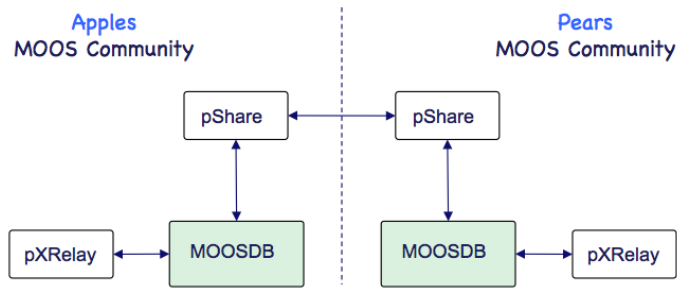


Figure 4: The new xrelay mission contains two **MOOSDBs** each with their own **pXRelay** application. The **pXRelay** application does not need to be uniquely named, but the MOOS communities are uniquely named.

Recall in the earlier XRelay mission, where two versions of **pXRelay** were launched and connected to the same **MOOSDB**, each version had to be launched with a unique name, like **pXRelay_apples**. Since we now will be launching two MOOS Communities, with one instance of **pXRelay** in each community, each **pXRelay** instance can simply remain named **pXRelay**.

4.1.2 Split the xrelay Mission up into Two Separate MOOS Communities

The xrelay mission, as originally configured, has three essential apps launched. The **MOOSDB**, and two **pXRelay** apps. In this experiment, you will create two **.moos** files, each launching a **MOOSDB** and one **pXRelay** app. You will also need the **pShare** app launched in each community.

Note: You will need to configure each **.moos** file with a unique community name (with the **Community** parameter), and port number (with the **ServerPort** parameter). The **ServerHost** parameter can remain **"localhost"** for now. Note each of those pieces of information since you will need it in the configuration of **pShare** in both files.

Some quick documentation on **pShare** can be found by just typing **"pShare --help"** on the command line. Or you can find more complete documentation here:

<http://oceanai.mit.edu/2.680/oxmoos/pshare.html>

Your **pShare** configuration block will look something like (removing the comments of course):

```

ServerHost = localhost
ServerPort = 9000
Community = apples

ProcessConfig = pShare
{
  AppTick    = 4
  CommsTick  = 4

  input  = route = localhost:9200
  output = src_name=APPLES, route=localhost:9201
}
  
```

Note that the port on which **pShare** is listening is not the same port on which the **MOOSDB** is serving. And remember that the same share configuration will not work for both sides. They must complement each other, in terms of the variable name being shared, the share input route, the destination host IP and port number. The following figure may help:

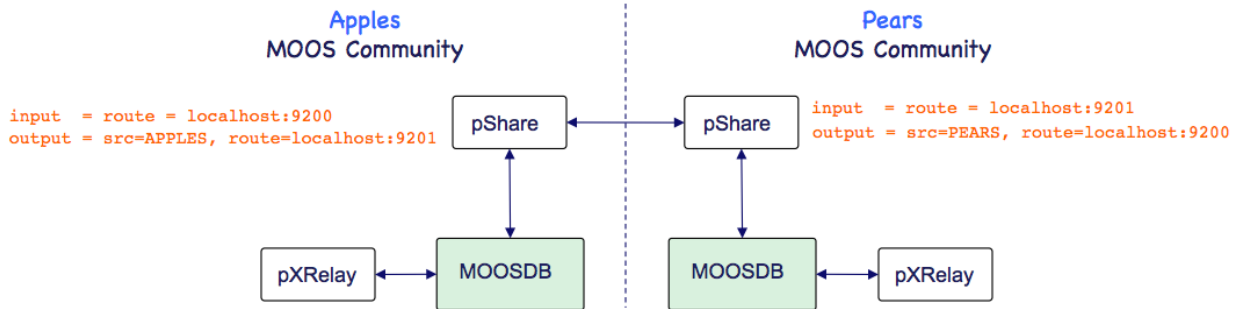


Figure 5: The new xrelay mission needs to have **pShare** configured to share the **APPLES** and **PEARS** messages with complementary configurations.

4.1.3 Launch the two communities and confirm that sharing works

Using perhaps two separate terminal windows, launch both MOOS communities and confirm that the modified xrelay mission works as before. You will still need to poke one of the communities to get things going. Confirm things are working by opening a scope in one of the communities. Enable the "Community" field on scoped items, either by launching **uXMS** with the `--show=community` parameter, or just toggling this field on with the 'c' key after **uXMS** is launched. You should see postings from both the local community, and the second remote community.

If things are not working, consider the following trouble-shooting points:

- Make sure the port specified in the share input route on each side matches the destination port on the other, and vice versa.
- Make sure the port numbers used are not the same as the **MOOSDB** port numbers.
- Make sure the **MOOSDB** port numbers are unique, like 9000 and 9001. This is the **ServerPort** parameter in the `.moos` file.
- Try just poking with **uPokeDB** to test the sharing. For example, poking **APPLES=99** in the community that is configured to export the the **APPLES** variable, and opening a scope in the destination community.

4.2 Assignment 2 (self check off) - The Alpha pShare Mission

In this part we will:

- Prepare a copy of the alpha mission for experimenting.
- Create two `.moos` files to launch two **MOOSDB** processes.
- Implement the Alpha mission with two MOOS communities using **pShare**.
- Launch the two communities and confirm that sharing works.

4.2.1 Make a Copy of the Alpha Mission

The first step is to copy the alpha example mission from the moos-ivp class tree into your own moos-ivp-extend tree.

```
$ cp -rp moos-ivp/ivp/missions/s1_alpha moos-ivp-janedoe/missions/lab_06/alpha_pshare
```

You won't be handing this in, but it's not a bad idea to check it in under your version control system.

4.2.2 Split the Alpha Mission Into Two Separate MOOS Communities

In this step you will create two separate MOOS communities: a *shoreside* community and an *alpha* vehicle community, by creating two separate .moos files. In the shoreside community there will be a **MOOSDB** and **pMarineViewer**. In the alpha community will be a **MOOSDB** and everything but **pMarineViewer**. In both communities you will also need to add a **pShare** configuration block and add **pShare** to the **Antler** configuration block.

The primary challenge here is to consider which variables to configure for sharing in each direction. One hint is that, from the vehicle to the shoreside you will need to share the **NODE.REPORT**. This is the message generated from **pNodeReporter** containing much of the vehicle state, and used by **pMarineViewer** to render the vehicle. It is generated locally on the vehicle as **NODE.REPORT.LOCAL** and should arrive in the shoreside as **NODE.REPORT**. The configuration in alpha's **pShare** config block will look something like:

```
output = src_name=NODE_REPORT_LOCAL, dest_name=NODE_REPORT, route=localhost:9200
```

You will also want to share the **VIEW.POLYGON**, **VIEW.SEGLIST** and **VIEW.POINT** variables to enable **pMarineViewer** on the shoreside to have the visual feedback of the vehicle waypoints. What variables do you need to share from the shoreside to the vehicle?

4.2.3 Launch the Two Communities and Confirm that Sharing Works

Using perhaps two separate terminal windows, launch both MOOS communities and confirm that the modified Alpha mission works as before. You still should be able to deploy and return the vehicle with the buttons in **pMarineViewer**. Consider what is being poked when hitting those buttons. You can always find this out by looking at the **pMarineViewer** configuration block in the mission file. Or, recent versions of **pMarineViewer**, you can hover your mouse over each button, and after a second a small pop-up window will appear showing which variables are being poked with that button. Make sure those variables are being properly shared to the alpha vehicle community.

If things are not working, consider the following trouble-shooting points:

- Make sure the port specified in the share input route on each side matches the destination port on the other, and vice versa.
- Make sure the port numbers used are not the same as the **MOOSDB** port numbers.
- Try just poking with **uPokeDB** to test the sharing. For example, poking **DEPLOY=true** in the shoreside community, and opening a **uXMS** scope in the destination (alpha) community. Even

easier: use the realmcasting interface built into **pMarineViewer** as of 2022, to verify that messages like **DEPLOY** are being shared from shore to the vehicle. Ask a TA for help if haven't used the realmcasting utility yet.

- You should see a vehicle in the **pMarineViewer** window even before deploying the vehicle. If you don't check the **pShare** configuration on the vehicle side.

The result should look just like the basic alpha mission from Lab 1, but, under the hood, things are just running in two separate MOOS communities:

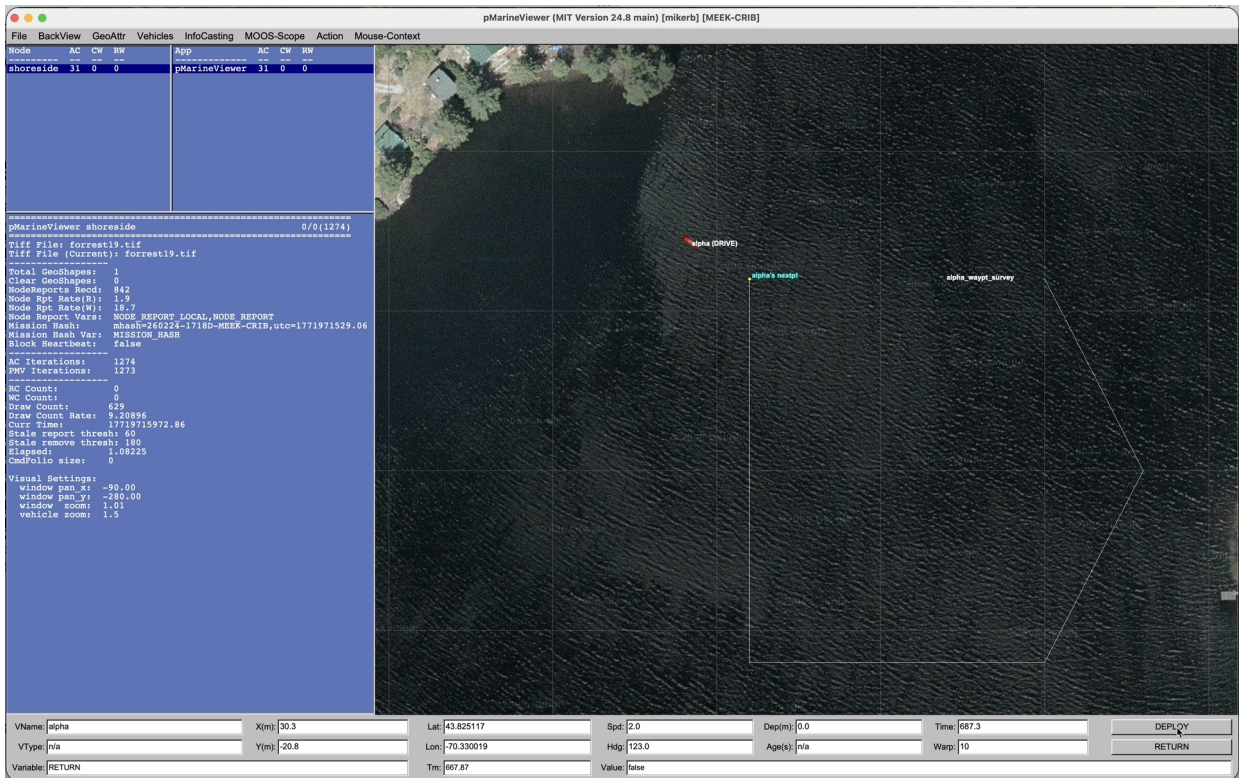


Figure 6: The Alpha mission. Only the shoreside MOOS community is showing in the appcassing window because the sharing between the vehicle and shoreside community has not been fully established yet, currently missing the appcassing messages needed.

5 Instructions for Handing In Assignments

5.1 Requested File Structure

You are encouraged to continue to upload all mission files. The mission folders for this lab (5) and the next lab, should all be put into a folder labeled **lab_06**. Here is the requested file structure:

```
moos-ivp-extend/  
missions/  
  lab_06/  
    xrelay_pshare/           // Assignment 1 - self check off  
    alpha_pshare/           // Assignment 2 - self check off  
    alpha_bravo_pshare/     // Assignment 3 - check off  
    henry_gilda_baseline/   // Assignment 4 - self check off  
    henry_gilda_refuel/     // Assignment 5 - self check off  
    henry_gilda_auto_refuel/ // Assignment 6 - check off
```