An Introduction to Robot Autonomy

ROBOTICS RESEARCH CENTER (RRC)

with

MOOS-IvP

and

Aquaticus

Lecture 5: Inter-Vehicle Messaging

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MOOS-IvP Supported by ONR Code 311 since 2000

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Aquaticus Supported by ONR, DARPA, Battelle and the Army Research Lab

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Inter-Vehicle Communications

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- Methods of Inter-vehicle communications
- Limits on inter-vehicle communications
- Simulating inter-vehicle communications on a network
- uFieldNodeComms
- uFieldMessageHandler
- Indicators of successful messaging
- Debugging dropped messages
- Lab Preview

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Inter-Vehicle Communications

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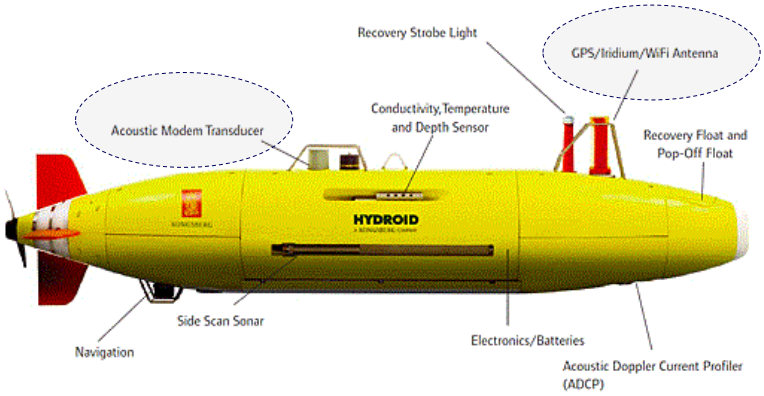
How do two vehicles / robots / machines talk to each other?

- Depends on how far away they are from each other
- Depends on what is between them (air, water, or both)
- Messages may be sent directly between robots, or over a network



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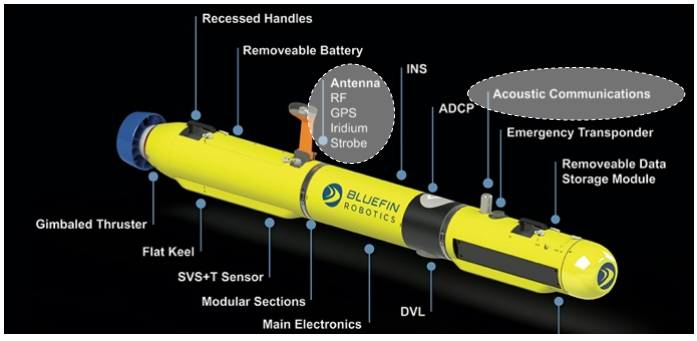

4

Inter-Vehicle Communications

ROBOTICS RESEARCH CENTER (RRC)

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Assumptions for now:

- All robots have a unique name with known address
- Messages may be sent to an individual robot, all robots, or a group of robots
- A message may or may not received by the target robot
- No acknowledgement is built in to the messaging structure (although you can do this yourself)
- A message may be range-limited (the receiving robot is too far away)
- A message may be band-width limited (the message has a max length)
- A message may be frequency limited (minimum wait time between messages)
- A message may have latency (arrival time at receiving robot is not guaranteed)

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Inter-Vehicle Communications

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Focus

How can we use robot mobility and autonomy to overcome these limitations?

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uField Toolbox – Sending a Message Between Vehicles

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Vehicle alpha (source vehicle)

(Some MOOS App) Publishes:

```
NODE_MESSAGE_LOCAL = "src_node=alpha,dest_node=bravo,
                      var_name=STATUS,string_var=searching"
```

Vehicle bravo (dest vehicle)

uFldMessageHandler Subscribes/Handles: Publishes:

```
NODE_MESSAGE = "src_node=alpha,dest_node=bravo,
               var_name=STATUS,string_var=searching"
```

```
STATUS = "searching"
```

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uField Toolbox – Sending a Message Between Vehicles

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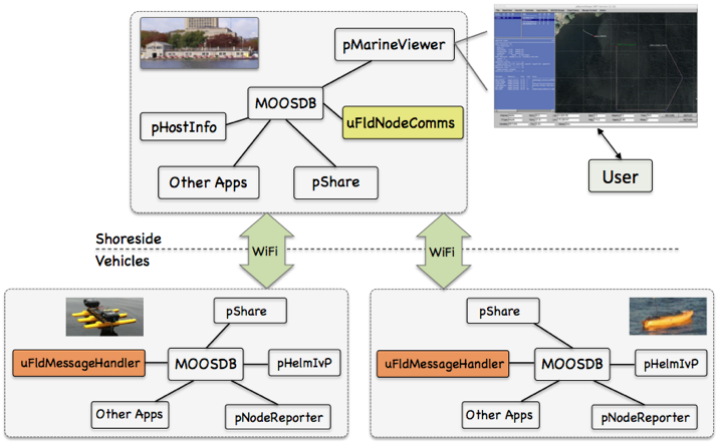
The uFldMessageHandler app is running on all vehicles wishing to receive messages.



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uField Message Routing

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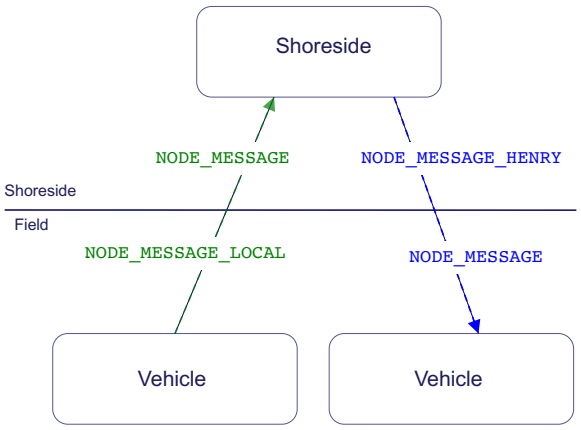
- Message routing is handled on the shoreside.
- But it's not the case that all messages make it through
- They are handled by uFldNodeComms




```
ProcessConfig = uFieldShoreBroker
{
   qbridge= NODE_MESSAGE
}
```

```
ProcessConfig = uFieldNodeBroker
{
   bridge = src=NODE_MESSAGE_LOCAL,
            alias=NODE_MESSAGE
}
```

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uField Message Routing Sequence

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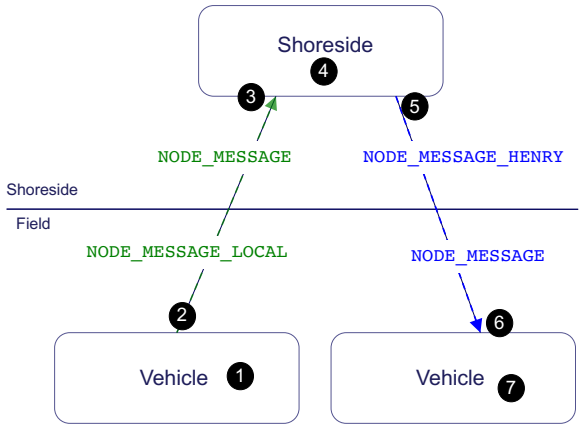
- The sequence of events, from the generation of the message all the way to the receipt on the destination robot(s)



1. Some app on the source vehicle publishes an outoing message in the form of **NODE_MESSAGE_LOCAL**
2. The source vehicle shares it via pShare to the Shoreside computer
3. It arrives at Shoreside as **NODE_MESSAGE**
4. Shoreside uFldNodeComms examines the message, location of vehicles and other range, bandwidth criteria and may decide to send it.
5. If uFldNodeComms decides to send it, it is published as **NODE_MESSAGE_VNAME** which is only shared to the robot named VNAME
6. It arrives on the destination vehicle simply as the MOOS variable **NODE_MESSAGE**
7. The final message is unpacked by uFldMessageHandler and posted as a MOOS variable-value pair to the local MOOSDB.

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The uFldNodeComms App

Typical Application Toplogy

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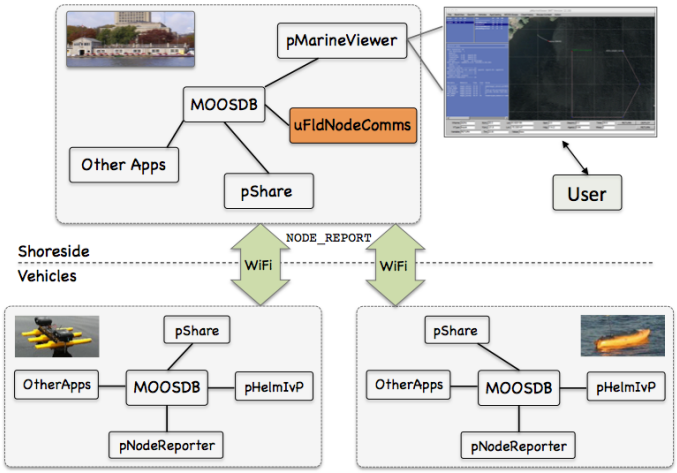
The uFldNodeComms app runs on the shoreside, limits intervehicle messaging.

- It subscribes for the the **NODE_REPORT** messages arriving from all vehicles.
- It knows the position of all vehicles.
- It shares vehicle position information to all other vehicles. To support collision avoidance. Separate from message passing.
- It knows the range between any pair of vehicles and may use that to block a message.
- It keeps track of when each vehicle sent its previous message, to perhaps limit message frequency.
- It publishes visual objects for pMarineViewer to indicate comms status.
- It keeps track of all sent and dropped messages for viewing and debugging in its AppCast output, viewable in pMarineViewer.



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The uFldNodeComms Configuration

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The uFldNodeComms configuration parameters:

```
ProcessConfig = uFieldNodeComms
{
   comms_range      = 200
   min_msg_interval = 60
   max_msg_length   = 100

   view_node_report_pulses = true

   stale_time       = 5
   groups           = true

   critical_range   = 1000

}
```

- Distance in meters between vehicles (default is 100m)
- Min time in seconds between messages from a vehicle (default is 30 sec)
- Max chars in a string message (default is 1,000 characters)
- Boolean indicating whether visual artifacts are to be generated indicating that node reports are being shared between vehicles

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The uFldNodeComms Basic Configuration

ROBOTICS RESEARCH CENTER (RRC)

The uFldNodeComms configuration parameters:

```
ProcessConfig = uFieldNodeComms
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   comms_range      = 200
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}
```
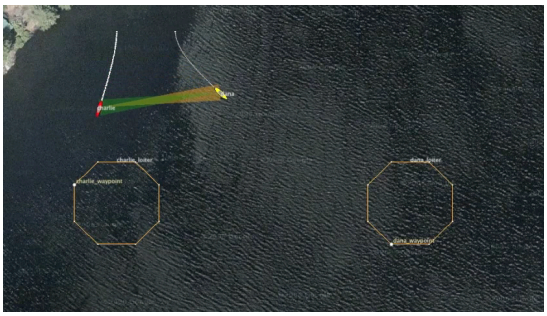

Distance in meters between vehicles (default is 100m)

Min time in seconds between messages from a vehicle (default is 30 sec)

Max chars in a string message (default is 1,000 characters)

Boolean indicating whether visual artifacts are to be generated indicating that node reports are being shared between vehicles



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The uFldNodeComms Handling Stale Vehicles

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The uFldNodeComms configuration parameters:

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ProcessConfig = uFieldNodeComms
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   stale_time       = 5
   groups           = true

   critical_range   = 1000

}
```

stale_time: Time in seconds after which a vehicle will not receive node reports or messages unless a node report has been received by that vehicle. The default is 5 seconds.

- Since up-to-date inter-vehicle range information is used as part of the criteria in determining whether a vehicle receives a new node report from another, the position of the candidate recipient vehicle needs to reasonably up-to-date.
- If a recipient vehicle becomes stale, it will not receive **`NODE_REPORT`** and will not receive **`NODE_MESSAGE`** messages.

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The uFldNodeComms Support for Groups

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The uFldNodeComms configuration parameters:

```
ProcessConfig = uFieldNodeComms
{
   comms_range      = 200
   min_msg_interval = 60
   max_msg_length   = 100

   view_node_report_pulses = true

   stale_time       = 5
   groups           = true

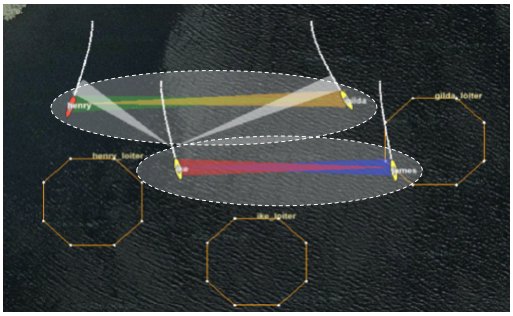
   critical_range   = 1000

}
```

groups: If true, inter-vehicle node reports are shared only if two vehicles are in the same group. Default is false.

- The group name is a field contained in the node report itself, so the onus is on the vehicle to include this information as part of its report.
- pNodeReporter can be configured with **`group=<group-name>`** where the group information is declared for inclusion in all node reports.

- Motivation for groups: to support multi-vehicle competitions where some vehicles want to convey positions to teammates, but not adversaries.



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The uFldNodeComms Critical Range

ROBOTICS RESEARCH CENTER (RRC)

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   max_msg_length   = 100

   view_node_report_pulses = true

   stale_time       = 5
   groups           = true

   critical_range   = 1000

}
```

critical range: Range in meters within which inter-vehicle node reports will be shared even if group membership would otherwise disallow. The default is 30 meters.

- When the two vehicles are within a range deemed critical, as set by the **critical_range** configuration parameter, node reports are shared between vehicles regardless of the comms_range parameter and the groups parameter.
- The default for this parameter is 30 meters.
- The thought behind this feature is that, while it may be advantageous to not broadcast your own vehicle position to non group members for the purposes of a competition, it may be a good idea to share this information for the sake of collision avoidance.

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The uFldMessageHandler Configuration

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The uFldMessageHandler configuration parameters:

```
ProcessConfig = uFieldMessageHandler
{
   strict_addressing = false

   appcast_trunc_msg = 60
}
```

strict_addressing: If true, only messages with a destination specified by dest_node, matching the local community name are processed. Other messages with a destination specified by a group designation are ignored. The default is false.

appcast_trunc_msg: Number of characters allowed in the appcast report for each line reporting a successful message. The default is 75. Setting it to zero means no truncating will be applied.

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Signs of Healthy Messaging

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Visual Signs of Healthy Messaging

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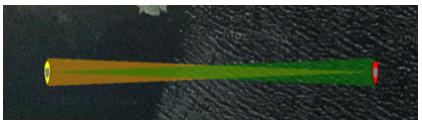
From the charlie_dana_messaging mission in Lab 11

NODE_REPORT messages are being shared



NODE_MESSAGE messages are being shared

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AppCasting Signs of Healthy Messaging

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Status of uFldNodeComms is contained in its AppCast output.

There are several fields confirmirmation healthy messaging.

```
1  ============================================================
2  uFldNodeComms shoreside                              0/0(339)
3  ============================================================
4  Node Report Summary
5  ====================================
6          Total Received: 3101
7                   GILDA: 1552       (0.0)
8                   HENRY: 1549       (0.0)
9      ------------------
10            Total Sent: 628
11                  GILDA: 315
12                  HENRY: 313
13
14 Node Message Summary
15 ====================================
16    Total Msgs Received: 4
17                  HENRY: 4      (24.1)
18     ------------------
19            Total Sent: 4
20                  GILDA: 4
21     ------------------
22    Total Blocked Msgs: 0
23               Invalid: 0
24         Stale Receiver: 0
25             Too Recent: 0
26           Msg Too Long: 0
27          Range Too Far: 0
28
29 ============================================================
30 Most Recent Events (4):
31 ============================================================
32 [96.22]: Msg rec'd: src_node=henry,dest_node=gilda,var_name=UPDATE_LOITER,string_val=speed=2.4
33 [71.10]: Msg rec'd: src_node=henry,dest_node=gilda,var_name=UPDATE_LOITER,string_val=speed=2.4
34 [56.46]: Msg rec'd: src_node=henry,dest_node=gilda,var_name=UPDATE_LOITER,string_val=speed=2.4
35 [38.32]: Msg rec'd: src_node=henry,dest_node=gilda,var_name=UPDATE_LOITER,string_val=speed=0.4
```

Lots of messages received and sent – that's a good sign!

No blocked messages. Also a good sign!

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AppCasting Signs of Healthy Messaging

ROBOTICS RESEARCH CENTER (RRC)

Status of uFldMessageHandler is contained in its AppCast output

- Totals valid messages
- Invalid messages are ill-formed
- Rejected messages failed one of the range, bandwidth etc. criteria

- Per source summary, one line per other robot.

- Finite list of most recent messages.
- Automatically truncated in number.
- Truncated in length as per set by the user with the appcast_trunc_msg parameter.

```
 1 ============================================================
 2 uFldMessageHandler gilda 0/0(841)
 3 ============================================================
 4 Overall Totals Summary
 5 ======================================
 6 Total Received Valid: 3
 7 Invalid: 0
 8 Rejected: 0
 9 Time since last Msg: 101.3
10
11 Per Source Node Summary
12 ======================================
13 Source Total Elapsed Variable Value
14 ------ ----- ------- -------- -----
15 henry  3     101.3   RETURN   true
16
17 Last Few Messages: (oldest to newest)
18 ======================================
19 Valid Mgs:
19   src_node=henry,dest_node=gilda,var_name=UPDATE_LOITER,string_val=speed
20   src_node=henry,dest_node=gilda,var_name=UPDATE_LOITER,string_val=speed
21   src_node=henry,dest_node=gilda,var_name=RETURN,string_val=true
22 Invalid Mgs:
23   NONE
24 Rejected Mgs:
25   NONE
```

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ALog Signs of Healthy Messaging

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We can check the log files *on the Shoreside:*

```
$ cd LOG_SHORESIDE_18_3_2018_____16_36_17
$ aloggrep *.alog NODE_MESSAGE_CHARLIE NODE_MESSAGE_DANA
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% LOG FILE:       ./LOG_SHORESIDE_18_3_2018_____16_36_18/LOG_SHORESIDE_18_3_2018_____16_36_18.alog
%% FILE OPENED ON  Wed Dec 31 19:00:00 1969
%% LOGSTART               22821080675.4
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
120.863         NODE_MESSAGE_CHARLIE uFldNodeComms   src_node=dana,dest_node=all,var_name=UP_LOITER,string_val=ycenter_assign=-43.075
127.423         NODE_MESSAGE_DANA    uFldNodeComms   src_node=charlie,dest_node=all,var_name=UP_LOITER,string_val=ycenter_assign=-19.65
553.160         NODE_MESSAGE_CHARLIE uFldNodeComms   src_node=dana,dest_node=all,var_name=UP_LOITER,string_val=ycenter_assign=-24.35
572.299         NODE_MESSAGE_DANA    uFldNodeComms   src_node=charlie,dest_node=all,var_name=UP_LOITER,string_val=ycenter_assign=-69.675
Total lines retained: 9 (0.01%)
Total lines excluded: 60558 (99.99%)
Total chars retained: 839 (0.01%)
Total chars excluded: 9972138 (99.99%)
  Variables retained: (2) NODE_MESSAGE_CHARLIE, NODE_MESSAGE_DANA
```

NODE_MESSAGE_CHARLIE entries indicate outgoing messages to charlie. In this case we can also see they are coming from dana.

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When Things Go Wrong

(How to Debug)

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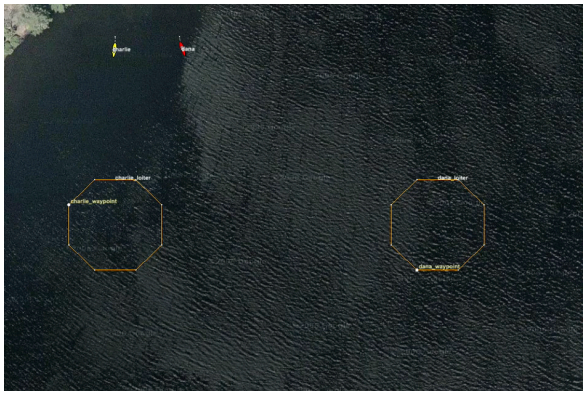
ROBOTICS RESEARCH CENTER (RRC)

When Things Go Wrong

You were expecting:

But you're seeing this instead (no comms pulses)



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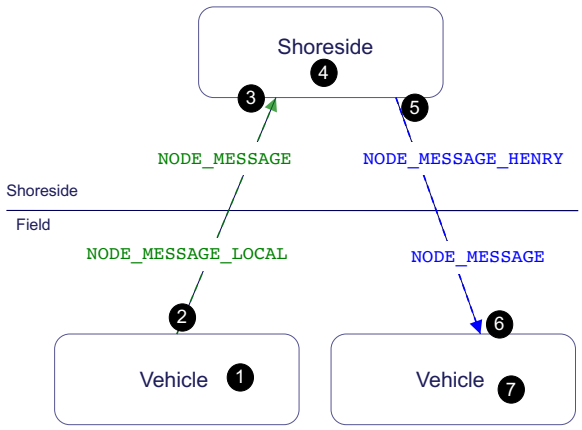
Debugging Broken Messaging

ROBOTICS RESEARCH CENTER (RRC)

- Re-visiting the message passing "pipeline":



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2. The source vehicle shares it via pShare to the Shoreside computer
3. It arrives at Shoreside as **NODE_MESSAGE**
4. Shoreside uFldNodeComms examines the message, location of vehicles and other range, bandwidth criteria and may decide to send it.
5. If uFldNodeComms decides to send it, it is published as **NODE_MESSAGE_VNAME** which is only shared to the robot named VNAME
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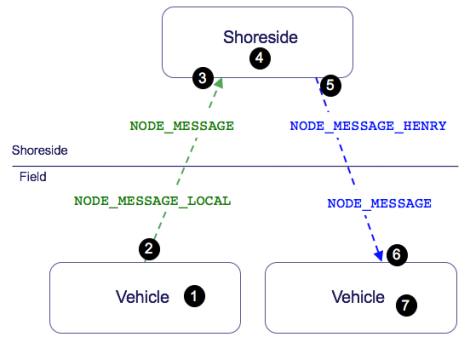
Debugging Broken Messaging (Stage 1)

ROBOTICS RESEARCH CENTER (RRC)

- Re-visiting the message passing "pipeline":



1. Some app on the source vehicle publishes an outoing message in the form of **NODE_MESSAGE_LOCAL**

DEBUGGING STEPS

- Was **NODE_MESSAGE_LOCAL** ever actually posted to the MOOSDB on the vehicle?
- You can check while running the mission by running a scope:

```
$ uXMS mission.moos NODE_MESSAGE_LOCAL
```

- You can check after running the mission by examining the alog file:

```
$ aloggrep file.alog NODE_MESSAGE_LOCAL
```

- If it was never posted, re-examine what was supposed to generate this posting.

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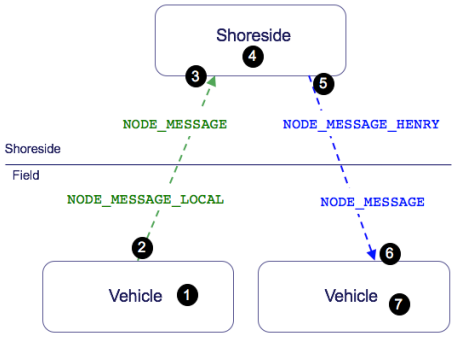
Debugging Broken Messaging (Stage 2/3)

ROBOTICS RESEARCH CENTER (RRC)

- Re-visiting the message passing "pipeline":



2. The source vehicle shares it via pShare to the Shoreside computer
3. It arrives at Shoreside as **NODE_MESSAGE**

DEBUGGING STEPS

- Did **NODE_MESSAGE** arrive in the Shoreside?
- You can check after running the mission by examining the *Shoreside* alog file:

```
$ aloggrep shoreside.alog NODE_MESSAGE
```

- If it was never posted, things to check:
- Was pShare running on vehicle? Shoreside?
- Did the vehicle uFldNodeBroker config block include sharing for **NODE_MESSAGE_LOCAL**?

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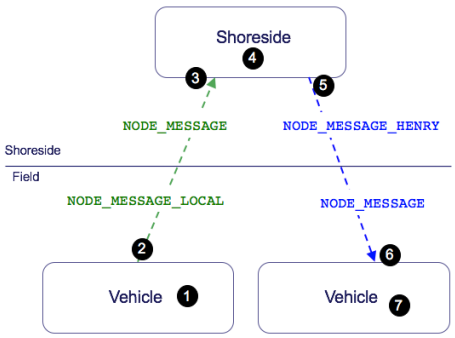
Debugging Broken Messaging (Stage 4)

ROBOTICS RESEARCH CENTER (RRC)

- Re-visiting the message passing "pipeline":



4. Shoreside uFldNodeComms examines the message, location of vehicles and other range, bandwidth criteria and may decide to send it.

DEBUGGING STEPS

- In this stage uFldNodeComms will ingest a **NODE_MESSAGE** and post a **NODE_MESSAGE_VNAME** if all goes well. Was **NODE_MESSAGE_VNAME** posted?
- You can check after running the mission by examining the *Shoreside* alog file:

```
$ aloggrep shoreside.alog NODE_MESSAGE_HENRY
```

- If it was never posted, things to check:
- Was the message blocked because it was ill-formed?
- Was the message blocked due to range between vehicles?
- Was the message blocked due to message length?
- Was the message blocked due to a stale receiving vehicle?
- Was the message blocked due to frequency constraints?

For debugging blocked messages, the AppCasting output of uFldNodeComms is your most powerful debugging tool.

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Debugging Blocked Messages at the Shoreside

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A *blocked message* at the Shoreside is a one where uFldNodeComms has ingested a **NODE_MESSAGE**, but has not made a corresponding **NODE_MESSAGE_VNAME** post.

Possible reasons for blocking:

- The message was ill-formed.
- The message was blocked due to range between vehicles.
- The message was blocked due to message length.
- The message was blocked due to frequency constraints. (too soon since the previous successful message)
- The message was blocked due to a stale receiver vehicle, or the receiver vehicle is not known to uFldNodeComms.
- Re-run the mission and check the AppCast output of uFldNodeComms (see right).
- As of now, uFldNodeComms does not produce similar output to debugging MOOS variables for logging.

```
1  ============================================================
2  uFldNodeComms shoreside                              0/0(339)
3  ============================================================
4  Node Report Summary
5  ====================================
6          Total Received: 3101
7                   GILDA: 1552       (0.0)
8                   HENRY: 1549       (0.0)
9       ------------------
10              Total Sent: 628
11                  GILDA: 315
12                  HENRY: 313
13
14 Node Message Summary
15 ====================================
16    Total Msgs Received: 4
17                  HENRY: 4       (24.1)
18      ------------------
19              Total Sent: 4
20                  GILDA: 4
21      ------------------
22     Total Blocked Msgs: 0
23                Invalid: 0
24           Stale Receiver: 0
25              Too Recent: 0
26            Msg Too Long: 0
27           Range Too Far: 0
28
29 ============================================================
30 Most Recent Events (4):
31 ============================================================
32 [96.22]: Msg rec'd: src_node=henry,dest_node=gilda,var_name=UPDATE_LOI
33 [71.10]: Msg rec'd: src_node=henry,dest_node=gilda,var_name=UPDATE_LOI
34 [56.46]: Msg rec'd: src_node=henry,dest_node=gilda,var_name=UPDATE_LOI
35 [38.32]: Msg rec'd: src_node=henry,dest_node=gilda,var_name=UPDATE_LOI
```

If there are blocked messages, they would be reported here

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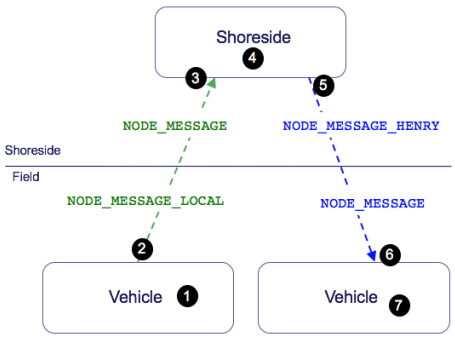
Debugging Broken Messaging (Stage 5/6)

ROBOTICS RESEARCH CENTER (RRC)

- Re-visiting the message passing "pipeline":



5. If uFldNodeComms decides to send it, it is published as **NODE_MESSAGE_VNAME** which is only shared to the robot named VNAME
6. It arrives on the destination vehicle simply as the MOOS variable **NODE_MESSAGE**

DEBUGGING STEPS

- uFldNodeComms has published a **NODE_MESSAGE_VNAME** and it should have resulted in **NODE_MESSAGE** on the vehicle.
- You can the *vehicle* alog file:

```
$ aloggrep vehicle.alog NODE_MESSAGE
```

If it was never posted, things to check:

- Was pShare running on the Shoreside
- Was pShare running on the vehicle?
- If you were able to deploy the vehicles and see their positions updated on pMarineViewer, then very likely pShare was running on both vehicles.
- Was the Shoreside pShare configured to share **NODE_MESSAGE_VNAME** and to **NODE_MESSAGE**? Check the configuration block for uFldShoreBroker and look for a configuration like like:

```
qbridge = NODE_MESSAGE
```

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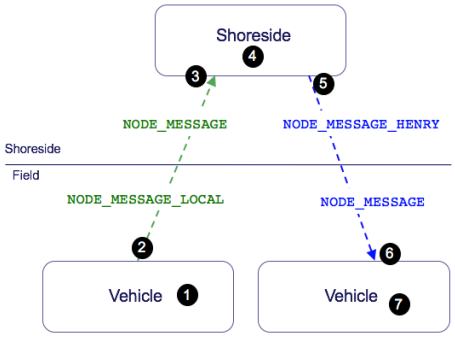
Debugging Broken Messaging (Stage 7)

ROBOTICS RESEARCH CENTER (RRC)

- Re-visiting the message passing "pipeline":



7 The final message is unpacked by uFldMessageHandler and posted as a MOOS variable-value pair to the local MOOSDB.

```
---------------------------------
DEBUGGING STEPS
---------------------------------
```

- A **NODE_MESSAGE** has arrived on the vehicle, but the contents of the message have not been posted.
- Again, you can verify that **NODE_MESSAGE** has been received on the vehicle by checking the *vehicle* alog file:

```
$ aloggrep vehicle.alog NODE_MESSAGE
```

If the contents of the message was not posted, things to check:

- The message was invalid (ill-formed syntactically)
- The message was rejected, perhap because the "addressee" was set to "all", and message handler was configured to require strict matching of vehicle name.
- **For debugging blocked messages, the AppCasting output of uFldMessageHandler is your most powerful debugging tool.**

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Debugging Broken Messaging (Stage 7)

ROBOTICS RESEARCH CENTER (RRC)

Possible reasons for unposted messages from an incoming NODE_MESSAGE on a vehicle:

- The message was invalid (ill-formed syntactically)
- The message was rejected, perhap because the "addressee" was set to "all", and message handler was configured to require strict matching of vehicle name.

```
 1 ============================================================
 2 uFldMessageHandler gus 0/0(841)
 3 ============================================================
 4 Overall Totals Summary
 5 ====================================
 6 Total Received Valid: 3
 7 Invalid: 0
 8 Rejected: 0
 9 Time since last Msg: 101.3
10
11 Per Source Node Summary
12 ====================================
13 Source Total Elapsed Variable Value
14 ------ ----- ------- -------- -----
15 hal    3     101.3   RETURN   true
16
17 Last Few Messages: (oldest to newest)
18 ====================================
19 Valid Mgs:
19   src_node=hal,dest_node=gus,var_name=UP_LOITER,string_val=speed
20   src_node=hal,dest_node=gus,var_name=UP_LOITER,string_val=speed
21   src_node=hal,dest_node=gus,var_name=RETURN,string_val=true
22 Invalid Mgs:
23   NONE
24 Rejected Mgs:
25   NONE
```

If there are invalid or rejected messages, they would be reported here

Contents of recent invalid or rejected messages, are shown here

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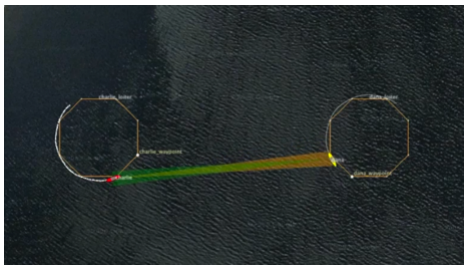
Lab Preview

ROBOTICS RESEARCH CENTER (RRC)

Exercise 1: Charlie-Dana baseline

Exercise 2: Charlie-Dana NodeComms



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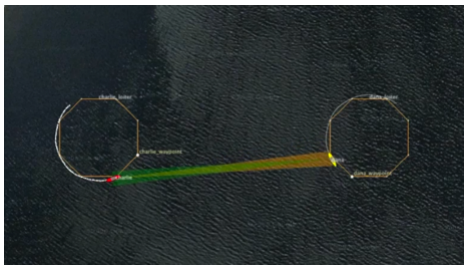
Lab Preview

ROBOTICS RESEARCH CENTER (RRC)

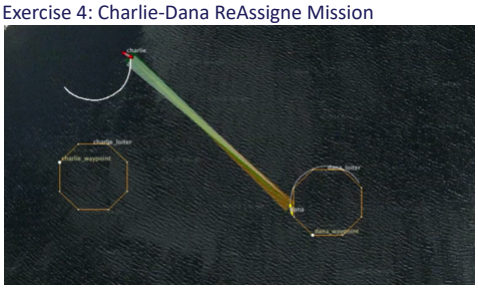
Exercise 1: Charlie-Dana baseline

Exercise 2: Charlie-Dana NodeComms



Exercise 3: Charlie-Dana Message Mission

Exercise 4: Charlie-Dana ReAssigne Mission



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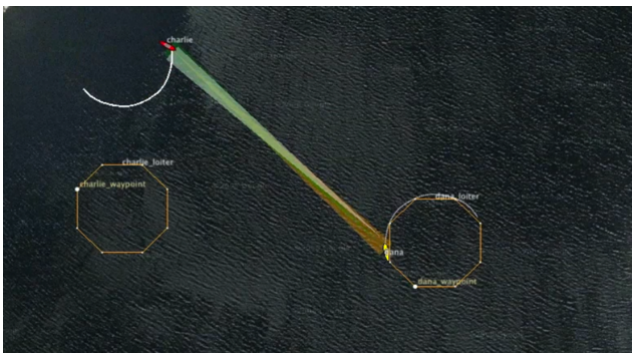
Lab Preview

ROBOTICS RESEARCH CENTER (RRC)

Exercise 5: (BONUS) Charlie-Dana Recover Mission



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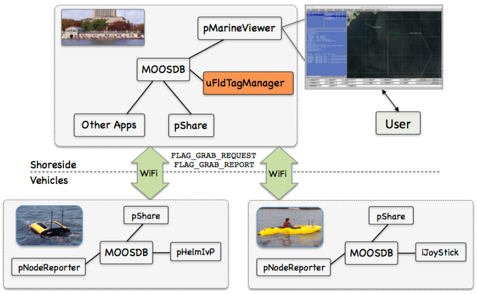
Tag Manager and Flag Manager

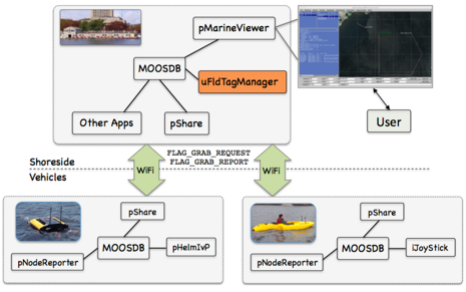
ROBOTICS RESEARCH CENTER (RRC)

The Tag Manager and the Flag Manager are two key apps that implement the Aquaticus Game Environment.

https://www.aquaticus.org/apps/tag_manager

https://www.aquaticus.org/apps/flag_manager





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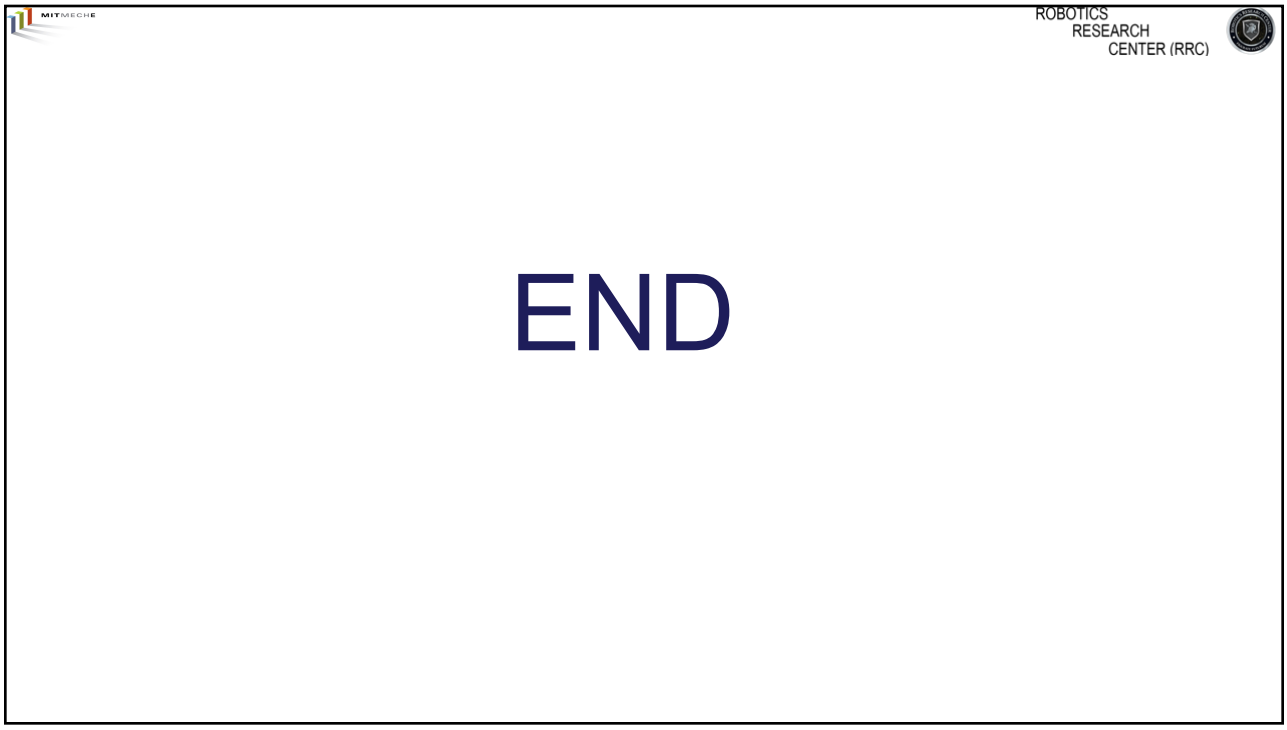

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