Role-Based Network Addressing for Fleets of Autonomous Underwater Vehicles

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ABSTRACT

This work proposes an exploratory system of network addressing and management for a fleet of autonomous underwater vehicles (AUVs). As fleets of AUVs become more common and their tasks more diverse, it become necessary to manage them more at the network layer, handling new group formations and organization. As groups form and re-form during missions, there needs to be a way to identify a particular AUV and its role in the entire network. This work proposes one such network-level addressing system for a fleet of AUVs, the Fleet Protocol (FP) addressing system.

KEYWORDS

Autonomous underwater vehicles, underwater networking, network layer

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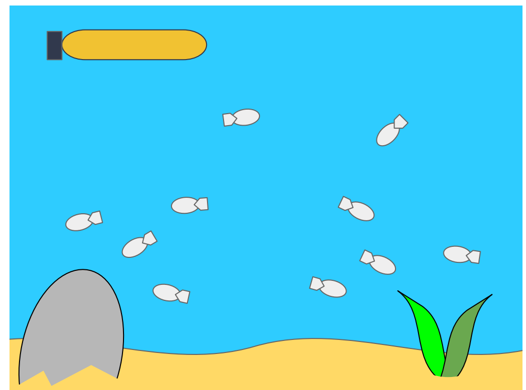

Figure 1: An example fleet of AUVs. The central node (top left) manages the fleet as the fleet leader, allowing the other AUVs to perform most of the work associated with the research mission.

1 INTRODUCTION

As the internet of underwater things (IoUT) develops, fleets of autonomous underwater vehicles (AUVs) are being explored as an option for enhanced study, exploration, and labor in underwater environments. In such fleets, AUV members can be assigned different roles and tasks within the group; as these fleets increase in size and complexity, they require additional controls at the networking layer. The controls can manage how AUVs of different roles interact with each other and how quickly they can assess another AUV's place in the network. Previous work has attempted to include these underwater nodes as part of the TCP/IP networking stack [3], but this protocol can cause packet delays and re-transmissions during communication. There is also a limit to how richly something like an IP address can describe an AUV's role in a fleet. Alternative network-level protocols must be explored that cause low overhead and help define an AUV's role in its fleet. This work provides such a system of network management for a fleet of AUVs.

This paper is designed in the framework of the Mothership Project [1], where a large Mothership AUV ferries a fleet of other AUVs to perform some mission, such as bathymetry, observing an algae bloom, or measuring glacial melt. Ideally, the needs this paper addresses can be applied to other IoUT networks beyond this application. Throughout this work, we analyze a fleet of AUVs akin to one shown in Figure 1, where a central node and other worker AUVs are dispersed to perform various tasks. This paper is outlined as follows: Section 2 proposes a division of labor into groups and the roles associated with different members of those groups, and Section 3 proposes a network-level addressing system for the fleet.

2 GROUPS AND ROLES

In the example network given, a fleet of AUVs might divide up into various groups to perform different tasks as part of the overall mission. We see an example of this in Figure 2a.

Each group can have a designated leader responsible for overseeing the main sub-task associated with the group. In this Figure, this group leader is most often referred to as the **Coordinator**. This Coordinator directs the other AUVs in the group to perform elements of the sub-task that is assigned to the group. These other AUVs in the group are referred to as **Workers**, and there can be any number of them in the group.

One group stands apart from the rest, and this is the **Admin Group**. In this group, the **Base Station** leads several of the AUVs to perform mission-wide tasks. These other AUVs are referred

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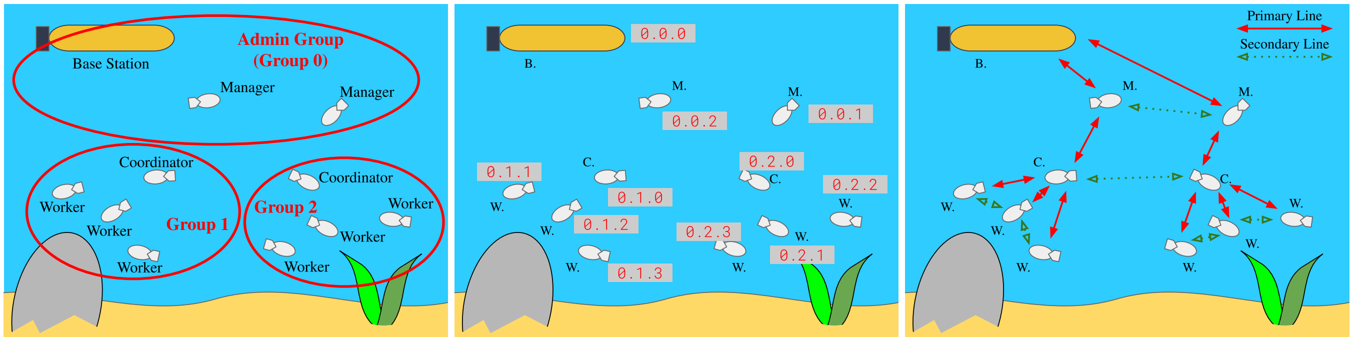

(a) (b) (c)

Figure 2: The AUVs of our example fleet (a) separated into groups and roles, (b) each given a Fleet Protocol address representing their place in the groups and the network, and (c) with the hierarchy of connections displayed among them.

to as **Managers**, and they can facilitate communication between Coordinators and the Base Station.

Each group, including the Admin Group, has a number associated with it (this will become useful in Section 3); the Admin Group's number is 0, and as more groups are organized and deployed, this group number increases with each group.

3 ROLE-BASED ADDRESSING

Much like how an IP address identifies a specific host in a terrestrial network, a number identifier can be used for AUVs in a fleet. Ideally, this number should also represent an AUV's role in that fleet and must be able to change, as groups and roles might change throughout the course of the fleet's mission.

This work proposes a way of creating these unique numbers, known as Fleet Protocol (FP) addresses, similar to an IP address. For an individual passenger AUV in the network, its FP address should include information about the overall fleet it is in, the group it is in, and its role within that group. As such, each of these three numbers is joined into a single FP address, separated by periods, similar to an IP address.

The first term in the FP address is the `fleet_number`. This number, the same for all AUVs in a fleet, is useful in scenarios where multiple fleets might be deployed in a similar area. Next comes the `group_number`, which we describe in Section 2; all AUVs in a group have this number in common. Lastly, there is the `role_number`, which indicates an AUV's role within its group. The Base Station and the Coordinators each have the `role_number` of 0, indicating their leadership of the group. The `role_number` of subsequent AUVs increases from 1 thereafter.

The entire FP address for an AUV is thus written as

```
<fleet_number>.<group_number>.<role_number>
```

With this setup, any AUV in the network can determine the role of another AUV as well as its group with a single number. In cases where the number of AUVs in a fleet is bounded by a power of 2, such as 128 which has been done in other studies [2], certain bits in a seven-bit binary number can be assigned to each field in the FP address. For example, one bit to the `fleet_number`, two bits for the `group_number`, and the last four bits for the `role_number`. This small FP number allows for a minimal addressing overhead footprint in packet communication between AUVs in the network. For our example network, Figure 2b shows how these FP addresss might be distributed among the AUVs.

In this proposed fleet dynamic, there is an innate sense of hierarchy; Base Station > Manager > Coordinator > Worker. While this hierarchy defines a clear chain of authority, the group dynamic also allows for division of labor and management; the Base Station, for example, does not have to spend computation and communication resources to dictate the actions of a single Worker. Figure 2c shows the primary lines of communication where command occurs. For times of collaboration, peers might be able to communicate over secondary lines of communication, but for sure there should always be a primary line to fall back onto. No AUV in the network needs to go more than one level above or below it in the hierarchy it to handle new commands or send other messages.

4 CONCLUSION

Fleets of AUVs will need to handle division of labor and leadership as their missions become more multi-faceted and complicated. This segmentation easily accommodates an information-rich network addressing system, where an AUV's group and role in the entire network is immediately accessible. These proposed concepts can help improve efficiency, automation, and performance of AUV fleets.

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