Automation of Environmental Data Collection Through the Commercial Fishing Industries

Alexander Brooker Ross, P. Eng
Ashored Innovations
Halifax, Canada
Alex.Ross@Ashored.ca

***Abstract*—This report provides an overview of the environmental data collection platform paired with the unique opportunities that Rope on Command (ROC) fishing has created. We will show how the data is stored on the device, collected passively from the end user's system, and stored securely for data aggregation and data analysis opportunities.**

Keywords—Passive observing sensors, low energy RF communications, ocean monitoring, climate change

I. Introduction

With the advent of Rope on Command (ROC) technology being at the forefront of whale entanglement prevention strategies [1], the opportunity to include additional sensors on the rope containment devices has proven viable. With the inclusion of these features, we can provide a platform for harvesters to be included in passive environmental data collection to better understand the effects of human activity and climate change on the oceans.

The end users are typically harvesters operating in challenging conditions. Current data collection operations are hindered by the required proper training of harvesters, cost, and data cleansing. By providing a hands free operation that is inherently built upon the foundations of the gear tracking systems, accurate location marking and time frame can automatically be captured. This system is comparatively low cost, and available on a leasing system for seasonal use.

Included in the Automated Tracking and Location Aggregation System (ATLAS) and Modular Oceanographic Buoy Instrument (MOBI) system, offered by Ashored Innovations (Figure 1), is the ability for the system to recognize when an overboard event has occurred. This is done by using features of the Bluetooth Low Energy (BLE) Mesh Low Power Node (LPN) feature set. This allows for seamless automated gear marking and retrieval. Due to the passive nature of the system requiring minimal user interaction, automated data collection can occur without impeding harvester operations.

II. Technology Overview

A. Rope On Command Fishing

ROC is an emerging technology used to mitigate marine life entanglement by containing the rope and buoys used for retrieval. The primary user of this technology are trap-based harvesters [2]. Typical systems have an acoustic communication element providing means for the harvesters to retrieve their gear at any time. The challenges in designing and manufacturing this equipment are driven by the needs and requirements of the harvester.

The electronics must be well protected requiring a rugged containment solution, and a low energy consumption to ensure that the device can last a season without the need to recharge or replace the battery. Additionally, they require a back end system to manage their release codes and gear markings for enforcement agencies to be able to inspect the harvesters deployments, as well as prevent other harvesters from placing their traps and trawls on top of each other.

Figure 1: Standard MOBI and ATLAS system [14]

B. Device Design and Sensors

Common commercial sensor packages typically include measurements and data logging consisting of conductivity, depth, and temperature (CTD). All factors of this system play a crucial part in accurate measurements as they all influence the internal readings of the individual sensors [3].

The MOBI system is designed to be modular with the Printed Circuit Board (PCB) providing common headers for the inclusion of different types of sensors operating over the Inter-Integrated Circuit (I2C) bus. An initial prototype has been achieved including both a pressure sensor and a high precision temperature sensor. The I2C sensor provides the means of multi device addressing such that the number of sensors that can be added is flexible with the devices that can be included [4].

The BLE module on the PCB can enter a device firmware update mode where a pre-signed application image is transferred over the air to ensure that future updates for additional sensor support can be provided. The updates are pushed to the back end for the companion ATLAS tablet application to facilitate the upgrade.

C. Back End Data Aggregation and Access

The back-end system provides the means of data aggregation and storage. Each harvester using the platform must create an account that assigns them a Universally Unique Identifier (UUID) that is included in each environmental data collection payload. The data is then stored and protected behind a Virtual Private Network (VPN) which allows external access to the database to be managed by the supporting cloud infrastructure.

The requirement for different types of users operating within different fisheries and activities has been recognized. Included in this architecture is the model that can be used to securely access and monitor fishing operations. This platform can allow for specially granted individuals and institutions to access this data while respecting the privacy of the harvesters.

The international expansion of the ATLAS back end has been considered by deploying via Terraform, an infrastructure as code framework [5]. This allows for the deployment of the pre-configured back-end stack and storage of support files that allow the system to be quickly deployed in different countries where privacy laws may be more restrictive.

III. Implementation Details

A. Mesh Model

BLE Mesh is a protocol commonly used to facilitate decentralized communication with many-to-many device functionality [6]. The mesh model is a subscription and publication 8-byte structured message with two separate addressing routes, server (Deck Box) and client (MOBI). The distinction in how they communicate is defined by the separate publishing and subscription addresses for client to server. This ensures that messages can broadcast to multiple devices with a single message transmission, as well as a unique identifier allowing for single device communication, with untargeted messages still able to be forwarded in instances where multiple relay devices are necessary.

A typical mesh configuration is shown in Figure 2. In the instance of the ATLAS configuration, the MOBI devices are the low power nodes, whereas the Deck Box is the Friend Node. Relay nodes can be used to expand the network to mitigate hardware limitations of the BLE modules both in terms of active connections and RF interference [7].

The LPNs achieve their low current draw by relying on the friend node to retain a message forwarded to it until after a set period, the node polls for pending messages and receives the content at a configurable periodic rate. This allows for the end user to be able to perform actions such as setting a backup release timer, requesting remaining battery, and validating that no system faults have been detected (e.g. low battery warning).

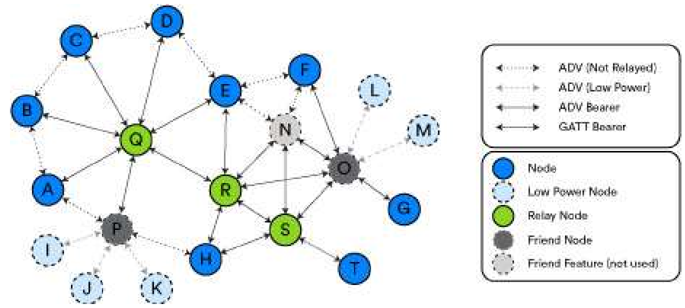

Figure 2: Standard LPN Mesh Configuration [15]

The firmware of the device can communicate asynchronously through the mesh. This does not require the polling method and allows for the BLE Server to forward the message contents to the paired BLE control device, in the harvester's case, the ATLAS Android application. This allows for the end user device to request an asynchronous data unloading transmission with a message identifier and a packet counter. The process is then able to start transmitting without requiring constant request messages which is significantly slower due to the limited throughput caused by the sleep time of the LPN.

In order for the a device to communicate in the mesh network, it must be provisioned with the network keys and assigned a unicast address. These keys are included in the user information backed up on the cloud allowing for restoration in the event of a device malfunctioning. Users have the ability to factory reset the devices allowing for seamless transfer to different harvesters.

Redundancy and custom logic were needed to ensure full operational stability. The mesh packets include a cyclic redundancy check (CRC), but due to the constraints of the medium, also require additional message retries, as well as an increased polling count to ensure that the device is truly in a disconnected state. Due to the sporadic nature of the message retry system, each packet has a packet counter added into the data frame and a known spot to ensure that message duplication does not flood the system.

B. Nordic UART Service

The BLE Generic Attribute Profile (GATT) Nordic Universal Asynchronous Receiver-Transmitter (UART) Service (NUS) is a specialized custom service designed for the reception and transmission of data [8]. It functions as an intermediary bridge, facilitating communication between the Bluetooth LE interface and the Universal Asynchronous Receiver-Transmitter (UART) with flexibility for custom message structures. It is by default, only used as a function between the Deck Box and the

Android tablet to facilitate user commands. Unsegmented message length is configured for up to a 66 Maximum Transmit Unit (MTU).

The firmware on the MOBI devices can be configured over the Mesh service to enable the NUS feature. This allows for the tablet to then communicate with the device directly allowing for a higher through put with a larger data packet size. It is with this method that an unsegmented data packets can be communicated directly from the devices.

The companion Android application serves as the primary user interface for the device operation. While in operation, it also functions as an automatic gear marking system with over board and on board message states being received from the Deck Box. It is through this method that the Deck Box can observe the unit being deployed and recovered automatically.

In the event of a MOBI being retrieved, ATLAS is able to query the device directly to observe the change in entry numbers. This provides a simple method that allows the system to request the appropriate range of data corresponding with the time the device has been deployed for. The ATLAS app can then automatically request the data unloading representing each entry point contained in sequences. It is with this method that coordinates of the data point, and exact times of measurement can be extrapolated. This allows for external factors such as weather to be combined with the readings.

C. On Board Memory Strategy

Due to the environmental conditions imposed on the MOBI (high vibration, and high pressure), the on board flash storage is soldered directly onto the PCB and accessed via a Serial Port Interface (SPI) [9]. In order to maintain low power draw, the SPI peripheral on the microcontroller is completely disabled until an interaction with the flash storage is requested.

Flash memory cells have an inherent physical limit with how often they are erased and wrote. Unique memory addresses require a page erase action requiring previous content to also be erased and rewrote. Flash memory cells have a finite number of write/erase cycles before they wear out and become unreliable [10]. To help ensure the longevity of the data collection, a wear levelling system is used to avoid premature failure.

The wear levelling system used operates with an allocated memory address strictly for control block operations, and for the data logging itself. This ensures that if a device reset is required, the startup time to find the next active block is minimized as the known write address is managed within a smaller block of memory.

The control block is responsible for recording of the devices provisioned status, active control block address, and active log block address, and update rate requested (set in minutes). This mechanism provides the ability for the next write address to be found with minimal SPI communications. The next write address is read individually, whereas typically a system would have to read the entire flash page sections seeking the next available write address.

These operations are typically managed by operating systems and file storage solutions. The MOBI must have a long battery life, hence any additional power and logic extended beyond what was necessary was not included in the system.

D. Sensors

Special care has to be given with consistency and calibration of the sensors being used in the system. To ensure flexibility and compatibility, the I2C system was chosen for sensor communications. The I2C protocol supports multiple devices connected on the same bus with communications managed by the device address. It also supports idle mode which allows the devices to enter a sleep mode when the communication lines are in the idle state [4]. This allows for the firmware to completely disable the I2C peripheral further decreasing idle current consumption.

Sensors have been selected that are comparatively low cost while still maintaining a high degree of accuracy. Open-source solutions have been investigated in this initial implementation to provide a base level requirement set [11]. Due to the calibration required, inherent system monitoring has been considered with procedures for calibration included in the Android application to walk the user through the processes and validate that the calibrated state is recognized as needed. In instances where a harvester is unable to do perform the calibration, Ashored offers a gear leasing program where the devices can be returned when not in use for calibration. If necessary, the data can be flagged as inadmissible should these conditions not be met.

The sensors that are being included in the initial pilot of this system are as follows:

- Temperature Sensor: Ideally requires no calibration, precision of +/-0.1 °C The operating temperature range is currently recommended to be -20 °C to 50 °C with expansion of the range available at a higher cost. The higher precision has been noted as it has been observed that aquatic populations in geographic locations have been impacted at rates tracked as low 0.4 °C year to year measurement variations [12].

- Pressure Sensor: From the measured pressure and compensated temperature, accurate depth readings (+/- one meter) can be extracted and provide the depths of which the measurements took place. This also allows additional power savings internal to the system as the BLE radio can be disabled when significant pressure is measured.

- Conductivity Sensor: A conductivity sensor operates by measuring the transfer of electrical currents over a controlled distance. It provides a measurement of salinity when combined with temperature and pressure which is crucial to understanding emergent issues [13]. With these readings, insights with the following areas can be better understood.
    - Salinity: Aids in determining seawater density, providing insight into ocean circulation, currents, and climate systems.

- Ecosystem Health: Detecting freshwater influx from environmental changes as it can be a stressor for marine life.
- Heat Absorption: Provides a clearer distinction between sudden environmental changes, and climate change as evaporation can be associated with higher temperature readings, conversely precipitation caused by more rain.

- Weight Sensor: As the platform for expansion of different node types is used, a mesh enabled scale can be integrated to better understand catch rates, correlated with the environmental data of where the stock was harvested. This allows for data informed policy decisions set by regulators.

Due to the modular architecture of the platform, additional sensors such as pH sensors and flow rate sensors can be integrated with minimal changes. In the case that specific research objectives requires a specific sensor, the ability to add it to the platform can be achieved with relative ease.

E. User Interaction

Secure access and validating legitimate users is a crucial step to ensuring data integrity. Harvesters are able to synchronize their collected data using ATLAS with the requirement that the user has a Deck Box to perform a handshake to verify gear is in use, as well as a secondary two step authentication process.

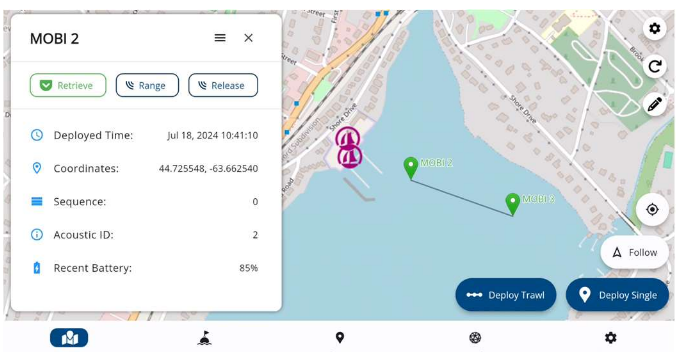

Figure 3: ATLAS Deployment Screen [14]

The ATLAS back end features a web portal and enforcement functionality. This allows enforcement agents to monitor the placement of traps by harvesters. This same infrastructure has laid the ground work for a scientific version of the back end that provides historical sliders with overlays of aggregated data.

The MOBI acoustic system is used primarily for releases, ranging to the device, and providing environmental data readings as requested. This allows for enforcement agents or granted scientific users to poll actively deployed units without requiring the gear to surface for recovery.

Direct access to the database directly requires tunneling through a secure VPN which in special circumstances can be extended to trusted users, with the ability to revoke their credential keys.

IV. Target Applications

With the environmental data aggregation framework in place, Ashored is aiming to provide support for various use cases.

A. Real Time Alarm System

In the event of subtle changes in the environment, more points of measurement will be actively incoming to provide an early detection mechanism. Combined with a wide span of geographic coordinates, historical tracking of conductivity readings can provide insight on the source of the leak. This is pertinent to a wide variety of applications such as aquaculture, oil spills, underwater pipelines and monitoring the effects of climate change in general.

B. Marine Stock Impact

Various marine life is impacted by environmental changes which can be associated with overall catch rate and estimated stock. With the inclusion of a larger environmental sample set, more accurate limits of total catch allocation per harvester can be recommended This could allow for over fished areas to recover when it is understood that the population rate is in decline, with the granularity to still recommend harvester activity in sections less effected.

C. Validation of Environmental Initiatives

Initiatives such as large-scale pH balancing require long term monitoring to validate the success. Providing a larger data set of pH readings can provide insight on the changes and overall effectiveness [3].

V. Conclusion

This initiative is seeking to establish a framework that combines both the commercial fishing industry with scientific endeavors. This can be used to better understand the impact of global climate change and the effect of human activity on the oceans. With minimal user interaction, an expansive, granular, flexible, and clean data set can be provided and used to better understand environmental dynamics.

Increased engagement and partnerships with the scientific communities will highlight additional sensor information that can be adapted to the system. It is the goal of this architecture to provide a streamlined approach to data collection with minimal need of researcher engagement in the aggregation of the data.

VI. Acknowledgment

Ashored has received funding from Canada's Ocean Super Cluster and The National Research Council of Canada Industrial Research Assistance Program (NRC IRAP).

REFERENCES

[1] M. J. Vaishali Dassan, "Oceana Canada Calls on Canadian Government to Adopt Ropeless Fishing Gear to Ensure Lasting Protection for Critically Endangered North Atlantic Right Whales," 26 March 2024. [Online]. Available: https://oceana.ca/en/press-releases/oceana-canada-calls-on-canadian-government-to-adopt-ropeless-fishing-gear-to-ensure-lasting-protection-for-critically-endangered-north-atlantic-right-whales/#:~:text=As%20climate%20change%20alters%20habitat,large%20mari.

[2] Northest Fisheries Science Center, "Developing Viable On-Demand Gear Systems," 07 02 2024. [Online]. Available: https://www.fisheries.noaa.gov/new-england-mid-atlantic/marine-mammal-protection/developing-viable-demand-gear-systems. [Accessed 23 07 2024].

[3] e. a. Sutton AJ, "Advancing best practices for assessing trends of ocean acidification time series," Front. Mar. Sci., 2022.

[4] NXP Semiconductors, "I2C- Bus Specification Rev 7," 1 11 2021. [Online]. Available: https://web.archive.org/web/20221006073143/http://www.nxp.com/docs/en/user-guide/UM10204.pdf. [Accessed 23 07 2024].

[5] HashiCorp, "Terraform," Hashicorp, [Online]. Available: https://www.hashicorp.com/products/terraform. [Accessed 23 07 2024].

[6] Bluetooth Special Interest Group, "Mesh Profile Blueooth Specification," 13 07 2017. [Online]. Available: https://www.bluetooth.org/docman/handlers/downloaddoc.ashx?doc_id=429633. [Accessed 23 07 2024].

[7] á. Hernández-Solana, D. Pérez-Díaz-De-Cerio, M. García-Lozano, A. V. Bardají and J.-L. Valenzuela, "Bluetooth Mesh Analysis, Issues, and Challenges," 30 01 2020. [Online]. Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9035389.

[8] Nordic, "Nordic UART Service (NUS)," 23 07 2024. [Online]. Available: https://docs.nordicsemi.com/bundle/ncs-latest/page/nrf/libraries/bluetooth_services/services/nus.html. [Accessed 23 07 2024].

[9] NXP, "SPI Block Guide v3.06; Motorola/Freescale/NXP; 2003.," NXP, 2003.

[10] P. K. S. Shweta, "Flash Translation Layer and its functionalities," in *2019 IEEE Conference on Information and Communication Technology*, Allahabad, India, 2019.

[11] S. K. S. R. Y. N. J. J. L. Andrew Thaler, "The OpenCTD: A Low-Cost, Open-Source CTD for Collecting Baseline Oceanographic Data in Coastal Waters," *Oceanography,* pp. 167-173, 26 01 2024.

[12] J. D. S. D. F. L. J. J. S. J. M. H. Maya L. Groner, "Rising Temperatures, Molting Phenology, and Epizootic Shell Disease in the American Lobster," *The University of Chicago Press,* vol. 192, 2018.

[13] K. Turekian, in *Encyclopedia of Ocean Sciences*, Academic Press, 2001, pp. 579-588.

[14] Ashored Innovations, "MOBI and ATLAS Starter Set," Ashored Innovations, Halifax, Nova Scotia, Canada, 2024.

[15] Bluetooth Special Interest, "Bluetooth Mesh Networking Series," 24 08 2017. [Online]. Available: https://www.bluetooth.com/blog/bluetooth-mesh-networking-series-friendship/. [Accessed 23 07 2024].